A Randomized Assessment of Online Learning

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ABSTRACT

An economics principles course employing random assignment across three sections with different teaching models is used to explore learning outcomes as measured by a cumulative final exam for students who participate in traditional face-to-face classroom instruction, blended face-to-face and online instruction with reduced instructor contact time, and a purely online instructional format. Evidence indicates learning outcomes were reduced for students in the purely online section relative to those in the face-to-face format by 5 to 10 points on a cumulative final exam. Disadvantage students appear to do worse in the online and blended formats.

I. Introduction

This paper contains estimates of the impact of different instructional delivery models that incorporate online course content on learning outcomes of college students of principles of microeconomics using a randomized study design. In the existing literature, there are, to our knowledge, only two published studies (Figlio, Rush and Yin, 2013 and Bowen, Chingos, Lack and Nygren 2014) and one working paper (Joyce, Crockett, Jaegar, Altindag, and O'Connell 2014) that use a random design to explore the impact of any variant of online education in a college length course on learning outcomes. Thus, this study provides an important extension to a literature that is extraordinarily small given the widespread adoption of online teaching and its potential impact on student outcomes at the postsecondary level.

The experimental design used in the study randomly assigns students to one of three delivery modalities: classroom instruction, blended instruction with some online content and reduced instructor contact, and purely online instruction. In the classroom section of the course, students meet with an instructor twice per week for 75 minutes, once in a lecture session and once in a discussion session. In the blended section, students meet one time per week for 75 minutes with the instructor in a discussion session, view online lectures and have access to other materials described below. In the online course section, students view online lecture materials as their course instruction and have access to extensive online materials developed to be consistent with a set of external standards for best practices in online education. For the three arms of the experiment, lectures, discussions, and other instructional content are prepared and delivered by the same instructor. The measure of learning outcomes examined throughout the analysis is a cumulative final exam.

With University Institutional Review Board approval, data was collected on demographic characteristics and measures of academic background for students who requested permission to enroll in the course and signed an informed consent agreement to participate in the experiment. The class size for each of the three arms of the experiment within each semester was capped at 35. The experiment ran for four consecutive semesters, beginning in the fall semester of 2012 and concluding at the end of the spring semester of 2014.

The data available for this paper consists of observations on the 519 students who were randomly given permission to enroll in an arm of the experiment. Of those, 429 students made use of their permission numbers to enroll in the course and 323 of those students completed the course. 90 students decided not to use their permission number to enroll in the course. 106 students did not complete the course once they had enrolled. As will be discussed further below, at each level of the experiment, attrition was heaviest among the purely online students and smallest among those enrolled in the face-to-face classroom section. This information is used to provide estimates that account for the potential impact of differential attrition at different stages of the experiment on student learning.

Comparisons of important characteristics across the three arms of the experiment at the point of randomization, after students enrolled in the course, and at course completion indicate that the randomization was successful in assigning similar students across the three arms of the experiment. Also, key characteristics of those who completed the experiment were not significantly different from other students taking a non-experimental section of the course at the same university at the time of the experiment. Thus, the results of this study appear to be generalizable at the university where the experiment was run but more broadly to other university settings where admissions are selective (with cumulative SAT scores near 1800) and with the availability of relatively small class sizes for principles courses.

The primary measure of learning outcomes examined is a graded cumulative final exam.[1] The learning outcomes on exam scores are not meaningfully different for the average student in the control group (classroom instruction) and blended treatment group for any of the estimates presented, consistent with the results of Chingos et al. (2014) and Joyce et al. (2014). However, the exam scores for the control group in a face-to-face classroom instructional environment are higher, at a statistically significant level, than for the online treatment group when examining outcomes for those who completed the course and when accounting for differential attrition across the arms of the experiment. This result is consistent with findings from the study of Figlio et al. (2013) although the

[1] A power analysis was conducted prior to running the experiment to assure reasonably small changes in academic outcomes across the three class types of the experiment could be detected given samples of the approximate size that actually occurred.

estimates presented here indicate that learning outcomes are more adversely affected than reported in that study. Some evidence is also provided that these results are concentrated among students with a lower prior Grade Point Average (GPA).

Even though the course taught within this experiment was designed in accordance with external standards for best practices for the delivery of online educational content, the results indicate that at least for economics principles courses, current techniques of online content delivery do not produce learning outcomes equal to those obtained from traditional classroom based face-to-face instruction. The implication is that additional thought regarding delivery of course content and possibly additional resources must be brought to bear to try and equalize educational outcomes across face-to-face and online settings.

In contrast, results from this study show that on average, performance on a cumulative exam does not differ across students assigned to blended classes with reduced instructor contact time and the classroom sections. This provides further support for the view that some instructional time can be reduced when quality courses that blend online instruction with face-to-face contact are offered without adversely impacting learning outcomes for students. However, this optimism comes with the caution that some disadvantaged minority groups appeared in this experiment to perform meaningfully worse than other students in blended class settings.

II. Literature Review

There is a large prior literature that has addressed the impact of incorporating online content delivery into educational instruction. That literature has examined impacts on classes at the primary, secondary, and postsecondary levels. As summarized in a meta-analysis released by the U.S. Department of Education (2010, p. xii), the initial search for articles within this massive literature located 1,132 publications as of 2008. Of those, 176 were reported to use either a quasi-experimental or experimental design while containing an objective measure of learning. Further requiring that a direct contrast be made in the analysis between any of the combinations of the three basic types of instructional settings considered here -- classroom, blended or purely online education -- reduced that set to 99 with 9 examining K-12 education. Later, the report (p. 14) explains that only 45 of those studies had sufficient data to construct necessary measures to enter

the meta-analysis. Only a handful had a random design and none considered a semester length college level course.

Against this backdrop, the Figlio et al. (2013) study of the impact of teaching microeconomics principles in a purely online or face-to-face classroom setting on student learning outcomes was the first randomized study for a semester length course at the postsecondary level. Students were randomized after enrollment in the course into either a classroom based or purely online section. The study reports (p. 767) that of 1,600 enrolled students, 327 participated in the experiment. There were 97 students in the face-to-face section and 268 in the online section.

In assessing the difference in outcomes across sections, estimates indicate (Figlio et al., 2013, Table 3) that students attending the live lectures do roughly 3 points better than those in the purely online section on a mid-term exam and about 2.5 points better on their final exam. The discussion of sub-group impacts (p. 776) states, "the average test score grade for Hispanic students is dramatically higher in the case of live instruction. In addition, the estimated live instruction advantage is statistically different from zero for male students and for low achievers." Thus, the average student performed worse in the online sections with larger deficits observed among some groups that would be of concern for those hopeful that quality education can help equalize outcomes for disadvantaged minority groups or those with relatively weaker academic backgrounds.

The study of Joyce et al. (2014) similarly uses a randomized study design to examine different instructional models for principles of microeconomics focusing on a contrast between a face-to-face section that met twice a week versus a blended one that instead met once per week. Both sections had access to online materials. This contrast of two course sections in a blended teaching format that varied by providing more or less face-to-face contact time addresses an important margin of decision making for educational administrators, particularly within economics departments. Across the sections with more or less contact time, the study reports that no significant differences are found for the average final exam score (p. 14).

One interesting aspect of the Joyce et al. (2014) study is that the sections were not all the same size. Classroom availability dictated that some sections had to be taught in a room that would hold 274 students and others in a room holding 114 students (p. 8). This

allowed for contrasts to be made within the study between the outcomes of students in the smaller sections that had two meetings with an instructor versus the larger enrollment sections that had half as much contact time. For that contrast, the results showed (p. 17):

> "Students in the compressed format scored over 5 percentage points less . . . than those in the traditional class when the compressed was delivered in the large lecture hall, but there was no difference between formats when the compressed class was given in the smaller classroom."

This suggests that in making comparisons across studies it is important to bear in mind that learning outcomes are likely worse for any class format when the increase in class size is large.

The analysis of blended versus purely online delivery of a basic statistics course contained in Bowen et al. (2014), while not directly applicable to instruction of microeconomics, is nonetheless notable within the very small set of studies that employ a randomized research design. The study was conducted across six campuses comparing a machine based learning model with one hour per week of instructor contact time to classroom courses with about three hours per week of contact time. The study examines a number of learning outcomes including final exam scores and concludes (p. 94) that learning outcomes across the sections are about the same. This comparison of student outcomes associated with a blended course design versus traditional classroom instruction, although in a different field, arrives at a similar conclusion to the study by Joyce et al. (2014).

One additional randomized study relevant to our research does not make a direct contrast across course designs but instead considers random variation in the size of purely online classes. That study, by Bettinger, Doss, Loeb, and Taylor (2014a), makes use of random variation in the size of course sections provided by a major online university. The online provider randomly varied marginal additions of students to course sections in order to examine the impact of class size on outcomes in an online setting. The average variation was fairly small (p. 8) providing a net addition of three students to courses that otherwise would have averaged about 30 students. At this level of variation, the authors report (p. 13) that there did not appear to be any meaningful impacts on student grades or course completion.

Before moving on to discuss a handful of high quality studies that have used

observational data combined with methods for controlling for sample selection to assess the impact of different course designs on learning outcomes of students, we pause to highlight two important differences in the study conducted here relative to these prior studies. First, the random design of this study simultaneously considers three course formats (face-to-face, blended and purely online course designs) whereas prior studies have made a single contrast (Figlio et al., 2013 face-face v online; Joyce et al., 2014, and Bowen et al., 2014 face-face v blended). This allows us to consolidate and confirm prior findings within a single study. Second, this study randomly assigned students to different arms of the experiment at the point of the expression of interest in taking the principles course rather than after enrollment (Figlio et al. 2104 ; Bowen et al., 2014 ; Joyce et al., 2014). This allows us to examine the potential importance of both non-enrollment and failure to complete courses on learning outcomes.

Turning to the prior observational literature on undergraduate principles of economics courses, there is a relatively small literature that examines the impact of differential course design on student outcomes making use of observational data while controlling for the self-selection of students of different ability into the types of courses offered. These studies generally report that students self-select in systematic ways into different types of courses; however, the results of those studies, once this selection is taken into account, support conclusions similar to those found in randomized study designs. Students in purely online courses appear to have worse learning outcomes than those in a traditional classroom instructional setting. Those in blended courses have outcomes that appear equivalent to students in a face-to-face course.

Brown and Liedholm (2002) carried out one of the earliest of these observational studies using a sample of students from a single university. They consider the instruction of microeconomics principles in face-to-face, blended, and purely online formats. The blended format had online materials and reduced instructor contact from three to two hours per week. The study shows (Table 1) that students in the blended and online sections were stronger, having higher ACT scores. They estimate a model of the students' backgrounds on their performance on a final exam containing 37 questions. Using that model to account for differences in student backgrounds across sections, they report that (p. 447) "We find that the students in the virtual classes, while having better characteristics, performed significantly worse on the examinations than the live students." They did not find any

meaningful difference between students in the live lectures and the blended model. Their results mirror those of the available studies that have used a randomized research design.

Coates, Humphreys, Kane and Vachris (2004) performed a similar study making use of data on students from three universities who enrolled in face-to-face versus online sections of micro and macroeconomic principles courses.[2] Students in the online sections again are shown (Table 5) to have stronger academic backgrounds as exhibited in higher SAT scores. Using ordinary least squares, the authors find (pp. 542-545) that students in the online sections get 2 fewer correct answers on the 33 questions contained in the Test of Understanding of College Economics. Using a two stage least squares model to control for non-random enrollment across sections, they find that the students taught through online content delivery get about 4 fewer correct answers. Using a switching regression model, the online students get about 6 fewer correct answers. Thus, once selection is accounted for, students do significantly worse in the online sections than when taught in a face-to-face format. These results are consistent with those of Figlio et al. (2013) that also considered a contrast between online and face-to-face instruction.

Gratton-Lavoie and Stanley (2009) also considers students enrolled in purely online versus face-to-face course formats for microeconomic principles courses. Descriptive characteristics again reveal that students enrolled in the purely online course are stronger, having significantly higher prior grade point averages (Table 2). Raw test scores (Table 3) show that students in the online sections did much better on a final exam. However, when making use of sample selection and endogenous switching models to control for enrollment choices, the authors report (pp. 19-20) strong negative impacts of online education on test outcomes. The signs of their estimates are consistent with those of Figlio et al. (2013) although the size of the estimated impact is larger.

Olitsky and Cosgrove (2014) compare students in face-to-face and blended classes of micro and macroeconomic principles.[3] In a contrast to the other studies discussed, they report that stronger and more experienced students in their samples

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[2] Anstine and Skidmore (2005) performed a similar study using M.B.A. students enrolled in Masters level courses taught online versus face-to-face. Their results mirror those of Coates et al. (2004).

[3] An additional study by Cosgrove and Olitsky (2015) follows students through classes tracking retention of concepts across grading instruments. They find that students in face-to-face sections retain more difficult conceptual material.

choose to enroll in the face-to-face sections (Table 1) as evidenced by significantly higher proportions that already had an economics course and higher (not statistically different) scores on the SAT. Raw exam scores suggest that students in the blended course perform worse on final exams and homeworks (Table 1). The authors make use of propensity score matching methods to account for the influence of student backgrounds on enrollment choices. Based on results from that method, they conclude (p. 30), "after controlling for individual academic and demographic characteristics, we find no significant difference in outcomes between the blended and non-blended sections." Their results mirror those of Joyce et al. (2014) and Chingos et al. (2014).

Finally, Bettinger, Fox, Loeb, and Taylor (2014b) examine the impact of online relative to face-to-face instruction making use of data from a major provider of online education that also offers classroom based instruction sections of the same course at some locations. They exploit the variation in course offerings across locations and distance of students from campuses in an instrumental variable estimation approach. They do not report (Table 1a) large observable differences across course formats in academic background. They find (Table 2) that students in the online course have grades that are about -.2 to -.4 worse for the semester on a 4-point grading scale. These mild negative outcomes for students in an online instruction format are consistent with the findings of Figlio et al. (2013).

In summary, studies that have used observational samples have found inconsistent types of student selection in terms of enrollment. Across the studies, positive and negative selection can be observed along with samples that are balanced across the class types considered. Where sample selection is present and common methods are used to correct for it, the resulting estimates move in an expected direction and often alter the substantive conclusions that would be drawn relative to making inferences using mean differences in raw data. The conclusions of the studies that have employed observational data along with appropriate methods of correcting for self-selection of students into courses appear to be consistent with the results from the handful of relevant studies that have employed experimental methods.

III. The Randomized Trial

Randomized Control Trial

Our sample is collected from a microeconomics principles course taught over four consecutive 16-week semesters at a large public university in the Northeast. The research used a randomized control trial design. With approval of the Institutional Review Board of the university, each semester we listed a course of microeconomic principles that had three sections, each containing a different instructional model. For a student to enroll in the course, they had to contact the instructor who returned to them an informed consent document that described the experiment being conducted. The student had to sign and return the informed consent form to the instructor in order to receive a permission number to enroll in the course. Information is presented later in the analysis demonstrating that students who participated in the experiment were similar to those who did not and enrolled in another non-experimental section of the course.

As an incentive to participate, students were offered five points extra credit on their term average for the course. Participants were informed of this in the informed consent document. Upon receipt of the signed consent form, the volunteer was issued a permission number to enroll. Enrollment was voluntary and 83 percent chose this option. Once enrolled, students had the option to withdraw according to the procedures of any other university course. Of those who enrolled, 75 percent completed the course. Attrition by course section is discussed further below.

Instructional Formats

The traditional section met weekly for two 75-minute sessions, rotating between a discussion period and a lecture period. The blended section met weekly for a 75-minute discussion period, As a substitute for the lecture period students were given access to online lecture materials. The online section had class discussion in an online asynchronous forum, and for the lecture period students were given access to the same online lecture materials as the students in the blended modality. Students in the three arms were given access to the same set of PowerPoint lecture notes for each lecture. Students in the online and blended section were also given access to additional online lecture materials that included a version of the PowerPoint lecture notes enhanced to include audio narration along with user friendly navigation controls, a tape of the “live”

lecture, and a compact 20-minute closed-captioned taped presentation by the instructor of some of the slides.

Instructional Design of the Online Course

The instructional design of the course materials used in this study was initiated during the academic year 2003-04 by a team of professionally qualified course developers. The course content was designed in conformity with the Quality Matters Standards (Quality Matters Organization) adopted by online divisions of several universities including the University of Maryland and Brown University. Beginning with the summer session of 2004, these course materials have been used for online instruction a total of fourteen times – six summer sessions, three winter intersessions, and five fall/spring terms -- prior to their use in this research project.

Over this period the course design has been regularly updated to keep pace with technology innovations. Swan, Matthews, Bogle, Boles, and Day (2012) report evidence that keeping pace with evolving best practices improves learning outcomes. The design of the online course and its content has been formally reviewed twice by external referees (from Blackboard.com) and once by internal referees at our institution. The reviews have been favorable and the course design has been revised in response to recommendations to be in compliance with changes in the best practice standards. It was reviewed in March 2012 by two referees of the Blackboard Exemplary Course Competition. On a scale of 1 to 4, with four as the highest, one reviewer rated the course as 4.0, the other as 3.5.

In the literature of best practices for instructional design of online classes, the disadvantages of an online course that is comprised only of the "taped lecture" design for an online course are well recognized. "Simply taking material that was developed for classroom delivery and directly porting it into course management programs such as WebCT or Blackboard tends neither to be effective nor recommended." (Henry & Meadows, 2008). A particular concern is that the length of a lecture taped "live" is too long for students taking the course online. A standard recommendation of best practice instructional design is that the lecture material be segmented either into shorter videos on specific topics, or to provide hyperlinks within the lecture to main topics (California State University, 2012; Las Positas College, 2012). This recommendation is consistent with the studies of Martinez & Galvis (2010) and Pratt (2012) that suggest that learning that

depends on prolonged periods of passive listening can be challenging for students because of monotone presentation, and the resulting influences of fatigue and distraction.

A different concern with online instruction is that the learning that occurs from interactions between the instructor and students as well as among students is eliminated. A standard recommendation of best practice instructional design is to create similar opportunities for interpersonal interactions by including online discussion forums (Brown University, 2012; California State University, 2012; Grant & and Thorton, 2007; Las Positas College, 2012; Li, 2010; Young & Norgard, 2006). The remainder of this section highlights some of the best practice features implemented in this course to address these and other concerns.

Online Lecture Materials

All sections were given access to the PowerPoint notes used in the lectures. In this section we discuss in greater detail the attributes of the additional online lecture materials provided to the online and blended sections. One additional online lecture material was a tape of the "live" lecture originally given to the face-to-face section. As a general learning benefit, the advantage of a taped lecture is that students can always access the relevant lecture without having to attend the class at a certain time and can review the material at any time. However, to reduce the incidence of lecture-listening fatigue and distraction the online and blended sections were also given access to a compact, 20-minute version of the 75-minute lecture that uses some of the same PowerPoint slides as the full length live lecture. The compact version is closed-captioned, which educators believe is helpful to students for whom English is a second language, as well as for hearing-impaired students (Huang & Eskey, 1999). Additionally, a version of the shortened lecture closed-captioned in Spanish was made available to students in the online and blended sections. The university IRB requested this provision in light of the findings in Figlio et al. (2013) that Hispanic students in the online section of that study had worse outcomes than other students. Also, the closed-captioning is key word searchable so students can more easily locate sections of the lecture for review, instead of using the more time-consuming approach of listening to large portions of the oral lecture to locate relevant material.

The online and blended sections were also given access to an enhanced PowerPoint version of the lecture with hyperlinks separating it into five manageable chunks and a voice-over of the main points. The slides contain economic diagrams that are drawn sequentially by user mouse clicks and guided by audio narration. The diagrams can be replayed to clarify points the student may find confusing. The script for the audio narration appears in the notes pane of PowerPoint and the user can use the translate function in PowerPoint to have the script displayed in a language of their preference. The diagrams are followed by slides where the user is provided with a drawing tool and encouraged to draw the diagram, thereby adding interaction and reinforcement of the concept just taught.

Online Discussion Forums

As a substitute for the learning from interactions between the instructor and student, and between students that can occur in a classroom setting, the best practices recommendation is to supplement online lectures with an online discussion forum that engages students and fosters a sense of community between the instructor and students and between students (Quality Matters Organization). In the online section the opportunity for asynchronous discussion was provided using two equal sized Facebook groups. A portion of the course grade depends on the level of participation. Participation can be in several ways, posting (or responding to) questions to clear up confusing points in the lecture, posting links to articles and short videos helpful for understanding the topics in the lecture, and engaging in discussion questions posted by the instructor.

Independent Learning and Time Management

The instructional design in this course directly addresses students handicapped by deficiencies in independent learning and time management skills by having frequent exams and weekly assignments. Beyond providing ongoing learning opportunities and continual reinforcement of important concepts, these activities incentivize the students to engage with the course materials on an ongoing and timely basis. In all three sections there are three hourly exams (approximately one every four weeks) and a cumulative final exam. To motivate students to study on an ongoing basis, each week students are assigned a quiz, a homework problem set, and participation in a discussion forum. Assignments are due at the end of the week, grades are posted at the beginning of the

next week, and students are provided with a spreadsheet to record their progress. To allow for unexpected events, the lowest two grades for each assignment type (quiz, problem set, discussion) are dropped in calculating the semester average.

Especially for the online section, the weekly assignments provide a strong incentive for the student to avoid cramming behavior, and can be thought of as the online equivalent of the structured pace induced by attending weekly discussion sessions (as students in the face-to-face and blended sections attend). While the weekly assignments are among a set of recommended best practices, they also provided a response to an inquiry from the university IRB about how adverse outcomes among male students in the online sections of the study of Figlio et al. (2013) that were attributed to students watching lecture videos in sequence for the first time immediately prior to taking exams would be addressed.

IV. Descriptive Statistics Regarding Randomization and Estimation Results

A. Course Completers

First, we present some basic evidence that across the arms of the experiment (face-to-face, blended, and online) that descriptive characteristics of the sample are largely indistinguishable. We also provide a comparison between the face-to-face section relative to the other sections (blended and pure) in combination as we calculate some regression estimates using this combination to estimate program impacts. The tables of descriptive statistics are contained in online Appendix A.

We begin with the information most relevant to estimates for those who completed the course. Appendix Table 1.A provides means of demographic and background characteristics for students in the face-to-face and pure online sections along with differences in the means and relevant t-statistics at the point of enrolling in the course. As can be seen in that table, the only characteristic that is statistically significantly different across those two arms at conventional levels is the number of prior credits taken. The typical enrollee in the purely online course would have taken the equivalent of about two extra courses. Importantly, prior GPA, and individual component scores of SAT exams are not significantly different from each other. We control for differences in credits taken in our estimates of the impact of different models of course delivery on learning outcomes as well as all of the other characteristics shown in the

Appendix tables. Given that we find negative impacts of completing the online course on our measure of learning outcomes, we would note that the only dimension in which online students who completed the course are found to be different than others would appear to indicate they are slightly more experienced.

Appendix Table 1.B contains similar tests of average differences across students in the face-to-face and blended sections. There, none of the characteristics examined across the two groups are statistically significant at conventional levels. Finally, Appendix 1.C provides similar tests across students in the face-to-face versus the two combined online course sections. There, students in the combined online sections are found to have prior completion of about 2 credits more than those in the face-to-face section. All other characteristics likely to be related to subsequent student outcomes across the two groups are not significantly different at conventional levels.

In virtually every dimension, we conclude that the randomization was successful on the key characteristics likely to be most related to subsequent outcomes (prior GPA and individual SAT component scores) at the point of enrollment. We provide estimates with a control for prior course credits and other covariates when examining learning outcomes.

We also provide comparable descriptive statistics for those who completed the course in Appendix Tables 2.A, 2.B and 2.C. Again, the only observable difference is that those who take the online or blended courses appear to be have taken roughly 4-6 additional credit hours in the past (or 1 to 2 courses) although in direct comparisons to students who received face-to-face instruction, this difference is only significant at the .05 level for those in the purely online section. Again, we control for this one difference in our estimates (along with other covariates). It should be noted that this one observed difference indicates that those in the online course section are a bit more experienced students while being roughly equivalent on all other available measures. Also, given the number of comparisons made, this one significant difference is within the range of random error.

These descriptive results suggest that the calculations of program impact for the face-to-face relative to either of the individual arms of the experiment for the purely online course or the blended section should be relatively free of selection bias. The same

can be said of estimates comparing face-to-face instruction to the two modalities in combination (online and blended) that make use of internet-based instruction.

We use linear regression for calculating the estimates capturing the difference in outcomes across the face-to-face, online, and blended class modalities for those who completed the course. Table 1 contains estimates for the difference in scores (out of a possible 100) on a cumulative final exam. Column (1) contains estimates not controlling for any of the available covariates. As can be seen there, students in the purely online course score about 4.9 points worse than those in the face-to-face course. This result is statistically significant at the .05 level. The students in the blended course are not found to do any worse than those in a face-to-face section. In column (2), covariates are added where the data coverage is most complete (prior GPA and cumulative credits). With these controls, students in the purely online course are still found to score 5.2 points lower on a final cumulative exam. This result is also statistically significant at the .05 level. Column (3) includes all available covariates. There, students are still found to score 4.2 points lower in the online section than the face-to-face variant. The result continues to be statistically significant at the .05 level. The sign of the impact of participating in the blended course is negative but the parameters are statistically insignificant across the three columns.

The result reported here, that students in an online course perform worse on a cumulative semester exam than those in a face-to-face environment, conforms with popular conceptions about the likely impact of online instruction on student outcomes as well as the prior academic literature on the topic. Here, the four to five point worse outcome is equivalent to half a letter grade. A student making a B+ (in the high 80s) would likely have their grade lowered to a B. A student in the middle of the A range would find their score lowered to an A- or B+. For any individual course, magnitudes of this size may not be seen as paramount. However, in laddered courses, the lack of comprehension may impact the ability of students to access higher levels of knowledge and might cumulate over a succession of purely online courses.

Although not shown here, additional estimates were calculated for all regressions presented in the manuscript including dummy variables where some characteristics of students were missing. Those estimates keep the sample size constant across the three

columns of estimates shown in the tables. Those estimates are available from the authors on request and in all cases result in similar quantitative impacts and qualitative conclusions.

Table 1

OLS Regression Final Cumulative Exam by Delivery Modality

	(1)	(2)	(3)
Dummy Online=1	-4.912**	-5.201**	-4.232**
	(3.09)	(3.26)	(2.68)
Dummy Blended=1	-1.454	-1.703	-0.996
	(0.95)	(1.12)	(0.66)
GPA		7.702***	8.580***
		(6.31)	(6.93)
Prior Total Credits		-0.0453	-0.0483
		(1.38)	(1.48)
Math SAT		0.0346***	0.0246*
		(3.64)	(2.35)
Verbal SAT		-0.0111	-0.00733
		(1.22)	(0.77)
Gender: Male=1			4.644***
			(3.42)
Asian: Asian=1			-0.973
			(0.57)
Black: Black=1			-3.335
			(1.30)
Hispanic: Hispanic=1			1.043
			(0.22)
Hawaiian: Hawaiian=1			6.056
			(1.10)
Unknown: Unknown Race=1			-10.95
			(1.15)
Constant	78.55***	41.17***	39.92***

	(74.65)	(5.54)	(4.73)
Observations	323	265	215
R^2	0.030	0.234	0.345
Adjusted R^2	0.024	0.216	0.307
Wald Chi2			
Prob > chi2	0.008	0.000	0.000
F	4.922	13.105	8.883
Log lik.	-1246.410	-990.749	-774.309

Absolute *t* statistics in parentheses. $^{+}$ $p < 0.10$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 2

OLS Regression Final Cumulative Exam by Delivery Modality

	(1)	(2)	(3)
Online or Blended=1	-3.055*	-3.292*	-2.485^{+}
	(2.29)	(2.43)	(1.87)
GPA		7.928***	8.874***
		(6.47)	(7.17)
Prior Total Credits		-0.0493	-0.0528
		(1.49)	(1.61)
Math SAT		0.0335***	0.0235*
		(3.51)	(2.23)
Verbal SAT		-0.0105	-0.00614
		(1.14)	(0.64)
Gender: Male=1			4.825***
			(3.54)
Asian: Asian=1			-0.677
			(0.39)
Black: Black=1			-2.740
			(1.06)
Hispanic: Hispanic=1			0.902

			(0.19)
Hawaiian: Hawaiian=1			6.824
			(1.23)
Unknown: Unknown Race =1			-8.854
			(0.93)
Constant	78.55***	40.85***	38.88***
	(74.25)	(5.46)	(4.59)
Observations	323	265	215
R^2	0.016	0.219	0.332
Adjusted R^2	0.013	0.204	0.296
Wald Chi2			
Prob > chi2	0.023	0.000	0.000
F	5.241	14.518	9.183
Log lik.	-1248.687	-993.261	-776.445

Absolute *t* statistics in parentheses. $^{+}$ $p < 0.10$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 2 contains a set of estimates that parallel those provided in Table 1 but the face-to-face courses are compared to the two online variants in combination. The estimates are similar to those found in Table 1: Negative impacts of the substitution of online for personal contact are mildly negative and statistically significant. Again, column (1) provides estimates that do not control for any covariates. In the two courses with online lectures, students perform 3.1 points worse on the final cumulative exam for the course. A similar result is found in column (2) where the most consistently available covariates are added and students are found to score 3.3 points worse on the final exam. In column (3), students are found to score 2.5 points worse on the cumulative final than those in the face-to-face course. Again, impacts of these magnitudes would be most likely to impact students by fractional letter grades.

B. Accounting for Non-Completion from the Point of Random Assignment

A concern with online education is the willingness of students to take a course and the impact of the delivery method on completion. While pedagogical techniques associated with online instruction will no doubt continue their advance and encourage

student enrollment and course completion, the development of the online tools used in this experiment are consistent with current best practices in course design. While attrition was observed across all course sections, there was clearly greater attrition among those randomly given the opportunity to enroll in the online section.

From the point of assignment of permission numbers to course completion, potential participation in the face to face section declined from 175 to 120 students (30%). For the blended course section, enrollment declined somewhat more, from 172 randomized students to 110 completers (36%). The largest attrition was observed for the online arm where 172 students were assigned to the course and 93 completed the course (46%). Relevant descriptive statistics for the complete sample at the point where students signed informed consent forms are provided in Tables 3.A, 3.B, and 3.C. T-statistics for differences in average characteristics across groups at this point of initial randomization are also contained in those tables. As at other points in the randomization process, student across the three course sections are almost identical to each other. Descriptive statistics for those who completed the course are in Tables 2.A, 2.B, and 2.C.

To estimate the potential additional impact on learning related to differential attrition across the three arms of the experiment, we use the complete sample of those given a permission number along with outcomes for those who completed the course to provide estimates where we assign those who did not complete the course an outcome of zero and recalculate the estimates contained in Tables 1 and 2. The estimates in Table 3 indicate that for the online course section, the additional attrition relative to the face-to-face setting amplifies the potential negative impact of the course on the students to be served. As shown in column (1), without including any covariates, the estimated impact for students given the opportunity to enroll in an online course offering has a negative impact of 13.85 points on a scale of 100. Including the covariates most related to student learning and for which we have greatest coverage in column (2), the estimated negative impact is 10.75 points. Including all covariates in column (3), the estimated reduction in the test score is 11.43. All of those estimates are statistically significant at conventional levels.

In summary, the three estimates of the impact of offering a student an online only versus face-to-face course section reduces student learning by a letter grade or more once

potential impacts of differential attrition are reflected in the estimates. However, the estimates for the blended groups are both statistically insignificant and near zero when relevant covariates are included in columns (2) and (3). This result is similar to that for the blended relative to face-to-face section for those who completed the course contained in Table 1.

Table 3

OLS Final Exam With Attrition from Randomization to Course Completion

	(1)	(2)	(3)
Dummy Online=1	-13.32**	-9.517*	-10.28*
	(3.29)	(2.20)	(2.17)
Dummy Blended=1	-4.261	1.518	-0.121
	(1.05)	(0.35)	(0.03)
GPA		8.143**	12.34***
		(2.75)	(3.80)
Prior Total Credits		-0.186*	-0.142+
		(2.45)	(1.71)
Math SAT		0.107***	0.104***
		(4.08)	(3.32)
Verbal SAT		0.0279	0.0542+
		(1.13)	(1.94)
Gender: Male=1			9.362*
			(2.29)
Asian: Asian=1			-0.185
			(0.03)
Black: Black=1			-4.676
			(0.65)
Hispanic: Hispanic=1			4.166
			(0.29)
Hawaiian: Hawaiian=1			22.95
			(1.30)

Unknown: Unknown Race = 1			4.507
			(0.25)
Constant	54.28***	-47.59*	-78.56***
	(19.00)	(2.44)	(3.33)
Observations	519	411	324
R^2	0.021	0.124	0.192
Adjusted R^2	0.018	0.111	0.161
Wald Chi2			
Prob > chi2	0.004	0.000	0.000
F	5.624	9.509	6.166
Log lik.	-2619.976	-2049.669	-1598.771

Absolute *t* statistics in parentheses

$^{+}$ $p < 0.10$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 4

OLS Final Exam With Attrition from Randomization to Course Completion

	(1)	(2)	(3)
Online or Blended=1	-8.815*	-4.125	-5.265
	(2.50)	(1.08)	(1.27)
GPA		8.419**	12.49***
		(2.82)	(3.83)
Prior Total Credits		-0.195*	-0.156+
		(2.55)	(1.88)
Math SAT		0.106***	0.103**
		(4.03)	(3.27)
Verbal SAT		0.0308	0.0582*
		(1.24)	(2.07)
Gender: Male=1			9.599*
			(2.33)
Asian: Asian=1			0.684

			(0.13)
Black: Black=1			-3.321
			(0.46)
Hispanic: Hispanic=1			3.163
			(0.22)
Hawaiian: Hawaiian=1			25.23
			(1.42)
Unknown: Unknown Race=1			3.012
			(0.17)
Constant	54.28***	-49.42*	-80.71***
	(18.93)	(2.52)	(3.41)
Observations	519	411	324
R^2	0.012	0.110	0.180
Adjusted R^2	0.010	0.099	0.151
Wald Chi2			
Prob > chi2	0.013	0.000	0.000
F	6.264	9.960	6.236
Log lik.	-2622.447	-2052.983	-1601.154

Absolute *t* statistics in parentheses

$^{+}$ $p < 0.10$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 4 contains estimates using the same data as in Table 3 while combining the effect for the online and blended course sections. For the combined sections, depending on whether covariates are included or not, the estimated impacts range from a reduction in the final exam score of about 5 to 9 points. As available covariates are included in the estimations in columns (2) and (3), the estimated impact declines and is statistically insignificant in both specifications.

To explore whether there are important differences in outcomes across sub-groups of interest we return to the sample of students who completed their course section in Table 1 and explore the impact of the course on student with a below average initial GPA, males, and alternative racial/ethnic groupings. Main effects of each variable shown

in the table are included in the regressions but those parameters are suppressed here to conserve space.

We include the variables as alternative groups beginning with below average GPA as shown in column 1 of Table 5. There, although the parameter estimates for students with below average prior GPAs are not statistically significant, the main parameter estimate for the impact of being in an online course becomes statistically insignificant. This suggests much of the negative impact we observed on student outcomes of those who participated in the online section is driven by below average students. In column (2) where the interactions for male students are included, no statistically significant findings are present. In column (3) when interactions for different racial/ethnic groupings are included in the estimations, the only significant finding is a large negative impact of blended education (-12 points) for black students. Thus, we find some evidence that students traditionally thought to face disadvantages in college level education have more adverse outcomes in both the online and blended course formats.

Table 5

Regression Results for Students Who Completed Their Course with Interactions

	(1)	(2)	(3)
Dummy Online=1	-2.993	-5.598*	-4.954*
	(1.49)	(2.30)	(2.49)
Dummy Blended=1	-0.491	-1.689	1.134
	(0.26)	(0.72)	(0.57)
Low Prior GPA			
Low Prior GPA*Online	-4.143		
	(1.32)		
Low Prior GPA*Blended	-2.481		
	(0.81)		
Gender			
Male*Online		1.872	
		(0.59)	
Male*Gender		0.973	
		(0.32)	

Race/Ethnicity			
Asian*Online			1.360
			(0.33)
Asian*Blended			-2.575
			(0.64)
Black*Online			-1.350
			(0.15)
Black*Blended			-12.20*
			(2.07)
Hispanic*Online			3.275
			(0.25)
Hispanic*Blended			-17.81
			(1.17)
Constant	79.97***	76.25***	79.00***
	(61.46)	(44.55)	(62.10)
Observations	323	323	247
R^2	0.094	0.067	0.088
Adjusted R^2	0.079	0.053	0.037

Absolute *t* statistics in parentheses

$^{+}$ $p < 0.10$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

As a final concern, one might wonder how those who participated in the randomized experiment compared to those who took microeconomic principles taught in other sections offered in the same department. We collected demographic information on the first day of class for a non-random lecture section of economics principles the first semester of the experiment. As can be seen in Appendix Table 4.A, there were no meaningful differences across the sections, comparing those enrolled in the non-random section to all course completers in the experiment, in measurable characteristics most strongly related to later test scores. Roughly 10 percent more of students in the non-experimental section were males and roughly 10 percent fewer were minority. In the estimates presented in the paper, being male was associated with higher test scores.

However, in aggregate, this one differential and its magnitude when multiplied by the impact of that variable on test scores (.1x4) would not be likely to explain much of the observed grade differentials across the arms of the experiment.

V. Conclusions

This paper contains results from a randomized study of student outcomes on a cumulative semester exam in a face-to-face course versus two popular variants of online education, a purely online course and a blended modality that cuts instructor contact in half. The online course and content was developed consistent with a set of standards for best practices in online education, were reviewed both by the external organization that developed the guidelines and the university where the instruction occurred, and had been continuously improved over many years of use.

Descriptive evidence indicates that students in the face-to-face, purely online, and blended course sections are observationally quite similar at the time that permission numbers were assigned, were used, and for those who completed the course. Additionally, across most key characteristics, those in the experiment appear similar to other students enrolled in another non-experimental section of the course in the first semester of data collection.

Estimates indicate that those who enrolled in and completed the purely online course had learning outcomes that were significantly worse than those in the face-to-face section of the course: this difference is about four to five points or half of a letter grade. Estimates for those who enrolled in and completed the blended course are not statistically significant but the sign is always estimated as being negative. None of these estimates vary meaningfully when additional covariates are added to the estimations.

We also compared the performance of the two sections of students who completed the online (blended or purely online) classes in combination to those in the face-to-face section that only received classroom instruction. There, we find consistently negative impacts on average scores on a cumulative final exam that remain statistically significant at conventional levels (.05 level) as we add additional control variables. The estimated reduction in the score on the final exam is about 3 points or a fractional letter grade.

Ignoring possible contamination through enrollment in other sections, we also provide estimates that incorporate the potential negative impact from differential attrition

across sections. Those results mirror those for course completers when comparing those who had the opportunity to enroll in the purely online and face-to-face sections of the course but are larger in magnitude while remaining negative. Accounting for the additional attrition from online courses, reduced learning for those who had the opportunity to enroll amounted to about a 10-point reduction on a 100-point final exam – the equivalent of a letter grade. The estimates that allow differential attrition to impact estimates of outcomes across those with the opportunity to enroll in the blended versus the face-to-face section were statistically insignificant at conventional levels and close to zero once important covariates were included in the analysis. Similarly, when the outcomes of students given the opportunity to enroll in both the online and blended relative to the face-to-face sections are compared, no significant differences are found when covariates are included in the estimations.

In exploring sub-group differences in performance, there is some evidence albeit indirect that the reduction in the average test scores for online learners are concentrated among those with low prior GPAs. Also, despite evidence that on average students in the blended and face-to-face sections had similar test scores, black students did significantly worse. Thus, additional attention to methods to address these adverse outcomes among disadvantaged groups is warranted.

These estimates from four semesters of data collection suggest that students in purely online courses learn less. For an individual course, reductions in a semester grade of 5 points may not be a large concern; however, if learning deficits cumulate over sequenced online courses, the overall reduction in attainment may be of more concern. The results of the study also suggest that reduced learning of those who do enroll when combined with inability to complete the course and/or the lack of willingness to enroll amplifies the magnitude of lost learning potential among those the experiment attempted to serve through purely online course delivery to a full letter grade.

One implication of the worse outcomes observed here is that there is room for improvement in the pedagogy of online instruction to attain equivalence of learning outcomes between the online and face-to-face delivery modalities. Like the prior literature, we do not find firm evidence that students in blended courses learn less if they enroll and complete the course. This suggests that a promising avenue for economizing

on teaching resources while maintaining student outcomes is to move to blended teaching models of instruction for economics principles; however, this optimism should be tempered by concern for possibly adverse outcomes among disadvantaged sub-groups. Similar research to explore these findings in other disciplines and models of class design would appear worthwhile, as it is unclear that instructional issues are consistent across disciplines and varieties of classroom settings.

More broadly, the results found here are largely consistent with the literatures that have used both randomized study designs and observational data to study the impact of similar course designs on student outcomes in economics principles courses. Those studies have consistently reported that students in purely online courses have worse outcomes relative to those who receive face-to-face instruction while those in blended sections do not appear to do worse.

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Online Appendix A

Table 1.A

TTEST Statistics PERMISSION NUMBER USED - Enrollment by Instruction Format: F2F versus Online

	F2F N	F2F Mean	Online N	Online Mean	Diff in Means	t	Pr(|T| > |t|)
Prior GPA	116	3.13	127	3.09	0.04	0.49	0.62
Prior Total Credits	138	31.45	137	35.31	-3.86	-1.31	0.19
Math SAT	140	626.25	130	625.69	0.56	0.06	0.95
Verbal SAT	140	586.79	131	575.19	11.59	1.39	0.17
Gender: Male=1	147	0.60	143	0.52	0.07	1.27	0.20
White: White=1	117	0.72	104	0.68	0.04	0.57	0.57
Black: Black=1	117	0.06	104	0.02	0.04	1.53	0.13
Asian: Asian=1	117	0.20	104	0.24	-0.04	-0.79	0.43
Hispanic: Hispanic=1	117	0.02	104	0.02	-0.00	-0.12	0.91
Unknown: Unknown Race=1	117	0.00	104	0.03	-0.03	-1.86	0.06
Observations	290						

Table 1.B

TTEST Statistics PERMISSION NUMBER USED - Enrollment by Instruction Format: Blended versus OL

	Blended N	Blended Mean	OL N	OL Mean	Diff in Means	t	Pr(|T| > |t|)
Prior GPA	111	3.14	127	3.09	0.05	0.64	0.52
Prior Total Credits	121	31.99	137	35.31	-3.31	-1.17	0.24
Math SAT	119	622.27	130	625.69	-3.42	-0.37	0.71
Verbal SAT	120	585.75	131	575.19	10.56	1.11	0.27
Gender: Male=1	139	0.57	143	0.52	0.04	0.74	0.46
White: White=1	91	0.64	104	0.68	-0.05	-0.66	0.51
Black: Black=1	91	0.10	104	0.02	0.08	2.43	0.02
Asian: Asian=1	91	0.22	104	0.24	-0.02	-0.34	0.73
Hispanic: Hispanic=1	91	0.01	104	0.02	-0.01	-0.46	0.64
Unknown: Unknown Race=1	91	0.01	104	0.03	-0.02	-0.87	0.38

Table 1.C

TTEST Statistics PERMISSION NUMBER USED - Enrollment by Instruction Format: Combined versus F2F

	Combined N	Combined Mean	F2F N	F2F Mean	Diff in Means	t	Pr(|T| > |t|)
Prior GPA	238	3.11	116	3.13	-0.01	-0.21	0.83
Prior Total Credits	258	33.75	138	31.45	2.30	0.96	0.34
Math SAT	249	624.06	140	626.25	-2.19	-0.28	0.78
Verbal SAT	251	580.24	140	586.79	-6.55	-0.85	0.39
Gender: Male=1	282	0.55	147	0.60	-0.05	-1.04	0.30
White: White=1	195	0.66	117	0.72	-0.06	-1.03	0.30
Black: Black=1	195	0.06	117	0.06	-0.00	-0.12	0.90
Asian: Asian=1	195	0.23	117	0.20	0.03	0.71	0.48
Hispanic: Hispanic=1	195	0.02	117	0.02	-0.00	-0.12	0.91
Unknown: Unknown Race=1	195	0.02	117	0.00	0.02	1.56	0.12
Observations	429						

Table 2.A

TTEST Statistics COMPLETED COURSE - Enrollment by Instruction Format: F2F versus Online

	F2F N	F2F Mean	Online N	Online Mean	Diff in Means	t	Pr(|T| > |t|)
Prior GPA	94	3.19	84	3.09	0.10	1.23	0.22
Prior Total Credits	114	28.35	92	34.57	-6.21	-2.08	0.04
Math SAT	115	633.17	87	632.93	0.24	0.02	0.98
Verbal SAT	115	589.13	87	581.38	7.75	0.80	0.42
Gender: Male=1	120	0.63	93	0.54	0.10	1.41	0.16
White: White=1	99	0.72	70	0.70	0.02	0.24	0.81
Black: Black=1	99	0.07	70	0.03	0.04	1.20	0.23
Asian: Asian=1	99	0.20	70	0.23	-0.03	-0.41	0.68
Hispanic: Hispanic=1	99	0.01	70	0.03	-0.02	-0.89	0.37
Unknown: Unknown Race=1	99	0.00	70	0.00	0.00	.	.
Observations	213						

Table 2.B

TTEST Statistics COMPLETED COURSE - Enrollment by Instruction Format: F2F versus Blended

	F2F N	F2F Mean	Blended N	Blended Mean	Diff in Means	t	Pr(|T| > |t|)
Prior GPA	94	3.19	97	3.19	0.00	0.05	0.96
Prior Total Credits	114	28.35	105	32.37	-4.02	-1.60	0.11
Math SAT	115	633.17	106	627.08	6.10	0.61	0.54
Verbal SAT	115	589.13	106	586.98	2.15	0.21	0.83
Gender: Male=1	120	0.63	110	0.55	0.08	1.21	0.23
White: White=1	99	0.72	78	0.63	0.09	1.26	0.21
Black: Black=1	99	0.07	78	0.10	-0.03	-0.75	0.45
Asian: Asian=1	99	0.20	78	0.22	-0.02	-0.26	0.80
Hispanic: Hispanic=1	99	0.01	78	0.01	-0.00	-0.17	0.87
Unknown: Unknown Race=1	99	0.00	78	0.01	-0.01	-1.13	0.26
Observations	230						

Table 2.C

TTEST Statistics COMPLETED COURSE - Enrollment by Instruction Format: Combined versus F2F

	Combined N	Combined Mean	F2F N	F2F Mean	Diff in Means	t	Pr(|T| > |t|)
Prior GPA	181	3.14	94	3.19	-0.05	-0.72	0.47
Prior Total Credits	197	33.40	114	28.35	5.05	2.12	0.04
Math SAT	193	629.72	115	633.17	-3.46	-0.41	0.68
Verbal SAT	193	584.46	115	589.13	-4.67	-0.55	0.59
Gender: Male=1	203	0.55	120	0.63	-0.09	-1.52	0.13
White: White=1	148	0.66	99	0.72	-0.06	-0.91	0.36
Black: Black=1	148	0.07	99	0.07	-0.00	-0.10	0.92
Asian: Asian=1	148	0.22	99	0.20	0.02	0.39	0.70
Hispanic: Hispanic=1	148	0.02	99	0.01	0.01	0.62	0.54
Unknown: Unknown Race=1	148	0.01	99	0.00	0.01	0.82	0.41
Observations	323						

Table 3.A

TTEST Statistics PERMISSION NUMBER Issued by Instruction Format: F2F versus Online

	F2F N	F2F Mean	Online N	Online Mean	Diff in Means	t	Pr(|T| > |t|)
Prior GPA	140	3.12	153	3.06	0.06	0.87	0.39
Prior Total Credits	164	31.70	165	36.65	-4.96	-1.79	0.07
Math SAT	165	621.97	158	615.82	6.15	0.75	0.45
Verbal SAT	165	586.79	158	570.06	16.72	2.07	0.04
Gender: Male=1	175	0.57	172	0.52	0.04	0.79	0.43
White: White=1	134	0.69	127	0.67	0.02	0.43	0.67
Black: Black=1	134	0.09	127	0.06	0.03	1.07	0.29
Asian: Asian=1	134	0.19	127	0.22	-0.03	-0.53	0.60
Hispanic: Hispanic=1	134	0.01	127	0.02	-0.01	-0.51	0.61
Unknown: Unknown Race=1	134	0.00	127	0.02	-0.02	-1.79	0.07
Observations	347						

Table 3.B

TTEST Statistics PERMISSION NUMBER Issued by Instruction Format: F2F versus Blended

	F2F N	F2F Mean	Blended N	Blended Mean	Diff in Means	t	Pr(|T| > |t|)
Prior GPA	140	3.12	142	3.13	-0.00	-0.05	0.96
Prior Total Credits	164	31.70	152	34.66	-2.96	-1.16	0.24
Math SAT	165	621.97	146	620.48	1.49	0.18	0.86
Verbal SAT	165	586.79	147	579.69	7.09	0.81	0.42
Gender: Male=1	175	0.57	172	0.56	0.00	0.03	0.97
White: White=1	134	0.69	113	0.62	0.07	1.23	0.22
Black: Black=1	134	0.09	113	0.12	-0.03	-0.66	0.51
Asian: Asian=1	134	0.19	113	0.23	-0.04	-0.69	0.49
Hispanic: Hispanic=1	134	0.01	113	0.01	0.01	0.43	0.67
Unknown: Unknown Race=1	134	0.00	113	0.01	-0.01	-1.09	0.28
Observations	347						

Table 3.C

TTEST Statistics PERMISSION NUMBER Issued by Instruction Format: F2F versus COMBINED

	Combined N	Combined Mean	F2F N	F2F Mean	Diff in Means	t	Pr(|T| > |t|)
Prior GPA	295	3.09	140	3.12	-0.03	-0.48	0.63
Prior Total Credits	317	35.70	164	31.70	4.00	1.72	0.09
Math SAT	304	618.06	165	621.97	-3.91	-0.54	0.59
Verbal SAT	305	574.70	165	586.79	-12.08	-1.65	0.10
Gender: Male=1	344	0.54	175	0.57	-0.02	-0.48	0.63
White: White=1	240	0.65	134	0.69	-0.05	-0.94	0.35
Black: Black=1	240	0.08	134	0.09	-0.01	-0.21	0.84
Asian: Asian=1	240	0.23	134	0.19	0.03	0.70	0.49
Hispanic: Hispanic=1	240	0.02	134	0.01	0.00	0.13	0.90
Unknown: Unknown Race=1	240	0.02	134	0.00	0.02	1.50	0.13
Observations	519						

Table 4.A

Descriptive Statistics Non Experimental Students All Semesters Enrolled Students

	Experimental			Non Experimental			T-Test		
	N	Mean	S.D.	N	Mean	S.D.	Diff in Means	t	Pr(|T| > |t|)
Prior GPA	287	3.12	0.61	95	3.06	0.57	-0.0542	-0.7645	0.4451
Prior Total Credits	326	31.98	20.60	157	32.07	22.39	0.0909	0.0441	0.9648
Math SAT	309	627.30	81.78	148	632.16	73.14	4.8580	0.6144	0.5392
Verbal SAT	309	585.66	73.58	148	596.76	76.93	11.0933	1.4860	0.1380
Written SAT	290	593.41	74.11	148	604.19	75.23	10.7754	1.4320	0.1529
Gender: Male=1	335	0.59	0.49	157	0.59	0.49	0.0073	0.1526	0.8788
White: White=1	261	0.69	0.47	131	0.79	0.41	0.1081	2.2616	0.0243
Ethnicity: Nonwhite=1	261	0.31	0.47	131	0.21	0.41	-0.1081	-2.2616	0.0243
Observations	336			157			493		