Teaching Them before We Teach: The Effectiveness of Conducting Classroom Experiments before Teaching the Underlying Theory

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Abstract

This study examines the effectiveness of classroom experiments conducted before the relevant theories were taught. The experiments were used to provide students with first-hand experience of decision-making under various rivalry settings and to demonstrate several key predictions of oligopoly models. Statistical methods were used to analyze the effectiveness of these experiments in helping students master the concepts covered by the experiments. In general, students had a positive experience in the process and they found the experiments useful in stimulating their interest and helping improve their understanding of the relevant theories. Statistically, students who took part in the experiments performed significantly better in an exam question on oligopoly markets.

Keywords: economics education, classroom experiments, prior knowledge, decision making, oligopoly model, treatment-effect model

Introduction

Economics is a discipline that can be characterized by rigorous theories developed to explain the behavior of economic agents or businesses. These theories can be evaluated by observation of actual human behavior or empirical analyses involving the use of relevant data. However, since economic decisions are usually made in a non-laboratory environment, it is difficult to evaluate these theories directly. To address this problem, economists have designed experiments that can be used to collect economic data under a controlled environment. These experiments can be useful in testing the validity of economic theories, as well as in teaching and learning. Learning is more effective when students can relate to what they are being taught. Oftentimes, students fail to understand economic models because they lack the first-hand experience and/or prior exposure to the context addressed by the models. The problem gets worse when the models are mathematical and students' attention gets diverted away from the economic reasoning behind the models. To help students understand these models, classroom experiments have been increasingly adopted by instructors. As noted by Neral and Ray (1995), classroom experiments not only provide students with concrete examples of the phenomena that the economic theories attempt to describe, but also the experience which can be related to particular aspects of the theories.

The effects of classroom experiments on student learning have been examined by various studies in the economics education literature. To our knowledge, in all but one of the existing studies (namely, Cartwright and Stepanova, 2012), classroom experiments were introduced *after* a relevant concept was taught. This approach helps reinforce concepts by allowing students to apply what they have learned in a (semi-)controlled environment. The aim of our research was to examine the efficacy of classroom experiments in improving student learning outcomes when the experiments are conducted *before* the relevant concepts are covered. We postulate that by giving students first-hand prior experience on the subject matter, it becomes easier for them to learn as a first-person rather than a third-party, and this enables students to master the models more effectively. We believe the results of this study will enable the development of a better understanding of the experiential learning pedagogy.

Our study began with an optional session of a computerized classroom experiment, where students were required to compete against the others in the classroom by making a series of business decisions in order to maximize their profits. The market conditions were known to the students, but relevant theories of this market setting were not yet covered in the lecture. Students' feedback on various aspects of the experiment were collected through a questionnaire and their course results were used to examine the effectiveness of our classroom experiment on improving students' learning outcomes. An endogenous treatment-effect regression model was used to mitigate the potential bias that voluntary experiment participation may exert on our regression results.

In the next section, we review the literature on experiential learning and the application of experimental learning in economics. Section 3 describes our experimental set up and some preliminary data on student learning outcomes. Section 4 contains the details of our regression analysis and Section 5 concludes.

Literature Review

Overview of Experiential Learning

The development of experiential learning began in the 20th century. Dewey (1916) first defines experiential learning as “learning by doing”. Hoover and Whitehead (1975) later elaborate that this learning approach is self-directed which includes a high level of active involvement and participation. According to Kolb and Kolb (2005), the primary focus of experiential learning is transformation of experience to knowledge. Knowledge is constructed through learners’ experience, reflection and thinking. Experiences serve as the basis for participants to reflect and think, and these reflections offer new implications to them. Kolb and Kolb (2005) point out that experiential learning is a process that draws out students' ideas about a topic and allows them to integrate new experiences with existing concepts.

Wolfe and Byrne (1975) suggest four major tasks of experiential learning, namely, design, conduct, evaluation, and feedback. Design consists of specifying learning objectives, producing activities for students and identifying factors affecting student learning. In order to create a favorable learning environment with structured learning experience, conduct is the following task which involves controlling the design. While evaluation is important by offering opportunities for participants to express what they have benefited, feedback is a continuous monitoring process aiming to improve the learning approach further.

Classroom experiments offer students with opportunities to discover economic concepts by themselves (Emerson, 2014). By engaging with the learning materials more fully, students are able to think deeper about the subject matter. This learning approach enhances students’ learning motivation because students will engage with the subject matter more as they must apply theoretical knowledge to conduct experiments for solving real-life problems (Hawtrey, 2007). In addition, experiments can significantly raise the degree to which students found the course stimulating (Ball, Eckel, & Rojas, 2006). Personal skill development is also emphasized under experiential learning (Egbert & Mertins, 2010). Students are encouraged to explain subject matters to each other or work effectively and support each other in teams. As a result, they can develop self-organization skills and team spirit through experiments. The benefits obtained from this learning experience will last beyond the lesson.

According to Egbert and Mertins (2010), instructors can also gain from experiential learning by enjoying teaching more. Classroom experiments serve as a good starting point for problem discussion, enhance instructor-student interactions, and help inspire students to understand theoretical concepts through discussions about the experiments. It is rewarding for instructors to see students being intrinsically motivated with their course design. By arousing students’ intellectual curiosity and having enjoyable interaction with them, instructors’ satisfaction from teaching will likely be raised.

Despite the merits mentioned above, the challenges of this active learning approach should not be ignored. Unlike traditional instructional approach, it is time intensive for the instructor to plan and prepare courses with experimental learning. Besides, uncertainties always exist when conducting experiments and the results of the experiments may not be predicted and controlled easily by the instructor. Emerson (2014) recommends running trials of an experiment so that the sample results will be useful for understanding the pitfalls that may arise. In light of this, instructors are advised to state the solutions to deal with those pitfalls in their manuscript in advance. Moreover, students may complain that learning with experiments is time consuming as they are required to do more work. As noted by Egbert and Mertins (2010), this is true as students often focus only on examinations. Thus, it is essential for students to understand the importance of learning informally through this active learning technique. In order to motivate students to be passionate in classroom experiments, Emerson (2014) encourages instructors to develop classroom experiments on those topics where students would enormously benefit from seeing the concept in action.

Previous Studies on Experimental Learning in Economics

According to Emerson and English (2016), the existing literature on the efficacy of experimental learning can be classified into two categories. Studies in the first category focus on particular experiments and examine the effects of these experiments on student learning in related topics. Frank (1997) and Gremmen and Potters (1997) are two major previous studies under this category. Frank (1997) examines the impact of a simple tragedy of the commons experiment while Gremmen and Potters (1997) study the effects of an international economic relations simulation game on student learning. By comparing the assessment marks, both studies found that students who engaged in or observed the experiment performed better and learned more about the economic model than those who are not involved in the experiment. The experiments in both studies were conducted after the delivery of a relevant lecture.

Studies in the second category examine whether exposure to the experimental learning pedagogy improves students' overall course achievements. In general, these studies are broader in nature and conduct experiments on an extensive range of economics topics. The empirical findings under this category of research are mixed. On one hand, Emerson and Taylor (2004), Ball et al. (2006) and Dickie (2006) found that experimental learning improves students' examination performance in general. In all three studies, students were divided into control groups and experiment groups. Traditional lectures or seminars were conducted in the control groups while the experimental learning approach was adopted in another group. Emerson and Taylor (2004) administer experiments covering topics such as supply and demand, sales taxes, externalities, monopolies and adverse selection while Ball et al. (2006) employ experiments relating to taxes, public goods, tragedy of the commons and other economics concepts. Dickie (2006) conducts experiments relating to the topics of comparative advantage, demand and supply, sales tax and effects of minimum wage. Regression models were used in all these studies. Emerson and Taylor (2004) identify student learning as a function of student specific characteristics, such as aptitude, education background and teaching methodology. Ball et al. (2006) focus on analyzing final examination performance and include year of study, gender and whether students have taken economics in high school as the independent variables in their study. Dickie (2006) measures how classroom experiments with and without grade incentives affect learning of microeconomics and supplements comparisons of treatment means by collecting additional data such as student's cumulative grade point average (GPA), composite score on the American College Test (ACT), number of semester credit hours passed, race, and gender. All three studies documented that students participating in the experiments perform significantly better in the examinations than those in the non-participating group. More recently, Rousu et al. (2015) examine whether or not providing monetary incentives will enhance students' examination performance. They find strong evidence that students who played a classroom experiment game with real monetary consequences eventually performed better in the examination than those who played a hypothetical game and those who did not play at all.

On the other hand, Cardell et al. (1996) were not able to find evidence on improved student achievement through experimental learning. They employed computerized experiments relating to demand and supply, public goods and income redistribution. Including students' gender, GPA, prior experience in taking economics course, attendance rate, Scholastic Aptitude Test (SAT) scores, age and ethnicity as the independent variables in the regression model, there is no statistically significant difference between students from the experiment and control groups in the performance of the Test of Understanding College Economics (TUCE). However, Cardell et al. (1996) noted that their results are preliminary because there is no direct control for sample selection and variations in the behavioral impact of instructors cannot be fully controlled until the experiment is completed.

Durham et al. (2007) found mixed results on the influence of experimental pedagogy on students' examination performance. They include class size, age, gender, ethnicity, ACT exam score, GPA, attendance rate and students' major in the regression model. Their research shows that students participating in experiments perform better than the non-participants in questions illustrating the concepts of demand and supply, cartels, resource allocation and public goods. However, participants were outperformed by non-participants in areas of monopoly and diminishing marginal utility.

While the majority of research studies on classroom experiments are focused on university education, Eisenkopf and Sulser (2016) focus on high school students in the German-speaking area of Switzerland. They randomly assigned students into an experiment and a conventional teaching group. Data suggests that their classroom experiments did not offer a significant benefit to students in terms of average test scores. The authors point out that this lack of significant benefit can potentially be due to the fact that economic theories taught at the high school level are generally less abstract, hence limiting the effectiveness of classroom experiments.

Instead of comparing student achievements with and without the use of experiments, Yandell (2004) and Cartwright and Stepanova (2012) studied other aspects of experimental learning. Yandell (2004) examines the influence of the number of experiments on student achievements. Experiments adopted in this study cover topics such as double oral auction, production function, public goods and prisoners' dilemma. A comparison of the examination performance between students who are exposed to only two sets of experiments and those with six sets reveals no statistically significant difference. It is concluded that additional experiments do not pose positive impacts on student achievement. Cartwright and Stepanova (2012) compare the performance of students who attended and/or wrote a report on an experiment versus those who did not. They observed a 40-60% improvement in students' score in a classroom experiment-based test question if students had written a report on that experiment. Their findings illustrate the benefit of integrating classroom experiments with some form of assessment.

Our study falls into the first category as classified by Emerson and English (2016). We focused on one set of oligopoly market experiment and study the effectiveness of the experiment on improving students' learning outcome. But unlike Frank (1997) and Gremmen and Potters (1997) in which the experiments are conducted after the relevant lectures, we conduct the experiments before the relevant lecture is delivered.

Experimental Design and Data Description

Background and Experimental Design

This study was implemented on a calculus-based intermediate microeconomics course offered in the Spring semester of the 2015-16 academic year at the Hong Kong Polytechnic University. The enrolment size was 59, with students either majoring in Investment Science or minoring in Business Economics. As this course is at the intermediate level, all students have prior knowledge in economics. Similar to the market structure curriculum of most microeconomics courses, perfect competition and monopoly models are covered before oligopoly models, such that students have a firm grasp on the concept of profit maximization before the introduction of interdependency between firms. An experiment session was inserted in the teaching schedule between the monopoly and oligopoly models. The session was pre-announced and held during a normal class time. Attendance at the session was voluntary, just as class attendance was voluntary.

Two experiments were adopted from Economics-games.com, an online platform offering free educational games and experiments for teaching economics. One was based on the Stackelberg model and the other on the Cournot model. Each student used an individual electronic device (mobile phone, tablet or laptop computer) to access the experiment system. In order to keep track of students' decisions and participation, they were required to log into the system with their student ID. They were then paired up with an unknown counterpart in class, whom they had to compete against. Instructions were shown to students before each experiment, outlining the setting of the market, the objective (i.e. profit-maximization), and the choice variable. In both experiments, the market demand function and marginal cost of production were known to every participant. Students were required to submit a production quantity decision to the system, either in turn (Stackelberg game) or simultaneously (Cournot game). After receiving all the decisions, the system calculates the profit earned by each participant and a leaderboard was projected on the screen so that everyone knows the outcomes. Each game was repeated five times. To encourage serious participation, a special bonus mark was given to the top three students who achieved the highest cumulated profit in each set of experiment.

Students were asked to share and review their experience after each series of experiment. Unsurprisingly, all top-performers had factored into their decisions the expected behavior of their rivals. This outcome allowed the instructor to stress the importance of strategic behavior in oligopoly markets. As the experiment session was held before the discussion of the relevant models, it gave students a first encounter with the context of the oligopoly models. This helps pave the way for the actual discussion of the actual models because students can relate to the models with their personal experience. It also helps arouse students' interest and increase their motivation in learning the models, as they would like to know how they could have achieved better results.

Questionnaire Results

At the end of the semester, students were required to complete a questionnaire evaluating the characteristics of the experiments and the perceived effectiveness of the experiments in helping them meet the learning objectives. The scope of this research and the use of students' data (including questionnaire feedback and course results) were explained clearly to students in the introduction of the questionnaire. Students were given the option to leave the questionnaire blank if they do not wish to have their data used for this research. All questionnaires were collected by a student representative and the questionnaires were kept in the School's administration office until final examination results were finalized and released.

Students were required to indicate on a five-point scale their opinion towards various statements about the experiment (1 = strongly disagree; 2 = disagree; 3 = neutral; 4 = agree; 5 = strongly agree). Students were generally positive to both the experiment setup and the associated learning experience. The arithmetic means of the responses to the statements range from 3.97 to 4.17. The primary objectives of the experiments are to stimulate students' interest in the subject matter and help students understand the relevant course content. As reported in Table 1 and Figure 1, 80% or more of the students agreed (i.e. giving a rating of 4 or above) to the questionnaire statements addressing these two objectives (S3 and S4). Also, most students can see the relevance of the experiments to their study (S5). Overall, students were positive towards the learning experience provided by the experiments, with over 70% of students agreeing to statement S6.

Table 1. Questionnaire statements and mean score

Statement	Mean
S1. The experiment requirements are easy to understand.	4.09
S2. The competitive nature of the experiments increased the level of excitement.	4.17
S3. The experiments help stimulate my interest in the subject contents.	4.03
S4. The experiments enhanced my understanding on how competitors interact in various market structures.	4.06
S5. I can see the relevance of the experiments to my studies.	4.09
S6. In general, the experiments have provided me with valuable learning experience and knowledge in the topic concerned.	3.97

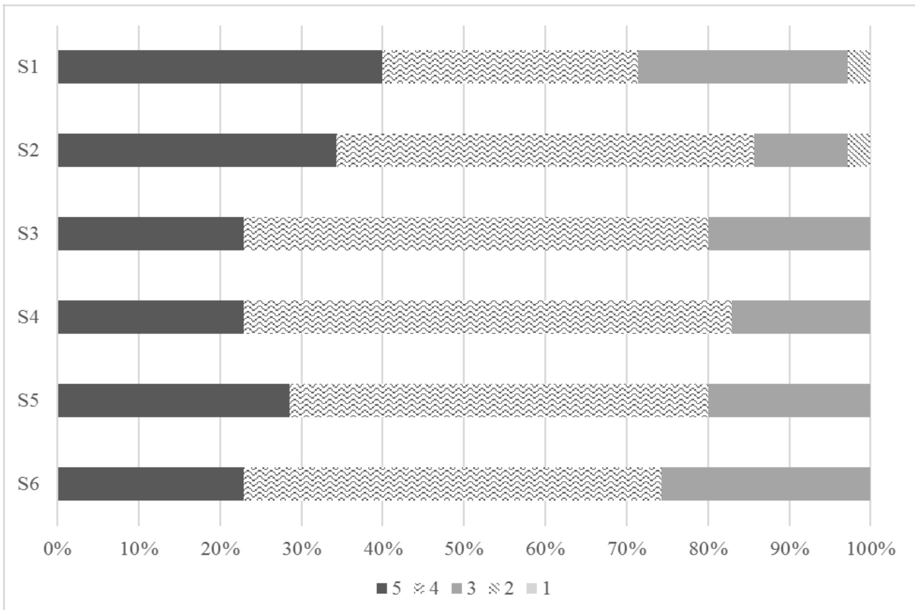

Figure 1. Percentage distribution of questionnaire responses

Impact on Learning Outcomes

We postulate that participation in the experiment session helps improve students' understanding of the oligopoly theories and subsequently improving their learning outcome.

In this study, we quantify student learning outcome through a final examination question devoted to oligopoly models. All questions in the final exam were compulsory and the oligopoly question accounted for 20 out of 100 points of the examination. Figure 2 compares the major assessment performance of students who participated in the experiment (*EXP*=1) and those who did not (*EXP*=0). We can see that the experiment group performed noticeably better in the mid-term test (*MT*), overall final examination (*EXAM_TOT*), questions in the final examination addressing other topics (*EXAM_OTH*), as well as the oligopoly question (*EXAM_OLI*). Table 2 summarizes the results of four t-tests of equal means on the assessment scores of the two groups. According to the p-values for the two-sided tests, the null hypothesis of equal mean is strongly rejected at 1% significance for each assessment outcome. The same results hold irrespective of the assumption on equality of variance.

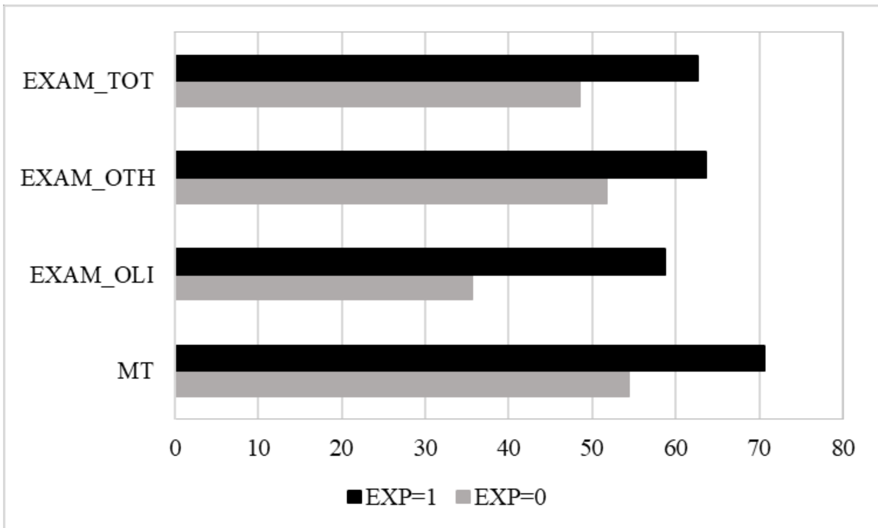

Figure 2. Student assessment outcomes

Table 2. Two-sample t-tests of equal means assuming unequal variances

	Mean	Variance	Obs	t-stat	p-value
MT					
EXP=1	70.629	283.711	35	3.665	0.001
EXP=0	54.417	275.123	24		
EXAM_TOT					
EXP=1	62.600	194.071	35	3.237	0.002
EXP=0	48.458	325.042	24		
EXAM_OTH					
EXP=1	50.857	116.773	35	2.856	0.007
EXP=0	41.333	186.841	24		
EXAM_OLI					
EXP=1	11.743	29.550	35	2.905	0.006
EXP=0	7.125	40.375	24		

The results in both Figure 2 and Table 2 apparently suggest that students who participated in the experiment session were the "better" ones in terms of their intellectual ability and/or motivation, because they performed significantly better in all assessment tasks. As a result, better performance in the oligopoly question, at least on its own, does not necessarily imply that the experiment session was beneficial to students' learning. However, on closer examination of Figure 2, we can observe a more pronounced difference between the mean scores in *EXAM_OLI* relative to that of the other assessments. The mean scores of the experiment group were 30%, 30%, 23% and 65% higher than the control group in *MT*, *EXAM_TOT*, *EXAM_OTH* and *EXAM_OLI*, respectively.

Econometric Model and Results

In order to isolate the impact of our experimental session on students' learning outcome, we further analyze students' score in the oligopoly question under a reduced-form education production function framework:

EXAM_OLI = f (student ability, study effort, learning attitude, experiment participation)

Since we do not have detailed and reliable data on students' ability, study effort and learning attitude during the semester, we use students' net continuous assessment score (= continuous assessment score minus participation score), *CA*, as a proxy variable to control for the effect of these factors on students' performance in the oligopoly question. Specifically, we anticipate a positive relationship between *CA* and *EXAM_OLI*. This yields the following basic regression model:

$$EXAM\_OLI_i = \beta_0 + \beta_1 CA_i + \beta_2 EXP_i + \varepsilon_i \quad (1)$$

where subscript i identifies the individual students and ε is an error term. Since participation in the experiment session was voluntary, students who participated were likely to be more motivated (and/or with better learning attitude). Therefore, experiment participation is likely to be endogenous. We accommodate this sample selection problem by estimating equation (1) as an endogenous treatment effects model (Maddala, 1983, ch.9), in which EXP_i is assumed to stem from an unobservable latent variable, EXP_i^*, that depends on students' class participation and overall performance during the semester. Experiment participation is modelled as follows:

$$EXP_i^* = \gamma_0 + \gamma_1 PART_i + \gamma_2 CA_i + u_i \quad (2)$$

$$EXP_i = 1 \text{ if } EXP_i^* > 0, \ = 0 \text{ otherwise} \quad (3)$$

where *PART* is a class participation score ranging between 0 and 10 to reflect a student's level of involvement in class and u is an error term for the treatment-assignment model. It is expected that both γ_1 and γ_2 are positive.

We estimate the endogenous treatment effects model with a one-step control-function estimator (Wooldridge, 2010, sec.14.2). The results are presented in Table 3. A Wald test on the null hypothesis of no correlation between ε and u has a χ^2 statistics of 1.340 and a p-value of 0.247, meaning that the outcome and treatment equations are statistically independent. In the treatment equation, the estimated coefficient for *PART* is statistically significant (p <

0.000) but that for *CA* is not (p = 0.201). It is unlikely that the statistical insignificance is due to multi-collinearity because the pairwise correlation coefficient between *CA* and *PART* is only 0.313. This means students who participate more actively in class are more likely to attend the experiment session, but a student's overall performance during the semester does not affect experiment participation. Turning to the outcome equation, we can see that the coefficients for both *CA* and *EXP* are statistically significant. As expected, a student's overall performance during the semester has a positive influence on the score of the oligopoly question. This implies that students who are more capable and/or with better learning attitude perform better in the oligopoly question. More importantly, experiment participation has a discernible positive effect on students' performance in the oligopoly question. On average, students who participated in the experiment scored 5.417 points higher than the other group in this 20-point question. This serves as a strong support to our hypothesis that classroom experiments conducted prior to relevant lectures can also help improve student learning outcomes.

Table 3. Endogenous treatment-effects regression results

	Estimated Coefficient	**Standard Error**	**p-value**
Outcome equation			
β_0	-1.097	3.024	0.717
β_1	0.276	0.133	0.038
β_2	5.417	2.187	0.013
Treatment equation			
γ_0	-6.020	1.870	0.000
γ_1	0.735	0.144	0.000
γ_2	0.069	0.054	0.201

Discussions and Conclusions

The goal of this study is to examine whether classroom experiments can improve student learning outcomes when the experiment is conducted before the relevant concepts are covered. We found that the group of students who voluntarily participated in an oligopoly experiment session performed noticeably better than the control group in all assessment tasks throughout the semester, but there is a much more pronounced difference between the two groups in their performance in a final exam question on oligopoly (65% difference) relative to that of the other assessments (23-30% difference). This potentially implies that experiment participation has a positive influence on students' performance in the exam question related to the classroom experiment. Our endogenous treatment effects regression results further reveal that experiment participation raised a student's score by 5.417 points on average in a 20-point question that was related to the experiment. Findings from the end-of-semester student evaluation questionnaires also indicate that students have gained valuable learning experience and knowledge in the topic concerned through the experiments. Their interest in the subject contents were stimulated and their understanding on how competitors interact in various market structures were enhanced. As discussed in the literature review section above, experiential learning is about the transformation of experience to knowledge. Our experiment served the role of providing students with a relevant experience in the context of the theories to be taught. It also helped students grasp the key components of the theories. The lecture teaching then guided the students through a reflection and thinking process to help them create knowledge. The effectiveness of this approach is demonstrated in the student learning outcomes.

Our results supplement existing findings in the literature by showing that experiments conducted before a relevant theory is taught can also improve student learning outcomes. Rather than helping students retain knowledge by allowing them to apply the theories they learned, our experimental design put students in the context of which a theory addresses. Our approach can provide students with prior knowledge and experience that is important for the understanding of a theory and improve students' motivation in learning the theory. Although our study focuses on the use of classroom experiments, the practical implication of our results is more far-reaching. In order to help associate students with the relevant subject matters to improve learning, lecturers may explore other effective and appropriate means that can be used to provide students with prior knowledge and experience. These means are course or topic-specific, and they may include case study, role play, gamification, etc., just to name a few examples. It should also be noted that the adoption of our approach is not limited to the economics and business disciplines. Given the educational value of first-hand prior knowledge, our approach may as well be suitable for other academic disciplines (e.g. humanities, social sciences, applied sciences, etc.) with a focus on real-world applicability.

Of course, our current research is not without limitations. Firstly, the sample size of this study is not big (around 60 students). This may have limited the capability of the endogenous treatment-effect model in correcting for the potential bias in our sample selection. Secondly, it will be more ideal if a comparison can be made between a group doing experiments before, and another group after relevant theories are taught. However, this calls for a very different experimental design and is out of the scope of this research.

To our knowledge, this study is the first that documents the efficacy of the use of classroom experiments in an Asian university. We encourage more research in this area with a broader geographical or demographical coverage, so that economic education researchers can better understand the application of experiential learning in different cultural settings. Further research in this area can also try to randomize the assignment of students into the experiment and control groups. This may minimize the influence of self-selection as encountered in this study.

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