The Effects of the Flipped Classroom and Online Education

Yasukazu Ichino[a]   **Mai Seki[b]**

Abstract

In a flipped classroom, a new style of teaching recently attracting attention among university educators, students study a recorded video lecture outside of class beforehand and they work on practice problems together with classmates during class. We use a randomized control design to estimate the impact of the flipped classroom on learning outcomes of students in an introductory economics course. Moreover, we happened to examine the effect of online learning as well, due to the spread of COVID-19 as a source of natural experiment. We find that both the flipped classroom and online education have negative effects in the short term, but these effects disappear by the time students take the final exam. The short-term negative impact of online education is weakened for those students with high academic ability and students with high efforts to the course. Overall, students perform the best in the traditional class style, i.e., the in-person standard lecture. The online and in-person flipped classroom come second and third. The online standard lecture turned out to be the worst class style.

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[a] Economics Department, Ritsumeikan University, yir10042@fc.ritsumei.ac.jp
[b] Economics Department, Ritsumeikan University, maiseki@fc.ritsumei.ac.jp

1. Introduction

In recent years, a new style of teaching, the active learning method, has been attracting attention among university educators. However, only a few studies have used randomized controlled trials (RCTs) to rigorously estimate the effects, and the results have been mixed (Calimeris and Sauer, 2015; Wozny, Balser and Ives, 2018; Setern et al., 2021). In this study, we use an RCT design to estimate the impact of the flipped classroom, one style of active learning, on learning outcomes of students in an introductory economics course. Moreover, we happened to examine the effects of online learning as well, due to the spread of COVID-19 as a source of natural experiment.

A flipped classroom "flips" a standard lecture style where the teacher gives a lecture during class. In a flipped classroom, students study a recorded video lecture outside of class beforehand, and then, during class, they discuss and work on assignments with classmates on what they have learned in the video. The main reasons why flipped classes are considered to be more effective for learning than standard lectures are as follows: (1) students can watch lecture videos as many times as they want at their own timing and pace, and (2) students can get real-time feedback from each other as they work on assignments during class. However, there is no concrete evidence identifying the positive impacts of flipped class over standard lecture so far in the literature. Regarding online learning, Means et al. (2010) summarized that student performance is slightly higher under online lectures than in-person lectures, especially when online learning is combined with in-person lectures. However, it is not clear whether online-only learning (as per COVID-19) is more effective under either standard lectures or flipped classroom teaching.

We investigate two research questions: (1) does a flipped class improve student learning outcomes compared to a standard lecture, and (2) do the effects of a flipped class on learning outcomes vary to the same extent for all students, or do they depend on the nature and attitude of students, such as academic ability and degree of engagement in the class? The potential contribution of this study is twofold. First, the original RCT design combined with a natural experiment allows us to evaluate the impact of the flipped classroom in both in-person and online setups under additive separable assumptions. Secondly, we adopt an experimental design that does not make students feel unfair or special. In this experiment, all students experience both standard and flipped classes, which mitigates the bias of the subjects' behavior to meet the experimenter's expectations.

2. Experimental Design

We conducted our experiment in the 2021 Spring semester in "Introduction to Economics," a required course for freshmen in the Department of Economics. The experiment was conducted in two sections of the course, Section C and Section D, taught by the same instructor, where students were randomly assigned to these sections (no placement test or tracking). Section C had 196

students and Section D had 191 students. In this course, fourteen lessons are divided into seven each. The first seven lessons were for "introduction to microeconomics and macroeconomics" and the second seven lessons were for "introduction to social economics" in Section C, and the other way around in Section D. The experiment was conducted in the microeconomics-macroeconomics part of the course. To ensure equal learning opportunities for students, all students experienced both the flipped and standard classroom, and only the timing was different. On top of the controls of standard/flipped classrooms, due to the spread of COVID-19, some lessons happened to be provided by online. This gave an additional dimension to the experiment, that is, in-person or online. Therefore, in the experiment, each lesson was conducted in one of the following class styles: in-person standard lecture, online standard lecture, in-person flipped classroom, and online flipped classroom. Because we have two sections with seven lessons each, there were fourteen clusters in total. Among them, four lessons were in the style of in-person standard lecture, three lessons were in the style of online standard lecture, two lessons were in the style of in-person flipped classroom, and five lessons were in the style of online flipped classroom. Figure 1 below illustrates the setup.

Figure 1. The setup of the experiment

	Lesson 1	Lesson 2	Lesson 3	Lesson 4	Lesson 5	Lesson 6	Lesson 7
Section C	Standard / In person	Standard / Online	Standard / Online	Standard / Online	Flipped / Online	Flipped / Online	Flipped / Online
Section D	Flipped / Online	Flipped / Online	Flipped / In person	Flipped / In person	Standard / In person	Standard / In person	Standard / In person

Table 1. Class structure

	Prior to class	During class	After class
Standard	Readings	Lecture	Practice problems, Quiz
Flipped	Video lectures, Readings	Practice problems	Quiz

Table 1 summarizes the class structure. In the standard classroom, students are asked to read the assigned pages of the textbook and supplementary readings prior to class. During class, the instructor gives lecture in the classroom under the in-person class format, or online live lecture on Zoom under the online class format. After class, students are required to submit a question about the lecture. Also, students are supposed to work on practice problems by themselves. An online quiz is given one week after the class. A quiz consists of five to six multiple-choice questions.

In the flipped classroom, students are asked to watch the video lectures prior to class. As an assignment, students are required to submit a question about the video lectures. During class, students work on practice problems. Under in-person class format, they are encouraged to work on together with their classmates sitting nearby. Under online class format, to let students work on practice problems together, they are assigned randomly to Zoom breakout rooms consisting of three to four students each. The instructor and three teaching assistants are walking around in the classroom or hopping around the breakout rooms to help students and to take questions from students. After class, students take the online quiz.

3. Data

The learning outcomes of the students was measured by the scores of the quizzes after each lesson and the scores of the final-exam questions related to the topic of each lesson. Because the quizzes were given within ten days of the end of the lesson, the quiz scores are seen measuring short-term learning outcomes. On the other hand, since the final exam is taken at the end of the semester, the exam scores are seen measuring long-term learning outcomes. With 387 students and 7 lessons, we have 2709 possible student-lesson observations for test scores.

In addition to the scores of quizzes and the exam, we have the following data for student-lesson pairs: the completion rate of video watching and submission of a question about the lecture. They are used as indices of the degree of students' efforts and engagement to lessons. We also have data for student characteristics: the average study time spent for a lesson, the scores of the final exam questions on social economics, and the scores of essay assignment on social economics. The first one is seen as an indicator of the degree of students' engagement to the course, and the last two can be interpreted as measuring general academic ability of the students.

4. Empirical Specification

Our RCT design for standard/flipped classrooms combined with the natural experiment for in-person/online classrooms enables us to estimate the effects of the flipped classroom and online education on students' learning outcomes. We assume that the effect of the flipped classroom and that of online education are additively separable and independent of lessons. By these assumptions, we estimate the following equation:

$$y_{ij} = \alpha + \beta_1 F_{ij} + \beta_2 O_{ij} + \beta_3 F_{ij} O_{ij} + \gamma L_j + \delta x_{ij} + \theta z_i$$
$$+\eta_1 x_{ij} F_{ij} + \eta_2 x_{ij} O_{ij} + \eta_3 x_{ij} F_{ij} O_{ij} + \phi_1 z_i F_{ij} + \phi_2 z_i O_{ij} + \phi_3 z_i F_{ij} O_{ij} + \varepsilon_{ij}. \quad (1)$$

The dependent variable y_{ij} is the quiz score or the exam score of student i in lesson j. The dummy variable F_{ij} takes 1 for students in the flipped classrooms, and the dummy variable O_{ij} takes 1 for students under online classes. The variable L_j is a dummy for lesson j to control for different contents of the lessons. x_{ij} is a vector of student-lesson specific variables such as

completion rate of video watching and submission of questions. z_i is a vector of student specific variables such as the final exam score of the social economics part, and average study time.

In this specification, estimates of β_1 capture the effect of flipped classroom under in-person class format. On the other hand, estimates β_2 capture the effect of online education under the format of standard lecture. The effect of flipping a class under the online class format is measured by $\beta_1 + \beta_3$, while the effect of online education under the flipped-classroom format is measured by $\beta_2 + \beta_3$. In addition, to examine if the flipped classroom and online education have different effects on different students, we included the cross terms in our specification, as seen in the second line of equation (1).

5. Empirical Results and Discussion

The regression results are summarized in the Table 2 below. We find that both the flipped classroom and online education have negative effects in the short term, and that these effects disappear in the long term, by the time students take the final exam. We also find that the size of the short-term effects of the flipped classroom and online education are different for each student. Recall that we interpret the exam scores on the social economics part as students' academic ability. The positive coefficients on the cross term of the social economics exam score and the flipped-classroom dummy imply that the negative effect of the flipped classroom is weaker for students with higher academic ability.

The short-term negative effect of online education is quite strong. It is more than one standard deviation. Similar to the effect of the flipped classroom, the negative effect of online education is weakened for those students with high academic ability. Also, the students putting higher efforts to the course were less negatively affected by online education. This is seen by the positive coefficients on the cross term of the submit-a-question dummy and the online dummy.

For the quiz-score regressions, coefficients on the cross term of the flipped-classroom dummy and the online dummy are positive and as large as the absolute value of the negative coefficient of the online dummy. This suggests that there is no negative effect of online education under the flipped-classroom style. Overall, our regression results show that the students perform the best in the traditional class style, i.e., the in-person standard lecture. The online flipped classroom comes second and the in-person flipped classroom third. The online standard lecture turned out to be the worst class style.

6. Limitation

A limitation of this study is the specificity of the context in which the students had difficulties in interacting with friends both inside and outside of classes due to COVID-19. It is also possible that students' readiness for the new style of teaching may have an impact, but there is no data

variation on that dimension at this time. We would like to further examine the impact of flipped classes under the in-person class format in the future.

Table 2. Regression results

Dependent variable →	Quiz score			Final exam score	
	(1)	(2)	(3)	(4)	(5)
Independent variables ↓	Unbalanced panel, Pooled OLS	Unbalanced panel, Fixed effect	Balanced panel, Fixed effect	Balanced panel, Pooled OLS	Balanced panel, Fixed effect
Constant	−0.839 (0.211)***	0.025(0.086)	0.261(0.098)***	0.054(0.105)	−0.037(0.081)
Flipped (F)	−0.233(0.197)	−0.248(0.162)	−0.319(0.183)*	0.022(0.185)	0.048(0.170)
Online (O)	−1.263(0.198)***	−1.250(0.174)***	−1.584(0.221)***	−0.067(0.184)	−0.094(0.183)
Flipped * Online	1.289(0.301)***	1.267(0.242)***	1.651(0.295)***	−0.081(0.284)	−0.069(0.263)
Submit-a-question dummy	0.032(0.092)	0.079(0.095)	−0.150(0.102)	0.032(0.086)	0.068(0.087)
Video-watch Completion rate (completion=1)	0.143(0.080)*	0.155(0.094)	0.073(0.106)	0.229(0.560)***	0.180(0.077)***
Study time (hours)	0.072(0.040)*			−0.061(0.039)	
Social econ. exam score	0.098(0.038)**			0.330(0.037)***	
Social econ. essay score	0.065(0.021)***			0.053(0.020)***	
Video-watch completion rate * F	−0.250(0.139)*	−0.222(0.147)	−0.086(0.016)	-0.235(0.125)*	-0.209(0.133)
Video-watch Completion rate * F * O	0.152(0.132)	0.062(0.128)	0.008(0.152)	0.121(0.127)	0.054(0.129)
Submit a question * F	−0.098(0.167)	−0.169(0.139)	0.048(0.159)	−0.166(0.156)	−0.219(0.145)
Submit a question * O	0.477(0.159)***	0.418(0.163)**	0.989(0.216)***	−0.058(0.144)	−0.068(0.152)
Submit a question * F * O	−0.332(0.228)	−0.169(0.209)	−0.950(0.266)***	0.219(0.210)	0.309(0.200)
Social econ. exam score * F	0.110(0.066)*	0.133(0.059)**	0.075(0.058)	0.089(0.065)	0.087(0.058)
Social econ. exam score * O	0.205(0.056)***	0.184(0.059)***	0.143(0.069)**	0.061(0.054)	0.107(0.059)*
Social econ. exam score * F * O	−0.168(0.085)**	−0.174(0.075)**	−0.103(0.081)	−0.183(0.083)**	−0.177(0.072)**
The number of quizzes attended	0.126(0.029)***				
The number of obs.	2228	2380	1680	2394	2541
F test on named regressors		F(19, 380) = 5.387	F(19, 245) = 3.905		F(19, 362) = 0.876
Adjusted R²	0.114	0.042 (within)	0.043 (within)	0.136	0.007 (within)

Notes: All scores are standardized to have a mean of 0 and standard deviation of 1. The video-watch completion rates for quiz-score regressions are the completion rates before taking quizzes. The video-watch completion rates for exam-score regressions are the completion rates before taking the final exam. The video-watch completion rates in the cross terms are those before attending class. In all regressions, lesson dummies and a section dummy are included when relevant. The standard errors are reported in parentheses. ***, **, and * denote significance at 1%, 5%, and 10%, respectively.

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