The Implementation of Peer Instruction in Mathematics and Physics Lectures

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Abstract
Peer Instruction (PI) is getting much more attention as one of the interactive teaching-learning methods. There are many practical reports of PI in physics, but in mathematics, there are few. Multiple-choice conceptual question, ``concept test" is a key part of PI. As a trial, we made over one hundred concept tests in mathematics, and delivered PI lectures in mathematics as well as in physics at the university. The subjects were calculus I, calculus II, linear algebra I, linear algebra II, probability statistics, and introductory physics. From first semester in the 2016 academic year to first semester in the 2017 academic year, total number of PI lectures in mathematics was 29 and that in physics was 4. Also, we conducted the quantitative survey for the students before and after PI lectures. As a result, the favorable rating for physics of the students increased from 49 % to 69 %, and the rating for mathematics increased from 49 % to 61 % in physics. Unfavorable rating for physics of the students decreased to 12 %, and the rating for mathematics decreased to 8 %. We collected the data of clickers before and after peer discussion as we consider the histogram of clickers' responses for the concept test helps the teacher to check the level of students' understanding. It is important for us to analyze which unit or concept the students are good at or not, because such data give us a great hint to improve our lectures and the concept tests.

Keywords: Peer Instruction, Concept Test, Mathematics, Physics, Interactive Teaching-Learning Methods, Clicker

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Introduction

In Peer Instruction (PI) lecture (Mazur E. 1997), a teacher gives a multiple-choice conceptual question, "concept test" to the students, and the students immediately respond the concept test by using audience response system, "clicker". After responses, all the students discuss the reasons why they chose their answers with each other for a few minutes. By repetition of such as “peer discussions”, students not only absorb knowledge but also learn to think about their concepts more deeply, and thus the abilities of logical thinking will be nourished inside them. Moreover, PI lecture helps teacher to check whole students’ understanding level with a histogram of their responses provided by clickers, and it helps the teacher to deliver a lecture adjusting to the students’ understanding level efficiently. Also PI lecture has an advantage that one teacher suffices to deliver a lecture even if the students’ number is beyond 100. Although there are many cases of delivering PI lectures in physics (Kudo T. 2017), there are not many examples in mathematics. Therefore, we had to make the concept tests for delivering a PI lecture in mathematics. As a trial, we made over one hundred tests, and delivered PI lectures in mathematics as well as in physics at the university. In the paper, we show the examples of concept tests in mathematics and the variation in the accuracy rate before and after peer discussions in PI lectures in mathematics and physics.

Implementation of Peer Instruction

We delivered PI lectures in mathematics and physics at our university from first semester in the 2016 academic year to first semester in the 2017 academic year. Total number of PI lectures was 29 in mathematics, and it was 4 in physics. The subjects were calculus I (Yamaoka H. 2018), calculus II, linear algebra I, linear algebra II, probability statistics (Taniguchi T. 2017; Taniguchi T. 2018), and introductory physics (Kudo T.).

The procedures for delivering a PI lecture are follows:

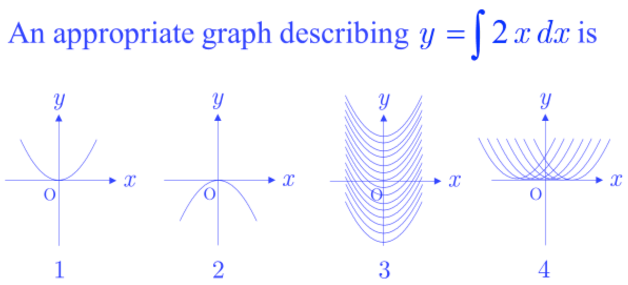
(1) Teacher gives concept test to students in the lecture.
(2) Students response the concept test by using clickers.
(3) Histogram of students’ responses provided by clickers is displayed on the screen.
(4) All the students discuss their responses with each other for a few minutes.
(5) Students response the concept test by using clickers, again.
(6) Teacher provides correct answer to the concept test and adds the explanation.

The key part of PI is the concept test for a peer discussion. We tried making the concept tests so as to lead accuracy rate of the students to achieve from 50% to 70% before having the peer discussion to make efficient and effective discussion. Thus, we made the concept tests intentionally to lead the students to choose wrong answers. If the accuracy rate on the tests before peer discussion is too low, the accuracy rate after discussion is hardly increased. In that case, the peer discussion becomes not effective. If the accuracy rate before the discussion is too high, peer discussion becomes almost unnecessary. When the students could not conduct an active discussion, a randomly selected student acted as facilitator for each group discussion. The facilitator has a role to ask the other students the numbers for the responses they chose and the reasons why they chose them, and to lead the other students to communicate with each other smoothly in the group. By rotating the facilitator role each time, even the student who is not accustomed to having a group discussion became less hesitant to speak gradually.

It is noted that after delivering a lecture using black board and PowerPoint, the teacher walks around the class to check how the students are practicing problems. All that time, the teacher answers questions from the students, and the students themselves teach each other the solutions.

Concept Tests in Mathematics

We show the examples of concept tests in mathematics and the variations in accuracy rates provided by the students using clickers before and after peer discussion.

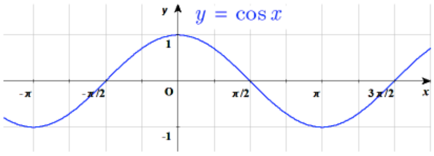


Number	Before discussion	After discussion
1	32%	5%
2	14%	0%
3	**45%**	**95%**
4	9%	0%

Figure 1: Concept test in calculus lecture and the students' response rates

Figures 1 and 2 show the examples of concept tests in calculus lecture. In figs 1-4, the right- hand tables show the students' response rates of using clickers before and after peer discussion where the accuracy rates are shown in bold. Figure 1 shows the concept test in indefinite integral. The number of the solutions for indefinite integral is infinite, and thus the correct answer is number 3. To get the correct answer, it is needed for the students to understand the distinction between indefinite integral and definite integral, and to image these graphs of solutions. The accuracy rates before and after peer discussion were 45 % and 95 %, respectively. The rate of the students chose wrong answer (answer choice 1) was 32 % before discussion, and it decreased to 5 % after the discussion. Here the teacher did not interrupt in peer discussion.

Choose a number that describes the value of definite integral being not 0.



1. $\int_0^{\pi} \cos x \, dx$
2. $\int_0^{\pi} \cos 2x \, dx$
3. $\int_0^{\frac{\pi}{2}} \cos x \, dx$
4. $\int_0^{\frac{\pi}{2}} \cos 2x \, dx$
5. $\int_0^{\pi} 2\cos x \, dx$

Number	Before discussion	After discussion
1	19%	4%
2	11%	2%
3	**57%**	**91%**
4	11%	2%
5	2%	0%

Figure 2: Concept test in calculus lecture and the students' response rates

Figure 2 shows the concept test in definite integral. The accuracy rates (correct answer is number 3) were 57 % and 91 % before and after peer discussion, respectively. It is needed for the students to image the shapes of cosine functions, ''2 cos *x*'' and ''cos 2 *x*'' in answer choices, and to consider the ranges of integration . There is no need to calculate definite integrals, directly.

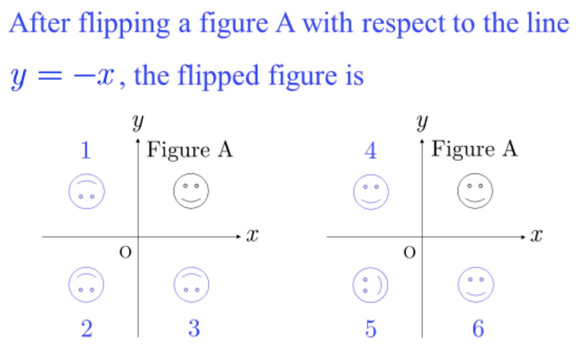
When the following vectors are not $(0, 0, 0)$, an appropriate information acquired from $\frac{x-1}{2} = \frac{y-2}{2} = \frac{z-3}{3}$ is

1. $(1, 2, 3) \parallel (2, 2, 3)$
2. $(x, y, z) \parallel (1, 2, 3)$
3. $(x, y, z) \parallel (2, 2, 3)$
4. $(x-1, y-2, z-3) \parallel (1, 2, 3)$
5. $(x-1, y-2, z-3) \parallel (2, 2, 3)$

Number	Before discussion	After discussion
1	9%	2%
2	26%	15%
3	6%	2%
4	11%	2%
5	**49%**	**79%**

Figure 3: Concept test in linear algebra lecture and the students' response rates

Figures 3 and 4 show the examples of concept tests in linear algebra lecture. Figure 3 is used in the concept test to check whether the students deeply understand a definition of an equation of a line or not. Even if the students cannot remember the definition of equation of a line, they can get a correct answer by considering the ratios of the given equations. The accuracy rates (correct answer is number 5) were 49 % and 79 % before and after peer discussion, respectively.



Number	Before discussion	After discussion
1	4%	0%
2	51%	36%
3	4%	0%
4	2%	2%
5	**32%**	**60%**
6	6%	2%

Figure 4: Concept test in linear algebra lecture and the students' response rates

Figure 4 shows a concept test describes flipping figure with respect to the straight line. The accuracy rates (correct answer is number 5) were 32 % and 60 % before and after peer discussion, respectively. It might be difficult for the students to image the movement of the figure with the shape. The rates of the students chose wrong answer (answer choice 2) were 51 % and 36 % before and after peer discussion, respectively. Here, answer choice 2 describes figure's rotation through 180 degrees. In the lecture, we covered the movements of a point, but the movements of a figure with the shape were not covered. In order to get the correct answer, the students need to image the movement of a total face as the eyes move in conjunction with mouse movements. In PI lecture, teacher can give additional explanations to the students by checking their level of understanding.

Accuracy Rates Before and After Peer Discussion

The accuracy rates before and after peer discussion is very useful for teachers not only to check the students' level of understanding but also to analyze the factors in mathematics and physics. Figure 5 shows the examples of the accuracy rates before and after peer discussion in PI lectures in linear algebra I, calculus II, and physics. In fig. 5 circles are drawn around the data of the concept tests in figs. 1-4.

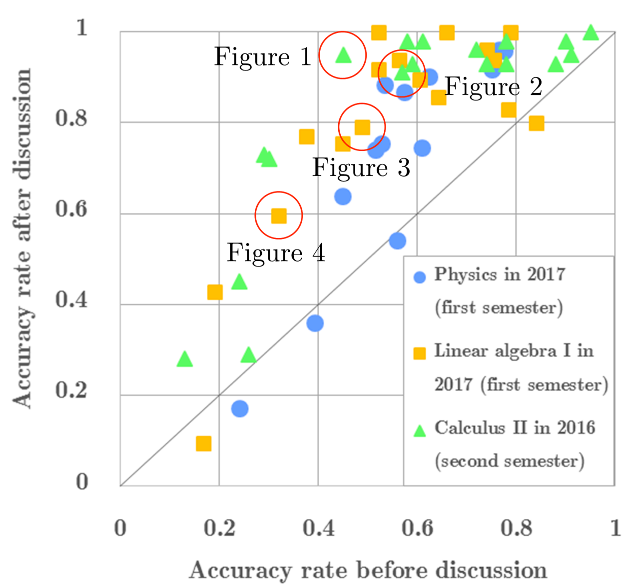


Figure 5: Examples of accuracy rates before and after peer discussion

If the accuracy rate before peer discussion is too low, the students cannot conduct an effective discussion. If the accuracy rate before peer discussion is too high, there is no need to have a discussion. It seems like the students had effective discussions for the concept tests in figs. 1-3. After PI lecture of physics in first semester in the 2017 academic year, the favorable rating for physics of the students increased from 49 % to 69 %, and the rating for mathematics increased from 49 % to 61 %. The unfavorable rating for physics of the students decreased to 12 %, and the rating for mathematics decreased to 8 %. In PI lectures, the students seemed to discuss each other with fun.

Conclusion

We made over one hundred concept tests in mathematics, and delivered PI lectures at the university. We showed the examples of concept tests in mathematics (e.g. calculus and linear algebra) and the students' response rates by clickers in PI lectures. Those rates help teacher to check all the students' level of understanding and to deliver lectures more effectively. The students seemed to have peer discussions with fun in PI lectures. After delivering PI lecture in physics, the favorable ratings for mathematics of the students as well as for physics are increased.

As a future assignment, we will reveal the factors of students' weak and strong points by analyzing the factors for mathematics and physics in fig. 5. Furthermore, we will modify the concept tests and deliver effective PI lectures.

Acknowledgements

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