Pre-Recorded Lectures, Live Online Lectures, and Student Academic Achievement

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ABSTRACT

In the midst of the COVID-19 Pandemic, universities throughout the world are embracing online learning, often depending on synchronous and asynchronous digital communications. In this paper, we compare the impacts of live online (synchronous) and pre-recorded (asynchronous) lectures on student achievement using a randomized experiment. We discovered that the pre-recorded lectures reduce lower ability students' academic achievement but have no effect on higher ability students' academic achievement. In particular, being taught via the pre-recorded lectures, as opposed to the live online lectures, decreases the likelihood of answering exam questions correctly by 1.6 percentage points for students in the bottom 50th percentile of the ability distribution (measured by GPA at the beginning of the semester). Furthermore, being taught via the pre-recorded lectures in the starting weeks of the semester tend to be more harmful to students' academic achievement, compared to the later ones. These findings have important implications for the effective design of education policies.

Keywords: Online education; Academic achievement; Pre-recorded lectures; Live online lectures

INTRODUCTION

In the midst of the COVID-19 pandemic, universities throughout the world are embracing online learning. In Vietnam, many universities have been pushed to make a fast transition from traditional face-to-face instruction to online classes since the beginning of the pandemic. It turned out that switching to online classes went more smoothly than anticipated. This level of preparedness stems from the fact that many universities around the country have already established the basic infrastructure for online learning, and many have already started offering online programs to their students. Despite the fact that there remain numerous problems, meta-analyses reveal that online learning can be viable alternatives to face-to-face instruction (Means et al., 2013). In Vietnam, the most common strategies for delivering online lectures are synchronous online education (e.g., live online lectures via Google Meet, Zoom, Microsoft Teams, etc.) and asynchronous online education (e.g., pre-recorded lectures, email exchanges, forum discussion, etc.).

Nevertheless, scientific studies exploring the effects of these two approaches on students' academic achievement is still limited, and the results are inconclusive thus far. For example, Kubey, Lavin, and Barrows (2001) discovered that students having synchronous online education tend to have lower academic achievement than having asynchronous online education. The superior amount of content obtained via asynchronous approaches, according to Perera and Richardson (2010), is the main factor contributing to better performance on the final examination. Somenarain et al. (2010), on the other hand, demonstrate that synchronous online education is more successful in improving students' conceptual comprehension. Besides, students evaluated synchronous virtual classrooms more highly because of the convenience and quality of live discussions being delivered (McBrien, Jones, and Cheng, 2009). Several studies, such as the works of Love and Fry (2006) and (Wells et al., 2008), uncover that students see synchronous online

education as only a kind of tutor section, thus averse to engaging in synchronous online classes and worsening academic achievement. There are also studies documenting that both synchronous and asynchronous online education are equally helpful in improving students' conceptual knowledge and academic achievement (Duncan et al., 2012).

In this paper, we contribute to the literature by comparing the effectiveness between live online (synchronous) and pre-recorded (asynchronous) lectures on students' academic achievement using a randomized experiment in a Vietnamese university. We conducted a randomized experiment in which first-semester second-year university students attending live online lectures were randomly selected to be taught via the pre-recorded lectures for their mandatory courses in economics. Not only across students, being taught via the pre-recorded lectures was also randomized within students. In other words, a given student was taught via the pre-recorded lectures in only some random weeks during the semester. In addition, we connected all of the exams' questions to the weeks of the semester in which the content needed to answer them was taught via either the online live or pre-recorded lectures. As a result, we can take advantage of the differences in question scoring both between students and within students (i.e. weeks with online live lectures vs. weeks with pre-recorded lectures for a given student). Our findings not only provide additional evidence to the debate on the effectiveness between synchronous and asynchronous online education, but also offer meaningful implications to the policymakers, especially in the midst of the COVID-19 pandemic.

Our empirical analysis uncover that pre-recorded lectures reduce lower ability students' academic achievement but have no effect on higher ability students' academic achievement. In particular, being taught via the pre-recorded lectures, as opposed to live online lectures, decreases the likelihood of answering exam questions correctly by 1.6 percentage points for students in the

bottom 50th percentile of the ability distribution (measured by GPA at the beginning of the semester). Furthermore, being taught via the pre-recorded lectures in the starting weeks of the semester tend to be more harmful to students' academic achievement, compared to the later ones. Specifically, being taught via the pre-recorded lectures, as opposed to live online lectures, in the early, middle, and late semester decreases the likelihood of answering exam questions correctly by 1.1, 0.9, and 0.8 percentage points, respectively.

A possible explanation for our findings is that in crowded classes (such as those in our experiment ranging from 55 to 83 students per instructor), interactions with the instructor could be limited, and the benefits of being taught via the live online lectures might only be marginally higher than the benefits of being taught via the pre-recorded lectures, especially for the brighter students who can possibly grasp much of the material on their own. The less bright students, on the other hand, might find it more difficult to grasp the content without asking instructors for more explanations during live online lectures. In other words, self-study from pre-recorded lectures might be less effective when compared to attending live online lectures for these less bright students. Besides, providing pre-recorded lectures in the starting weeks of the semester could be more harmful because the first few weeks might set the tone for the rest of the semester in many aspects. For example, getting used to the course knowledge early might be helpful in digesting the later course contents that are increasingly difficult and require previously studied knowledge. Furthermore, students often make early decisions about whether or not they will enjoy the course, its material, the instructor, and their peers during the first few weeks.

The heterogeneity in the impacts of providing pre-record lectures, as opposed to the live online ones, on students of high and low abilities are a discovery that may readily guide the design of distance learning education policies. For instance, universities concerned about their students'

academic achievement might gain from our research that just offering pre-recorded lectures could deepen the academic inequality between students with higher and lower abilities. Under limited resources (such as bad internet connection and crowded classes), a better solution for distance learning could be to provide pre-recorded lectures for the students with high GPAs and live online lectures for those with low GPAs. Furthermore, when considering the combined option of live online and pre-recorded lectures, it would be better off for the students' academic achievement when scheduling live online lectures early in the semester.

LITERATURE REVIEW

Synchronous online education is real-time communication between instructors and students when they are geographically distant but online at the same time to receive instantaneous responses from each other (Tallent-Runnels et al., 2006). This type of instructional approach is often delivered through real-time communication technologies, such as instant messaging and online video/audio conferences (Hrastinski, 2008). Asynchronous online education refers to delayed communication over a period of time between instructors and students. This type of instructional approach usually relies on text-based or recording technologies such as online forums and e-mails (Hrastinski, 2008).

Both synchronous and asynchronous online education have their own advantages and disadvantages. Synchronous online education allows students to discover social indicators such as body language and facial expression during the conversation, which can lead to the establishment of social bonds and improve students' participation in interactions (Peterson et al., 2018). Miscommunications can also be reduced by instantaneous questions and answers during

synchronous online education. In addition, synchronous online education can save time for both instructors and students since the discussions happen simultaneously, i.e. repeated questions and answers are significantly reduced.

Asynchronous online education, on the other hand, might make the learning atmosphere more comfortable by allowing for greater freedom in communicating time and mode. Students will have more time to enjoy the lectures and formulate their comments. As a result, exchanges between instructors and students in asynchronous online education are often more relevant and meaningful (Marra et al., 2004). This advantage of asynchronous online education is particularly beneficial to introvert, hesitant, or language-challenged students (Belcher, 1999). Nevertheless, asynchronous online education has obstacles such as required commitment from the student and inefficient communication caused since exchanges are delayed (Wang & Woo, 2007).

Thus far, the majority of empirical research directly comparing synchronous and asynchronous online education has only focused on students' perceptions. For example, Chundur & Prakash, (2009), Rockinson-Szapkiw & Wendt (2015), and Peterson et al., (2018) find that students prefer synchronous online education, while Griffiths & Graham (2010) and Buxton (2014) discover the opposite. Some studies further document that students are indifferent between attending synchronous and asynchronous online education (Mabrito, 2006; Hrastinski, 2008). The primary cause of why students prefer one approach to the other in these studies is mostly related to the advantages of each approach, such as the interaction of synchronous online education and the convenience of asynchronous online education.

Nevertheless, scientific studies exploring the effects of these two approaches on students' academic achievement is still limited, and the results are inconclusive thus far. For example, Kubey, Lavin, and Barrows (2001) discovered that students having synchronous online education

tend to have lower academic achievement than having asynchronous online education. The superior amount of content obtained via asynchronous approaches, according to Perera and Richardson (2010), is the main factor contributing to better performance on the final examination. Somenarain et al. (2010), on the other hand, demonstrate that synchronous online education is more successful in improving students' conceptual comprehension. Several studies, such as the works of Love and Fry (2006) and (Wells et al., 2008), uncover that students see synchronous online education as only a kind of tutor section, thus averse to engaging in synchronous online classes and worsening academic achievement. There are also studies documenting that both synchronous and asynchronous online education are equally helpful in improving students' conceptual knowledge and academic achievement (Duncan et al., 2012).

In this paper, we contribute to this growing literature by comparing the effectiveness between live online (synchronous) and pre-recorded (asynchronous) lectures on students' academic achievement using a randomized experiment in a Vietnamese university. We conducted a randomized experiment in which first-semester second-year university students attending live online lectures were randomly provided pre-recorded lectures for their mandatory courses in economics. Not only across students, access to pre-recorded lectures was also randomized within students. In other words, a given student is provided pre-recorded lectures in only some random weeks during the semester. Our findings not only provide additional evidence to the debate on the effectiveness between synchronous and asynchronous online education, but also offer meaningful implications to the policymakers, especially in the midst of the COVID-19 pandemic.

METHODOLOGY

During the Fall semester of 2021 at Ho Chi Minh City Open University, we deliver the live online lectures of two mandatory courses of economics (*Principles of Macroeconomics* and *Principles of Microeconomics*) for the bachelor program via Google Meet (the default platform of the university). Depending on their major, students are required to take the subject in either Vietnamese or English.

Each subject-by-language was delivered by a different instructor. All classes of the same subject, regardless of the delivered language, were completely harmonized. In other words, the course contents, lecture notes, exercises, and homework, are exactly the same in all classes of the same subject (only translated into Vietnamese or English depending on the language requirement). Furthermore, the students having the same subject were given the identical exam (again, only translated into the two languages). Students were registered to a class at the beginning of the semester and were not allowed to change due to the university policy.

All the live online lectures were delivered and recorded via Google Meet. These recorded lectures were then used as the pre-recorded lectures. The pre-recorded lectures were accessible 24 hours after the live online lecture. The delay is unavoidable because we need to process the recorded live online lectures and upload them to the school platform. Students accessed the pre-recorded lectures via the school platform using their usual university accounts.

At Ho Chi Minh City Open University, a semester consists of 10 weeks/sessions. Each session lasts 270 minutes (i.e. 4.5 hours). In the first week, the instructors of these classes introduced the experiment to the students. Then, they were given one week to register for participation in the experiment. Overall, there are 154 out of 552 students decided to participate in the experiment. In

Table 1, we summarize the participating classes, the language of instruction, the class size (i.e. the number of students), and the number of students participating in the experiment (*Participation*).

Table 1: Classes and Students Involved in the Experiment

Class	Language	Class Size	Participation
Principles of Macroeconomics	English	55	16
Principles of Macroeconomics	English	55	12
Principles of Macroeconomics	Vietnamese	83	24
Principles of Macroeconomics	Vietnamese	83	31
Principles of Microeconomics	English	55	17
Principles of Microeconomics	English	55	15
Principles of Microeconomics	Vietnamese	83	23
Principles of Microeconomics	Vietnamese	83	16

Based on the participation lists of each class, we proceed to randomly divide the students into three groups. The first one, *Never*, consists of 31 students (20% of the experiment-participating students) that had never been taught via the pre-recorded lectures throughout the semester. The second one, *Always*, consists of 31 students (i.e. another 20%) that were taught entirely via the pre-recorded lectures in all of the weeks throughout the semester. The third one, *Sometimes*, consists of the remaining 92 students (i.e. the remaining 60%) who were taught via the pre-recorded lectures in only some random weeks. Not only across students, being taught via the pre-recorded lectures was also randomized within students. We do so by randomly assigning 50% of the Sometimes-students to be taught via the pre-recorded lectures for each individual week. This additional layer of randomization allows us to take advantage of the differences in academic achievement both between students and within students (i.e. weeks with the online live lectures vs. weeks with the pre-recorded lectures for a given student). At the end of the first week, the experiment-participating students were provided the exact schedule throughout the semester (i.e. which weeks were being taught via which modes). The experiment started in the second week until the end of the semester.

We also collected information of the experiment-participating students on individual characteristics such as gender, age, GPA, residential areas, and their performance in the final exams of the experiment-semester. All of the classes included in the experiment featured multiple-choice exams with a total of 40 questions in 60 minutes. More importantly, we design the exam questions and answers in a matrix format that precisely mapped to individual weeks. This matrix details which week and which lecture mode that the material required to answer a given exam question was given.

Our final sample consists of 154 students. In Table 2, we provide the summary statistics of the experiment-participating students. Approximately 60.1% of them are female. Their average age is 20.118, and their GPA at the beginning of the semester is 3.347 (out of 4), respectively. Besides, 37.3% and 44.4% of them have a mother and father completing high school, respectively. The final exam grades in all classes are in the 10 points scale and are standardized within each class to have the mean of zero and the variance of one. Note that the numbers of experiment-participating students differ across classes, thus the overall mean is 0.001, and not exactly zero.

Next, using the questions-answers matrix mentioned previously, we compute our main outcome, which is the share of correct answers to the exam questions related to the material covered at the class-week level (*Share of Correct Answers*). If only one question is related to the material of the week, *Share of Correct Answers* takes the value of one if that answer is correct, and zero otherwise. If two or more questions are related, *Share of Correct Answers* equals the total number of correct answers divided by the total number of the related questions. On average, the experiment-participating students correctly answer 64.4% of the questions. We also provide statistics by the assignment groups. Consistent with randomization, differences in the statistics across the assignment groups are small in magnitude and statistically insignificant.

Table 2 : Summary Statistics

	All (N=154)	Never (N=31)	Sometimes (N=92)	Always (N=31)
Female	0.601	0.613	0.603	0.585
	(0.491)	(0.489)	(0.491)	(0.495)
Age	20.118	19.825	20.169	20.259
	(2.228)	(2.063)	(2.197)	(2.493)
GPA	3.347	3.397	3.316	3.394
	(1.865)	(1.933)	(1.846)	(1.885)
Mother High School	0.373	0.388	0.376	0.349
	(0.479)	(0.484)	(0.478)	(0.471)
Father High School	0.444	0.441	0.443	0.451
	(0.494)	(0.494)	(0.493)	(0.497)
Exam grade	0.001	-0.002	0.006	-0.009
	(0.939)	(0.870)	(0.958)	(0.923)
Share of Correct Answers	0.644	0.656	0.641	0.644
	(0.203)	(0.198)	(0.203)	(0.209)

RESULTS

In this section, we discuss the estimating strategy and provide the estimated impacts of being taught via the pre-recorded lectures, as opposed to the live online lectures, on students' performance on the exams. To do so, we estimate the following regression equation:

$$Y_{icw} = \beta_0 + \beta_1 Treated_{icw} + \delta_i + \theta_c + \lambda_w + X'_{icw}\Omega + \epsilon_{icw} \quad (1)$$

where the subscripts *i*, *c*, and *w* correspond to student, class, and week, respectively. The main outcome variable, Y_{icw}, is the *Share of Correct Answers* as discussed above. The main explanatory $Treated_{icw}$ is a zero-one indicator taking a value of one if the referred student of a given class was randomly assigned to be taught via the pre-recorded lectures in the referred week. The covariate X_{icw} denotes a set of individual characteristics including age, squared-age, sex, GPA, maternal education, paternal education, and the fixed effects of the birth district, current district,

as well as enrolment cohorts. We also denote by δ_i, θ_c, and λ_w individual, class, and week fixed effects, respectively. Finally, ϵ_{icw} is the error term.

The estimating results are reported in Table 3. Column 1 displays the estimate from the most parsimonious specification where we only control for the main explanatory variable, *Treated*. In Column 2, we add the set of individual characteristics to the most parsimonious specification. In Column 3, we further control for the class and week fixed effects. Finally, Column 4 represents the most extensive specification where we account for student fixed effects, in addition to the previous controls.

According to Column 1, we find that being taught via the pre-recorded lectures, as opposed to the live online lectures, decreases the likelihood of answering exam questions correctly by 1.8 percentage points. However, this estimate from the most parsimonious specification only reflects the correlation between pre-recorded lectures and students' academic achievement as important factors are not accounted for. Therefore, from Column 2 to 3, we gradually add the individual characteristics (age, squared-age, sex, GPA, maternal education, paternal education, and the fixed effects of the birth district, current district, as well as enrolment cohorts) and class as well as week fixed effects, the estimate becomes a little smaller in magnitude but remains statistically significant.

Finally, according to our most extensive specification in Column 4 in which the student fixed effects model is utilized, we find that being taught via the pre-recorded lectures, as opposed to the live online lectures, decreases the likelihood of answering exam questions correctly by 1.0 percentage points. The estimate is statistically significant at the 1% level. In addition, since the total number of questions given in the final exam is 40, the treatment effect is equivalent to 0.4 additional wrong answers for the students.

Table 3: Main Results

	Y = Share of Correct Answers			
	(1)	(2)	(3)	(4)
Treated	-0.018***	-0.012***	-0.012***	-0.010***
	(0.005)	(0.004)	(0.004)	(0.003)
Observations	4968	4968	4968	4968
Student Fixed Effects	.	.	.	X
Class & Week Fixed Effects	.	.	X	X
Characteristics	.	X	X	X

Note: *p<0.1, **p<0.05, ***p<0.01. Characteristics include age, squared-age, sex, GPA, maternal education, paternal education, and the fixed effects of the birth district, current district, as well as enrolment cohorts.

So far, we have detected the unfavorable effects of being taught via the pre-recorded lectures, as opposed to the live online lectures, on student performance on the exam. We then proceed to explore the heterogeneous effects along the lines of student ability and the timing of the delivery of the pre-recorded lectures. First, we divide the students into two subsamples: (i) Lower Ability subsample includes the students with GPA below the 50th percentile, and (ii) Higher Ability subsample includes those with GPA above the 50th percentile. We then estimate the regression equation (1) separately for each subsample.

The estimating results come from the most extensive specification (similar to Column 4 in Tables 3) and are reported in Table 4. Interestingly, we discovered that pre-recorded lectures reduce lower ability students' academic achievement but have no effect on higher ability students' academic achievement. In particular, being taught via the pre-recorded lectures, as opposed to the live online lectures, decreases the likelihood of answering exam questions correctly by 1.6 percentage points for students in the bottom 50th percentile of the ability distribution (measured by GPA at the beginning of the semester). The estimate is small and statistically insignificant for the subsample

of higher ability students. Since the total number of questions is 40, the treatment effect is equivalent to 0.64 additional wrong answers for the lower ability students.

A possible explanation for the findings is that in crowded classes (such as those in our experiment ranging from 55 to 83 students per instructor), interactions with the instructor could be limited, and the benefits of being taught via the live online lectures might only be marginally higher than the benefits of being taught via the pre-recorded lectures, especially for the brighter students who can possibly grasp much of the material on their own. The less bright students, on the other hand, might find it more difficult to grasp the content without asking instructors for more explanations during live online lectures. In other words, self-study from pre-recorded lectures might be less effective when compared to attending live online lectures for these less bright students.

Table 4: Heterogeneity in Ability

	Y = Share of Correct Answers	
	Low Ability	High Ability
	(1)	(2)
Treated	-0.016***	-0.003
	(0.004)	(0.003)
Observations	2502	2466
Student Fixed Effects	X	X
Class & Week Fixed Effects	X	X
Characteristics	X	X

Note: *p<0.1, **p<0.05, ***p<0.01. Characteristics include age, squared-age, sex, GPA, maternal education, paternal education, and the fixed effects of the birth district, current district, as well as enrolment cohorts.

Next, we further explore the relative importance of the delivery timing of the pre-recorded lectures. Specifically, we want to know the delivery of pre-recorded lectures in which period exerts the largest impacts on student achievement in the exam. To do so, we replace the single indicator

Treated in the regression equation (1) with three indicators namely, *Treated First 3-Weeks*, *Treated Second 3-Weeks*, and *Treated Third 3-Weeks*, which indicates whether the student was taught by the pre-recorded lectures in the first, second, and third 3-weeks of the experiment period. The estimating results come from the most extensive specification (similar to Column 4 in Tables 3) and are reported in Table 5.

Overall, we uncover that providing the pre-recorded lectures in any of the three 3-week periods is all harmful to student achievement, compared to the live online lectures. However, we find that being taught via the pre-recorded lectures affects students' academic achievement the most in the first 3-weeks by lowering the likelihood of answering exam questions correctly by 1.1 percentage points (i.e. 0.44 additional wrong answers). The impact is slightly lower in the second 3-weeks with a reduction in the likelihood of answering exam questions correctly by 0.9 percentage points (i.e. 0.36 additional wrong answers). Lastly, delivering the pre-recorded lectures in the last 3-weeks of the semester has the smallest effect with a decrease of 0.8 percentage points in the likelihood of answering exam questions correctly (i.e. 0.32 additional wrong answers).

A potential explanation for this pattern is that the first few weeks might set the tone for the rest of the semester in many aspects. For example, getting used to the course knowledge early might be helpful in digesting the later course contents that are increasingly difficult and require previously studied knowledge. Furthermore, students often make early decisions about whether or not they will enjoy the course, its material, the instructor, and their peers during the first few weeks.

Table 5: Heterogeneity in Treatment Time

	Y = Share of Correct Answers
	(1)
Treated First 3-Weeks	-0.011***
	(0.003)
Treated Second 3-Weeks	-0.009**
	(0.004)
Treated Third 3-Weeks	-0.008**
	(0.003)
Observations	4968
Student Fixed Effects	X
Class & Week Fixed Effects	X
Characteristics	X

Note: *p<0.1, **p<0.05, ***p<0.01. Characteristics include age, squared-age, sex, GPA, maternal education, paternal education, and the fixed effects of the birth district, current district, as well as enrolment cohorts.

CONCLUSION

Many universities across the globe have been pushed to make a fast transition from traditional face-to-face instruction to online classes due to the outbreak of COVID-19. The most common strategies for delivering online lectures are synchronous online education (e.g., live online lectures via Google Meet, Zoom, Microsoft Teams, etc.) and asynchronous online education (e.g., pre-recorded lectures, email exchanges, forum discussion, etc.). Nevertheless, scientific studies exploring the effects of these two approaches on students' academic achievement is still limited, and the results are inconclusive thus far. In this paper, we contribute to the literature by comparing

the effectiveness between live online (synchronous) and pre-recorded (asynchronous) lectures on students' academic achievement using a randomized experiment in a Vietnamese university.

We conducted a randomized experiment in which first-semester second-year university students attending live online lectures were randomly selected to be taught via the pre-recorded lectures. Not only across students, being taught via the pre-recorded lectures was also randomized within students in our experimental design. As a result, we can take advantage of the differences in question scoring both between students and within students. Our empirical analysis uncover that pre-recorded lectures reduce lower ability students' academic achievement but have no effect on higher ability students' academic achievement. In particular, being taught via the pre-recorded lectures, as opposed to live online lectures, decreases the likelihood of answering exam questions correctly by 1.6 percentage points for students in the bottom 50th percentile of the ability distribution (measured by GPA at the beginning of the semester). Furthermore, being taught via the pre-recorded lectures in the starting weeks of the semester tend to be more harmful to students' academic achievement, compared to the later ones.

The heterogeneity in the impacts of providing pre-record lectures, as opposed to the live online ones, on students of high and low abilities are a discovery that may readily guide the design of distance learning education policies. For instance, universities concerned about their students' academic achievement might gain from our research that just offering pre-recorded lectures could deepen the academic inequality between students with higher and lower abilities. Under limited resources (such as bad internet connection and crowded classes), a better solution for distance learning could be to provide pre-recorded lectures for the students with high GPAs and live online lectures for those with low GPAs. Furthermore, when considering the combined option of live

online and pre-recorded lectures, it would be better off for the students' academic achievement when scheduling live online lectures early in the semester.

Our work also contributes to a growing body of knowledge about the relationship between alternative instructional modes and learning processes. For instance, some studies document that MOOCs students (i.e. those enrolled in Massive Open Online Courses) have higher dropout rates compared to the traditional ones (McPherson & Bacow, 2015). Others uncover that flipped classes (a teaching method in which students watch pre-recorded videos of lectures and use classroom time to discuss problem sets with instructors) disproportionally benefit students with higher ability (Setren et al., 2020). Within online education, several studies examining the role of social presence in online classrooms have found that presenting the instructor's face increases students' learning outcomes and enjoyment (Lyons et al., 2012). However, others suggest that the potential benefit of eliciting social interactions by presenting the instructor's face is offset by the extra visual processing caused by the face (Clark & Mayer, 2016).

The presenting heterogeneous effects of different modes of online teaching might extend beyond students' academic achievement since the decline in education could affect a variety of aspects such as earnings, health, social capital, among others (Lemieux and Card, 2001; Le and Nguyen, 2021, 2022; Nguyen and Le, 2022; World Health Organization, 2003, 2007, 2008). Affected individuals might transmit these socioeconomic disadvantages to the future generation, exacerbating social inequality and impeding economic development (Le and Nguyen, 2020; World Health Organization, 2018). Therefore, our findings not only provide additional evidence to the debate on the effectiveness between synchronous and asynchronous online education, but also offer meaningful implications to the policymakers, especially in the midst of the COVID-19 pandemic.

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