The Impact of Laptop Use in the College Classroom

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Abstract

We present quasi-experimental evidence of the impact of laptop use in college classrooms on academic performance. This study takes advantage of a college policy that requires all students to own a laptop computer, but allows individual teachers to require, allow, or ban laptops in their classrooms. Using student surveys, we find that students who are required to bring laptops to any of their classes on a certain day are significantly more likely to use laptops in laptop-optional classes than students who are not required to bring laptops to classes. Conversely, we find that students who are prohibited from bringing a laptop to at least one of their classes are significantly less likely to use laptops in their laptop-optional classes. We compare the grades of students who were and were not influenced to bring laptops to class by their course schedule and find consistent evidence of a negative impact of laptop use on student grades. Back-of-the-envelope calculations suggest that laptop use decreases course grades by between 0.14 and 0.37 grade points or 0.17 and 0.46 standard deviations.

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1 Introduction

Computers have the potential to drastically improve the productivity of students in the classroom. Laptop computers enable students to take more comprehensive notes, stay more organized, and instantly access a broad range of learning material. Yet many instructors suspect that the back of a computer screen is more indicative of a Facebook status check than a signal of increased learning productivity. It may seem irrational for students to make the effort required to attend class only to spend their time surfing the internet, but behavioral factors such as present-biased preferences and limited willpower could explain why well intentioned students could be distracted by their computers.[1] While laptop use in college classrooms has become commonplace in recent years, relatively little is known about how classroom computer use impacts overall student performance.

Several recent trends highlight why understanding the impact of classroom computer use on student outcomes is becoming increasingly important. First, the prevalence of personal computer use in the classroom has increased dramatically in recent years; in 2011 57% of recent college graduates reported using a smartphone, laptop, or tablet in class at least some of the time (Parker et al., 2011). In more recent studies, laptop use is even higher. In our study, we find that 72% of students use laptops in the classroom and Carter et al. (2016) find that 79% of students use laptops.[2] Additionally, the efficacy of classroom learning is becoming increasingly important as the ratio of class to study time has increased to the point where the average college student spends more time in the classroom than studying outside of it. Babcock and Marks (2011) find that although the time college students spend in the classroom each week has remained roughly constant at about 16 hours a week over the last 50 years, the time students spend outside the classroom studying each week has fallen precipitously from 24 hours in 1961 to just 11 hours in 2004. Finally, concerns about equity motivate a study of the impact of computer use in the college classroom. African American and

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[1]See Laibson et al. (2002) for a review of time-inconsistent preferences and Winters et al. (2008) for a review of impact of computer distractions on productivity.

[2]Carter et al. (2016) examine the difference between courses that prohibit and allow laptop use. The 79% figure is the average among classes that allow laptop use.

Hispanic students, as well as those from economically disadvantaged backgrounds, are less likely to own laptops, which may widen or shrink gaps in student outcomes depending on the impact of laptops inside and outside the classroom (Lenhart et al., 2010).

In this paper we present quasi-experimental evidence of the impact of laptop use in college classrooms on academic outcomes. This study takes advantage of a college policy that requires all students to own a laptop computer, but allows individual teachers to require, allow, or ban laptops in their classrooms. Conducting surveys among a subset of students (n=229), we find that students who are required to bring laptops to any of their classes on a certain day are 21% more likely to use laptops in laptop-optional classes than students who are not required to bring laptops to any of their classes. Similarly, we find that students who are prohibited from to bringing laptops to at least one class on a certain day are 49% less likely to use laptops in in laptop-optional classes. Treating laptop rules in same-day classes as an instrument for laptop use in laptop-optional classes, we compare the grades of students (n=5,570, obs=32,947) of who are and are not influenced to bring laptops to class by their course schedule. This approach yields reduced-form evidence that laptops have a significant negative impact on course grades. We find that a requirement to bring a laptop to school decreases a student's course grades in classes that allow laptops by between 0.04 and 0.05 grade points while a prohibition to use a laptop in a class improves a student's course grades by between 0.05 and 0.09 grade points. When scaled by our first-stage survey results,[3] our estimates suggest that laptop use laptop use decreases course grades by between 0.14 and 0.37 grade points or 0.17 and 0.46 standard deviations. Our results are robust to multiple specifications and are consistent across multiple identification strategies. Additional heterogeneity analysis suggests that the negative effect of laptop use is strongest among male students and driven by weaker students as identified by their cumulative GPA.

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[3]Survey results collected from a subsample of 229 students in 14 classes.

2 Background

In spite of the important role computer use in classrooms may play in student outcomes, there is limited evidence on the causal impact of laptop use in the classroom and whether the impact differs by student characteristics. Proponents of computers in the classroom argue that laptops in the classroom increase access to information, adoption of active learning strategies, collaboration, and computer literacy as well as improve overall course performance (e.g. Gulek and Demirtas, 2005). Critics of laptop use in the classroom argue that laptops not only generate distractions for students using the laptops but for nearby students as well (Sana et al., 2013). Furthermore, Mueller and Oppenheimer (2014) find that the process of taking notes by hand generates better recall than by computer. These diverging opinions highlight the need to identify whether laptops generally help or hinder academic performance and the degree to which the impact of laptop performance varies by student characteristics.

The existing evidence on the impact of laptops in the classroom can be broadly grouped into two categories: (1) studies that examine the correlation between laptop use and (2) studies that experimentally manipulate whether students are able to use laptops in the classroom and how laptops may be used. In general, the studies that examine the correlation between laptop use and academic performance in college find that students who use laptops in classrooms perform worse than students that do not use laptops (e.g. Fried, 2008; Grace-Martin and Gay, 2001; Kraushaar and Novak, 2010). However, these correlational studies likely suffer from selection issues, as students who choose to use laptops are likely to differ from students who choose not to use laptops in important ways.

The experimental studies examining the impact of laptop use in the classroom vary significantly in their purpose and scope. Several laboratory experiments have sought to identify how certain components of laptop use may impact academic performance. For example, Mueller and Oppenheimer (2014) experimentally test whether the medium used in note-taking impacts recall

and find students randomly assigned to take notes via notepad instead of computer had significantly better recall of the information taught. Sana et al. (2013) randomly assigned study participants to take lecture notes on a computer with some students randomly assigned to multitask (complete non lecture-related web activities during the lecture) and find that multitasking reduces the academic performance of both the multitasker and those students who are able to see the multitasker's screen.[4] Other studies examine the impact of providing college students free laptops. Although these studies cannot distinguish between use inside and outside the classroom, Wurst et al. (2008) and Fairlie (2012) find that laptops have no significant impact on academic performance and a positive impact on academic performance for minority students, respectively.

More closely related to this study are studies by Hembrooke and Gay (2003) and Carter et al. (2016) that experimentally test the impact of laptops in actual classrooms. Both studies find negative impacts of laptop performance but Hembrooke and Gay (2003) is limited by a very small sample (n=44) from a single class on a single day over 10 years ago. Carter et al. (2016) provide stronger evidence in a randomized controlled trial conducted over the course of two semesters at the United States Military Academy.[5] They find that allowing laptops in the classroom has a significant negative impact on students, decreasing final exam test scores by roughly 0.2 standard deviations. However, their study design is unable to separate the impact of laptop use from other factors that vary between classes that do and do not prohibit laptops, such as how the teacher interacts with students, the number of distractions created by other students, the level of student engagement, and other factors that vary at the classroom level.[6]

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[4]Evidence for laptop spillover effects is mixed. Aguilar-Roca et al. (2012) randomly assign certain classes to have laptop free zones and find no impact on student performance.

[5]One caveat to the results this study is that the United States Military Academy has a somewhat unique learning environment. For example, students are required to attend classes and must work up to 10 service hours for an unexcused absence. Also, a majority of courses are also taught by active duty servicemembers.

[6]These class-level factors could potentially explain a significant portion of the effects observed in Carter et al. (2016). A number of papers find evidence of peer effects in college environments(e.g. Carrell et al., 2009; Lyle, 2007). Also, Lavy and Schlosser (2011) find that two of driving mechanisms of peer effects are disruptions created by students and the influence students have on how teachers interact with the class.

Our study contributes to the literature in the following ways: First, our study is among the first to provide causal evidence of the impact of laptop use on academic performance. Second, our study uses variation that applies to all class subjects and types of students, which allows for broader generalizability than previous studies. Third, our study is unique in that the identifying variation in laptop use comes from *within* the classroom. In our study, students who are and are not influenced to use laptops share the same classroom, same peers, same teacher, and experience the exact same lecture. This allows us to isolate laptop use from other potential factors that may contribute to differences found in between-class designs such as changes in teacher behavior, distractions generated by other student laptop use, and other differences between classrooms unrelated to laptop use.

3   Research Design and Sample

In this study, we take advantage of a natural experiment where the probability that students at a private liberal arts college bring a laptop to class depends on the order of their class schedules. At this college, all students are required to have access to a laptop, but teachers may decide to (a) require laptops, (b) allow laptops, or (c) prohibit laptops in their class.[7] Our research design is based on the hypothesis that student laptop use in laptop-optional classes is significantly impacted by the laptop policies in their other classes. Specifically, we hypothesize that students who are required to bring laptops to at least one of their classes on a certain day are more likely to bring and use laptops in laptop-optional courses that same day and students who are prohibited from bringing laptops to at least one of their classes are less likely to bring and use laptops in laptop-optional classes. For example, if a student is required to bring a laptop to her history class at 10:00 AM on Monday, she is more likely to have her laptop in her bag and use that laptop in her 11:30 AM biology class that same day. On the other hand, if the history class at 10:00 AM bans laptop use in class, then she is less likely to have the laptop in her bag and therefore less likely to use her

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[7]The laptop policy states "All incoming students must have access to a laptop computer with at least Windows 7 or Snow Leopard (10.6.8)."

laptop in her biology class. We also hypothesize that, after controlling for a few basic covariates, laptop policies in other classes are uncorrelated with course performance in laptop-optional courses *except* through the change in laptop use.[8] If our hypotheses hold, then our estimates of the impact of external course laptop policies on grades in laptop-optional courses generate unbiased estimates of the directional impact of laptop use on course performance.

3.1   Faculty Survey

In order to test whether laptop requirements impact student laptop use in the classroom we needed to determine the laptop policies of instructors. To determine the laptop polices in each class, we sent a short survey via email to each full-time faculty member that asked them about their classroom laptop policy and their opinions about how computers in the classroom impacted teaching and learning.[9] Table 1 indicates that among the 72% of full-time faculty that responded to the survey, 20% require laptops, 67% allow laptops and 4% prohibit laptops.[10] Additionally, faculty indicated that classroom laptop use is prevalent–73% of faculty reported that half or more of their students used laptops in class. Somewhat surprising are the favorable views faculty held on the impact of classroom laptop use on learning. In our survey, 57% of faculty felt that laptop use in class increased learning compared to just 25% of faculty that felt that classroom laptop use decreased student learning.

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[8]The unique policy requirement for all students to have access to a laptop is an important factor in this assumption. If students were not required to have access to a laptop, then students would be likely to select into laptop-required and laptop-prohibited classes based on whether they had access to a laptop. Our policy environment eliminates the possibility that differential access to laptops could be driving or biasing our results.

[9]A copy of the survey is included in Appendix B. The survey was created on the Survey Monkey platform and initially distributed via email in March 2014. A follow-up survey request was sent in April 2014, and an abbreviated email simply asking for faculty to report their laptop policies was sent in March 2015.

[10]The remaining 9% of faculty indicated that the laptop policy varied by class or by day.

3.2 Missing Instructor Policy Algorithm

Although our faculty survey identified the laptop policies of 72% of full-time instructors, we are unable to observe the laptop policies for the remaining 28% of full-time instructors and the entire population of part-time and adjunct professors. These missing data complicate our analysis as we are unable to claim with certainty that students that have no identified laptop-required or prohibited courses, but also have courses without reported policies, have all laptop-optional courses. To increase the coverage of faculty laptop policies, we use the 241 responses to our student survey to help us identify the laptop policies of instructors who did not respond to our faculty survey. The student survey questions that we use to identify missing policies include a question that asks the number of classes a student has that ban and allow laptops on the day of the survey and another question that asks whether they have courses that ban or allow laptops on each day of the week. Given these survey answers, we use a series of logical arguments to predict laptop policies in classes with missing instructor policies.[11] We aggregate responses by instructor to ensure that the policies are consistent within an instructor. In total, this algorithm consistently identifies the policies of 81 additional instructors leading to a total coverage of 73% of all student-class observations. In the cases where discrepancies arise, we apply the policy with the greatest share of responses.[12]

3.3 Student Population

The student population, described in Table 2, includes 5570 students enrolled in a private liberal arts college over the course of 6 semesters. This population consist of both undergraduate (77%)

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[11]For example, if a student reports having no laptop-required or laptop-prohibited courses, then all her courses would be categorized as laptop-optional. We aggregate all responses by instructor to determine if the categorization is consistent within instructor. If a student reports having a laptop-prohibited course on a certain day, is only missing a laptop-policy for 1 class, and all of her other classes on that day are either laptop-optional or laptop-required, then the missing class is categorized as laptop-prohibited. We continue with similar patterns to identify as many instructor policies as possible. The code used to identify these laptop policies will be posted in our online appendix.

[12]Ties are broken by categorizing a course as "laptop optional." We do not include courses with missing laptop policies in our primary analysis, but our results are robust to the re-categorization of classes with missing laptop policies as "laptop optional" and our results also remain consistent when students with missing courses are omitted from the analysis.

and masters degree students (23%). Students enrolled in this college are demographically similar to other liberal arts students, with 55% female enrollment and 80% white student enrollment.[13] Students take courses with a mix of laptop policies. Among classes with recorded laptop policies, 83% of each student's courses allow laptops, 15% require laptops and only 2% ban laptops. In our sample, 52% of students ever take a laptop-required course and 14% ever take a laptop-prohibited course.[14]

One potential confound in our study is that students who have laptop-required and laptop-prohibited courses may systematically differ from students who only have laptop-optional classes. To investigate whether student characteristics vary across laptop policies, in Table 3 we compare students who (1) have all laptop-optional classes, (2) have at least one laptop-required course and (3) have at least one laptop-prohibited course. In this table, we take students from the first semester we observe them in the course and make comparisons separately for students with Monday/Wednesday courses and Tuesday-Thursday courses.[15] We use this approach instead of aggregating policies to the individual level because students often switch from having laptop-optional or laptop-required classes to only having laptop-optional classes from day to day and term to term.[16] With 10 out of 54 pairwise comparisons varying at the 5% level, we see slightly more imbalance than we would expect from a randomized controlled trial. However we do not believe that this imbalance could generate systematically biased results in our study. First, 2 of the 10 statistically significant differences arise from students with laptop-required or laptop-prohibited courses taking more courses than students with all laptop-optional courses. We would expect this difference to occur mechanically in our data even if laptop polices are randomly assigned, as students who take more classes

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[13]Source: http://nces.ed.gov/programs/coe/indicator_csb.asp accessed 5/26/2016.

[14]A list of required and prohibited courses are provided in Appendix B.

[15]Monday/Wednesday and Tuesday/Thursday courses are the most common schedules representing a combined 59.6% of all student-course observations.

[16]This approach also minimizes mechanical differences in students who have different laptop policies. Comparing students who ever have laptop requirements and prohibitions to those that are only ever in laptop-optional classes can generate large mechanical differences between students even if assignment to laptop-optional classes is completely random. This is because persistence, which is correlated with a number of student characteristics, mechanically increases the probability that a student will ever take a laptop required or laptop-prohibited course.

are more likely to have a laptop-required courses and laptop-prohibited courses in their schedules. Of the remaining 8 statistically significant pairwise comparisons only 1 characteristic (GPA in laptop-prohibited vs. laptop-optional classroom) is significant in both Monday/Wednesday and Tuesday/Thursday samples. Furthermore, our unique study context requires opposing selection patterns into laptop-required and laptop-prohibited courses for selection to generate same-direction biases across estimation strategies. If high-ability students are sorting into *both* laptop-required and laptop-prohibited courses, this would bias us towards finding a positive impact of laptop use when using laptop-required courses as an instrument for laptop use, but bias us towards finding a negative impact when using laptop-prohibited courses. Conversely, if low-ability students are sorting into both laptop-required and laptop-prohibited courses, this would bias us towards finding a negative impact of laptops when using a laptop-requirements as an instrument for laptop use but bias us towards finding a positive impact of laptops when using laptop-prohibitions as an instrument for laptop use. For estimates of the impact of laptop use from laptop-required and laptop-prohibited instruments to be biased in the same direction requires students with different underlying abilities to be sorting laptop-required laptop-prohibited courses in opposite ways. However, we do not find evidence that different types of students are sorting into laptop-required and laptop-prohibited courses. Between laptop-required and laptop-prohibited courses only, 2/16 pairwise comparisons are statistically distinguishable at the 5% or 10% level and neither of these differences are significant in both Monday/Wednesday and Tuesday/Thursday classes. With little evidence of systematic differences in observable characteristics across laptop policy groups, Table 3 supports our identifying assumption that laptop policies in are uncorrelated with course performance except through the change in laptop use.

3.4 Student Survey

Our identification strategy relies on our hypothesis that laptop requirements and prohibitions impact computer use in laptop-optional courses. To test whether laptop use in laptop-optional classes is

influenced by laptop policies in other classes, we surveyed laptop use in 14 laptop-optional classes that had significant variation in the laptop policies students were exposed to in other classes that same day. The results of this survey are reported in Table 4. In total, we surveyed 229 students[17] and found that having a laptop-required class on the same day increased the probability that a student used a laptop in class by 20.6% or 14.2 percentage points (significant at the 1% level) and having a class that prohibited laptop use on the same day decreased the probability of using a laptop by 48.9% or 36.7 percentage points (significant at the 5% level) as reported in Table 4. In columns 1, 3, and 5 of Table 4 we report raw differences and in columns 2, 4, and 6 we control for class fixed effects.[18] Including class fixed effects has no significant impact on our estimates and actually increases the absolute magnitude of our estimates. These first-stage estimates provide consistent evidence that laptop policies influence laptop-use in optional classrooms.

In addition to identifying the impact of laptop requirements on whether students use laptops to the classroom, our identification strategy also requires that the laptop policies in students' schedules are only correlated with student outcomes in optional classes through the channel of laptop use. A number of factors could lead to the laptop policies in student schedules to be correlated with outcomes through alternate channels. Some of these channels can be directly controlled. For example, while it is possible that the number of classes a student takes is related to the expected grade in a course and to the probability that a student has laptop requirements or prohibitions in their schedule, we can control for the number of courses taken. Similarly, it is possible that certain majors are more or less difficult and more or less likely to be required to use a laptop. In this case, we are able to look at variation within a class and control for previous performance and majors. However, if students are making decisions about which classes to take based on the class laptop policies, this would make it particularly challenging to ascribe our results to random variation in laptop use. To address this potential concern, we surveyed students about whether they were aware

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[17]11 students were in two surveyed classes and responded twice, yielding a total sample size of 241 responses.

[18]We do not include additional controls because we were unable to link our survey data to administrative records that included demographic and grade information.

of the laptop policies in their classes prior to enrollment and whether they selected classes based on the classroom computer policies. In our survey, we found that only 22% of students were aware of the laptop policies in any of their classes prior to enrollment and that only 4% of students were both aware of any laptop polices and indicated that laptop policies had any influence on their class decisions.[19] This finding increases our confidence that selection into laptop classes is unrelated to unobserved differences among students.

3.5 Empirical Design

3.5.1 Primary Analysis

In our empirical design, we estimate the reduced form impact of laptop use on student academic performance using the laptop policies surrounding a student's laptop-optional classes as an instrument for laptop use.[20] This estimation strategy involves estimating the impact of two different types of policies on overall course-grades: policies that require students to bring laptops to class and policies that prohibit students from bringing laptops to class. If our identifying assumptions are met, then we can infer that a positive correlation between laptop requirements and course grades (in laptop optional classes) indicates that laptops have a positive impact on student performance and that a negative correlation between laptop requirements and course grades indicates that laptops have a negative impact on student performance. For laptop prohibitions we would infer that a positive correlation between prohibitions and course grades indicates a *negative* impact of laptop use and a negative correlation between laptop prohibitions and course grades indicate a *positive* impact of laptops on student performance.[21] With the above approach in mind, we estimate the

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[19]3% indicated that laptop policies were somewhat important and 1% indicated that laptops were very important to their class decisions.

[20]Ideally, we would observe individual student laptop use in each of the laptop optional courses in our data (32,946 student-course observations), which would us to estimate the effect of laptop using in a two-stage least-squares design. Because we are unable to collect laptop use at the individual course level, we instead estimate reduced form effects of laptop use using faculty policy.

[21]While our reduced form approach limits our ability to precisely identify the magnitude of effects, our first stage estimates for a subsample of students can provide a general sense of the magnitude of effect sizes.

following two equations in our main specification:

$$y_{ict} = \beta_0 + \beta_1 * LaptopReq_{ict} + \gamma * X_i + \lambda_{ct} + \epsilon_{ict} | LaptopAllowed = 1 \tag{1}$$

$$y_{ict} = \beta_0 + \beta_2 * LaptopBan_{ict} + \gamma * X_i + \lambda_{ct} + \epsilon_{ict} | LaptopAllowed = 1 \tag{2}$$

where y_{ict} is the grade received in a laptop-optional course by an individual in a specific semester, $LaptopReq_{ict}$ and $LaptopBan_{ict}$ are indicators for whether a laptop was required or prohibited on at least one of the class days of the laptop-optional class, X_i is a vector of demographic characteristics including controls for race, gender, course load, course schedule difficulty,[22] major,[23] and lagged GPA,[24] and λ_{ct} is a vector of class-term fixed effects. With the inclusion of class-term fixed effects, our estimates only compare students who are exposed to identical lectures, peers, and other classroom-specific variation. Our primary variables of interest are β_1 and β_2, which provide reduced-form evidence of the impact of laptop use on course grades. In each specification we cluster our standard errors at the individual level. A positive β_1 in equation (1) and a negative β_2 in equation (2) suggest that laptops have a positive impact on students, as students who were influenced to bring laptops to class do better and those who are dissuaded from using laptops do worse. Conversely, a negative β_1 and positive β_2 would suggest that laptops have a negative impact on student outcomes.[25]

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[22]Course schedule difficulty is a measure of the difficulty of the courses a student takes on the same day as the laptop-optional class of interest. Difficulty for each class is determined by taking the average distance between GPA and course grade for all students enrolled in the class other than the student. Course schedule difficulty is the average across these courses.

[23]A majority of students do not have a declared major in the colleges administrative system, so major is inferred from the modal course major topic area taken by a student.

[24]We are missing lagged GPA for 34% of observations. We include an indicator for missing lagged GPA in all specifications that include lagged GPA. Our estimates remain consistent when the observations with missing lagged GPA are excluded from our analysis.

[25] If β_1 and β_2 move in the same direction, our estimates from equation (1) and (2) imply contradictory impacts of laptop use, suggesting that our identification assumption that laptop policies are a valid instrument for laptop use is invalid.

3.5.2 Heterogeneity Analysis

In addition to measuring the main effects of laptop policies on academic performance, we also examine whether laptop use has a heterogeneous impact on various subgroups of students. Specifically, we examine whether laptops have a more significant impact on males or females, white or non-white students, and high performing or low performing students.[26] Our estimates follow the structure of equations (1) and (2) above, but also include interactions between the subgroup characteristics of interest (female, non-white, and high-GPA) and laptop policies.

3.5.3 Falsification and robustness specifications

The fidelity of our results depends on the scheduling of laptop-required and laptop-prohibited courses being unrelated to unobservable student characteristics that might influence grades. The two primary threats to our design are non-random selection into laptop-required and prohibited courses and courses with laptop policies impacting course grades in laptop optional classes through channels other than changes in laptop use. In addition to showing that our estimates are robust to the inclusion of potentially confounding controls in our main specification, we also include a falsification test to test whether our results could be driven by selection or factors other than laptop use. This falsification test takes advantage of the fact that most classes are either on a Monday/Wednesday schedule or a Tuesday/Thursday schedule and most full-time students have both Monday/Wednesday and Tuesday/Thursday classes. We hypothesize that it is unlikely that having a laptop-required or prohibited class in a Monday/Wednesday class will affect laptop use in a Tuesday/Thursday class (and vice versa). However if our results are primarily driven by unobserved selection into laptop-required or prohibited classes, we would likely see opposite-day policies impact course grades. Therefore we run the following falsification specifications for both laptop required and laptop-prohibited classes:

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[26]We define high performing as having a cumulative GPA in the upper half of the GPA distribution.

$$y_{ict} = \beta_0 + \beta_1 * OppositeDayLaptopReq_{ict} + \gamma * X_i + \lambda_{ct} + \epsilon_{ict} | LaptopAllowed = 1 \quad (3)$$

$$y_{ict} = \beta_0 + \beta_2 * OppositeDayLaptopBan_{ict} + \gamma * X_i + \lambda_{ct} + \epsilon_{ict} | LaptopAllowed = 1 \quad (4)$$

where $OppositeDayLaptopReq_{ict}$ and $OppositeDayLaptopBan_{ict}$ are indicators for whether a laptop was required or prohibited on the days opposite the scheduled class and all other variables are as previously specified.[27] These specifications provide additional evidence of the validity of our primary estimation strategy.

In our final robustness exercise, we include individual fixed effects to examine the impact of laptop policies on performance in laptop-optional classes within individuals. In this setting, identification comes from individuals that have multiple non-overlapping laptop-optional courses with varying policies between the days of those classes. For example, a student that is required to bring a laptop to one of her Monday/Wednesday classes, has at least one laptop-optional Monday/Wednesday class, has at least one laptop-optional Tuesday-Thursday class, and is not required to bring laptops to any class on Tuesday or Thursday would provide identifying variation for this estimation. To estimate the within student reduced form impact of laptop use on course performance, we run the following within-student specifications:

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[27]We additionaly condition on $LaptopRequired = 0$ in equation (3) and $LaptopBan = 0$ in equation (4) to insure that students are untreated on the day of the laptop-optional course. Our results, however, remain unchanged if we do not include these conditions.

$$y_{ict} = \beta_0 + \beta_1 * LaptopReq_{ict} + \delta * X_{ict} + \lambda_c + \zeta_i + \epsilon_{ict} | LaptopAllowed = 1 \qquad (5)$$

$$y_{ict} = \beta_0 + \beta_2 * LaptopBan_{ict} + \delta * X_{ict} + \lambda_c + \zeta_i + \epsilon_{ict} | LaptopAllowed = 1 \qquad (6)$$

where X_{ict} is a vector of characteristics that vary by individual, course, and term including the number of same-day courses and course schedule difficulty, λ_c is a vector of course fixed effects,[28] and ζ_i is a vector of individual effects. While this specification no longer has the attractive feature of examining variation within a classroom and relies on a much more limited source of variation than our primary analysis, it completely eliminates the possibility of our results being driven by selection bias across individuals. Therefore, this exercise generates a powerful test of one our primary identifying assumptions.

4 Results

4.1 Primary Analysis

Our primary results are presented in Table 5. The impact of having at least one laptop-required course on grades in laptop-optional courses, reported in Panel A, is consistently negative and significant across specifications. In column 1, where only class fixed effects are controlled, we find that having a laptop-required class is correlated with 0.04 grade point drop in laptop-optional classes (significant at the 10% level). If this negative relationship were due to selection we might expect it to dissipate when additional controls are added. However, when demographic controls,[29] schedule controls,[30] and major fixed effects are included, the estimates remain stable (between -0.04

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[28]A degrees of freedom limitation prevent us from including course-term fixed effects.

[29]Demographic controls include sex, race, and lagged GPA of student.

[30]Schedule controls include the number of same-day courses taken by the student, and the average difficulty of other same-day courses.

and -0.05) and become more precisely estimated (significant at the 5%, 1% and 1%, respectively). Because laptop-required courses increase the probability of laptop use, these results suggest that laptop use significantly worsens academic performance. Scaling the results by the first-stage survey results reported in Table 4 suggests that laptop use decreases course grades by between 0.27 and 0.38 grade points, or between 0.32 and 0.46 standard deviations.

The impact of having at least one laptop-prohibited courses on course grades laptop-optional courses, reported in Panel B of Table 5, suggest a very similar impact of laptop use on GPA. When only course fixed effects are controlled in column 1, having a laptop-prohibited course is associated with a 0.09 grade point improvement (significant at the 1% level). When demographic, schedule, and major controls are included, the point estimates drop to between 0.05 and 0.06 grade points, but remain statistically significant around the 5% level. Because having laptop-prohibited courses decrease the probability of laptop use, these estimates also suggest that laptops have a significant negative impact on grades. When we scale the laptop-prohibited results by the first stage reported in Table 4, our results suggest that laptops decrease course grades by between 0.14 and 0.25 grade points or 0.17 and 0.30 standard deviations.

That both laptop-required and laptop-prohibited courses predict that laptops significantly worsen academic performance and both approaches are robust to a series of controls provides compelling evidence that laptops, in fact, worsen academic performance. In addition to generating multiple points of evidence of a negative impact of laptop policies, the consistent estimates generated these opposing policies help rule out any sources of selection that are positively correlated or uncorrelated across having laptop-required and laptop-prohibited courses.

4.2   Heterogeneity Analysis

Because we would like to identify whether laptops are more helpful or harmful to some populations, we test whether the impact of laptop use appears to differ by student characteristics. In Table 6 we explore whether treatment effects vary by gender, race/ethnicity, and academic ability. In columns

1 and 2 we investigate whether female students are differentially impacted by laptop use. While the coefficient on $Female * Policy$ in column 1 is imprecisely estimated, it is consistent with the -0.10 point estimate in column 2 (significant at the 5% level). When this interaction effect is compared to main effect of 0.11 grade points, this suggests that the impact of laptops on course grades is largely driven by male students. This finding is consistent with Carter et al. (2016) and may be consistent with research that finds young males tend to have weaker noncognitive skills (including attentiveness) than females (e.g. Cornwell et al., 2013; Jacob, 2002). Columns 3 and 4 show inconsistent and imprecise estimates of a differential impact of laptops by white and non-white racial/ethnic categorization, suggesting that race is not a strong predictor of response to laptop use.

Our heterogeneity analysis find evidence that weaker students are most negatively affected by laptop use. In both columns 5 and 6 of Table 6, the coefficients on $HighGPA * Policy$ (0.09 and -0.09 respectively) are statistically significant and completely negate the coefficients on $LaptopPolicy$ (-0.09 and 0.09 respectively), suggesting that only weak students, as predicted by their GPA are negatively impact by laptop use. This result contrasts with Carter et al. (2016), who find larger impacts on strong as opposed to weak students but is consistent with Beland and Murphy (2015) who find that classroom cell-phone bans in K-12 grades benefit weak students and have no effect on stronger students.

4.3 Falsification and Robustness Tests

Although our balance tests, survey results, and the consistency of our primary estimates all increase our confidence that our results are estimating a causal relationship between laptop use and course grades, we also corroborate these results with the falsification test described in our empirical strategy. Table 7 shows the impact of opposite day policies on course grades in laptop optional courses. If our identification assumptions hold, we expect there to be no impact of opposite day policies on course grades. This is, in fact, what we find. In columns 1 and 2, the point estimates for the impact

of opposite day required courses on course grades are very close to zero (-0.002 and -0.003 grade points, respectively) and statistically insignificant. Columns 3 and 4 report the estimated impact of opposite day prohibited courses on grades and show similar patterns. The estimated impact of opposite day prohibited courses on course grades in column 3 of 0.01 is small and insignificant and the estimate with controls of -0.03 is both insignificant and in the opposite direction of our primary results. This balance provides further evidence that laptops do, in fact, have a negative impact on academic performance.

Finally, we estimate the impact of laptop policies using within student fixed effects in Table 8, as outlined in our empirical strategy. While these estimates rely on significantly less variation than our primary estimates and are more imprecisely estimated, they corroborate our primary results. In panel A columns 1-3, we estimate the impact of having a laptop-required class on performance in a laptop-optional classes within student with no controls, controls for schedule variables (term fixed effects, number of same-day courses, and difficulty of same-day courses), and course fixed effects, respectively. In Panel A we find consistently negative but either a marginally significant or statistically insignificant impact of laptop-requirements in laptop-optional courses (between -0.01 and -0.03 grade points). These results are both consistent with laptops having a negative impact on student performance and with our primary estimates.

In Panel B of Table 8, we estimate the impact of having laptop-prohibited classes on grades in laptop-optional classes within student. Not only do columns 1-3 each generate positive point estimates of 0.02-0.05 grade points that are consistent with our primary results, but the estimate of 0.05 grade points in column 3 is the same as our primary estimate in column 4 of Table 5 and is marginally significant at the 10% level.[31]

If we scale our individual fixed effects models by our first estimates in Table 4, our laptop-

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[31] As additional robustness checks, we re-run our primary analysis excluding all students who do not have any laptop-required courses in their schedules and also re-categorizing courses with missing laptop policies as 'laptop-optional' courses. Our results are robust to these alternate samples. The alternate sample results are reported in Appendix Tables 3 and 4.

required estimates suggest that laptops reduce grades by between 0.08 and 0.20 grade points and our laptop-prohibited estimates suggest laptops reduce grades by between 0.04 and 0.14 grade points. These estimates fall within the bounds of our primary estimates. Taken altogether, the consistency of the student fixed-effect results with our primary results furthers our confidence that laptops have a deleterious impact on student grades.

5 Discussion

In this paper we present quasi-experimental evidence of the impact of laptop use in college classrooms on academic outcomes. We leverage differences in student schedules and laptop policies to generate plausibly exogenous variation in laptop use in laptop-optional courses. Our results suggest that laptop use has a significant negative impact on course performance, on the scale of 0.14-0.37 grade points or 0.17-0.46 standard deviations. We also find evidence that laptops have the most negative impact on male and low-performing students. Throughout our study we find evidence supporting a causal interpretation of our results. First, we obtain survey evidence that suggests students are unlikely to select into courses based on their laptop policies. Second, we find that observable characteristics generally balance across our laptop-policy groups in Table 3. Third, we find consistent evidence in Table 5 that laptops reduce student performance from two different instruments–having laptop-required and laptop-prohibited courses in one's schedule. Fourth, our falsification test in Table 7, which examines the impact of opposite-day policies on course outcomes, shows no evidence of selection problems. Fifth and finally, we find that the within-student estimates reported in Table 8 are uniformly consistent with our primary results. Thus we are confident that our results show that laptop use worsens student academic outcomes.

Nevertheless, our results should be interpreted with some care. Our study design precludes us from directly measuring the impact of laptop use on academic performance, so we must rely on our survey results from 229 students to estimate the scale of our results. Also, as with any

instrumental variable approach, our study isolates the impact of laptop use on the students who are on the margin of using a laptop in class. It is possible that students who always use laptops in class could still benefit from use while those on the margin suffer. Finally, because our results are driven by variation within the classroom, we are cautious in interpreting our results from a class-level policy perspective. While our results suggest that prohibiting laptops in the classroom could benefit students who are on the margin of using laptops, we are unable to observe how classroom dynamics might change when moved to a no-laptop environment.

While our within classroom variation is a weakness in one sense, it is a strength in another. Because treated and untreated students in our study are in the same classroom, being exposed to the exact same course with the exact same peers, we are able to directly attribute our results to personal laptop use. Instead of identifying a policy parameter of how laptop prohibitions and requirements impact student outcomes, we identify a behavioral parameter of how classroom laptop use impacts students. Our results suggest that laptop use directly worsens academic outcomes for students who choose to use them. That students would choose to use laptops in spite of significant negative academic consequences opens up a number of questions. Why are students making choices in the classrooms that seem inconsistent with their long-run interests? If students are made aware of the deleterious effects of laptops, do they persist? Would students benefit if the potential distractions created by computers were eliminated? With the near ubiquity of computers in the college classroom and professional workplace, research investigating how to help students and workers avoid productivity losses associated with computer may be particularly impactful.

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Table 1: Instructor Laptop Policies

Laptops optional	0.67
Laptops required	0.20
Laptops prohibited	0.04
Opinion: Laptops increase learning	0.57
Opinion: Laptops decrease learning	0.26
Opinion: Laptops increase participation	0.31
Opinion: Laptops decrease participation	0.42
Number of instructors	163

90 Faculty responded to the impact of laptop policies.

Table 2: Student Characteristics

Masters student	0.230
Female	0.547
Asian	0.034
African American	0.018
Hispanic or Latino	0.105
White	0.800
Other race or ethnicity	0.044
Age	24.605
	(7.381)
Number of courses	3.817
	(1.072)
Cumulative GPA	3.409
	(0.612)
Laptops allowed	0.834
Laptops required	0.147
Laptops prohibited	0.019
Missing laptop policy	0.263
Ever laptop required	0.522
Ever laptop prohibited	0.141
Grade: laptops allowed	3.386
	(0.756)
Grade: laptops required	3.455
	(0.763)
Grade: laptops prohibited	3.410
	(0.806)
Grade: missing policy	3.488
	(0.744)
Observations	5570

Standard deviations in parentheses. Observations from students over the course of 6 semesters.

Table 3: Student Characteristics by Laptop Policies

Panel A: Monday/Wednesday Courses

| | | | | P-values for pairwise t-tests | | |
	Optional	Required	Prohibited	1-2	1-3	2-3
Female	0.540	0.534	0.621	0.82	0.11	0.12
Asian	0.030	0.032	0.012	0.81	0.13	0.18
African American	0.019	0.010	0.012	0.12	0.52	0.88
Hispanic or Latino	0.112	0.106	0.081	0.78	0.32	0.47
White	0.790	0.803	0.849	0.59	0.14	0.31
Other race or ethnicity	0.049	0.048	0.047	0.96	0.91	0.94
Age	21.411	22.132	21.579	0.03	0.68	0.28
	(4.826)	(5.916)	(3.883)			
Cumulative GPA	3.257	3.344	3.382	0.02**	0.02**	0.55
	(0.694)	(0.629)	(0.517)			
Number of courses	4.060	4.393	4.274	0.00***	0.05*	0.32
	(1.024)	(0.969)	(1.056)			
Observations	2950	341	95	–	–	–

Panel B: Tuesday/Thursday Courses

	Optional	Required	Prohibited	1-2	1-3	2-3
Female	0.523	0.586	0.512	0.01***	0.85	0.22
Asian	0.025	0.044	0.031	0.08*	0.79	0.59
African American	0.017	0.015	0.016	0.74	0.93	0.96
Hispanic or Latino	0.110	0.123	0.078	0.44	0.35	0.23
White	0.797	0.781	0.859	0.45	0.16	0.10
Other race or ethnicity	0.050	0.037	0.016	0.19	0.03**	0.24
Age	21.595	20.575	21.439	0.00***	0.68	0.03**
	(5.010)	(3.059)	(3.341)			
Cumulative GPA	3.276	3.215	3.464	0.09*	0.00***	0.00***
	(0.670)	(0.738)	(0.416)			
Number of courses	4.044	4.309	4.220	0.00***	0.11	0.44
	(1.032)	(0.818)	(0.994)			
Observations	2803	466	82	–	–	–

Standard deviations in parentheses. Stars indicate whether values are statistically significantly different from laptop allowed category levels as follows: *** $p<0.01$, ** $p<0.05$, * $p<0.1$. Observations are at the indidual level for Monday/Wednesday and Tuesday/Thursday courses, the two most common class schedules. Categories are mutually exclusive as the 4 students who have both laptop-required and laptop-prohibited classes are omitted.

Table 4: Impact of Same-Day Laptop Policies on Laptop Use in Laptop-Optional Classes

	(1)	(2)	(3)	(4)	(5)	(6)
Laptop required	0.133***	0.142***	–	–	0.112**	0.116**
	(0.054)	(0.055)	–	–	(0.056)	(0.057)
Laptop prohibited	–	–	-0.320**	-0.367**	-0.284*	-0.329**
	–	–	(0.147)	(0.158)	(0.148)	(0.160)
Constant	0.680***	–	0.749***	–	0.705***	–
	(0.038)	–	(0.030)	–	(0.042)	–
R-squared	0.017	0.146	0.024	0.161	0.035	0.172
Class FE	no	yes	no	yes	no	yes
Sample size	241	241	241	241	241	241

Robust Standard errors in parentheses. Stars indicate whether coefficients are statistically significantly different from zero at conventional levels as follows: *** p<0.01, ** p<0.05, * p<0.1. Observations are clustered at the indidual level (229 individuals) and come from 14 classes that were surveyed about their laptop use. Laptop required variable is an indicator for the student having at least one class on the same day that requires laptop use. Laptop prohibited variable is an indicator for the student having at least one class that bans laptop use on the same day.

Table 5: Reduced Form Estimates of Laptop Policies on GPA

	Panel A: Laptops Required			
	(1)	(2)	(3)	(4)
Laptop required	-0.038*	-0.043**	-0.048***	-0.054***
	(0.022)	(0.018)	(0.019)	(0.019)
R-squared	0.215	0.418	0.421	0.426

	Panel B: Laptops Prohibited			
	(1)	(2)	(3)	(4)
Laptop prohibited	0.092***	0.053*	0.061**	0.054**
	(0.033)	(0.028)	(0.028)	(0.028)
R-squared	0.216	0.418	0.421	0.426
Sample size	32946	32946	32946	32946
Demographic vars	no	yes	yes	yes
Schedule vars	no	no	yes	yes
Major FE	no	no	no	yes
Class/semester FE	yes	yes	yes	yes

Estimates in terms of grade points. Robust Standard errors in parentheses, clustered by individual (5570 clusters). Stars indicate whether coefficients are statistically significantly different from zero at conventional levels as follows: *** $p<0.01$, ** $p<0.05$, * $p<0.1$. Laptop required variable is an indicator for the student having at least one class on the same day that requires laptop use. Laptop prohibited variable is an indicator for the student having at least one class that bans laptop use on the same day. Demographic variables include sex, race, and lagged GPA. Schedule variables include number of same-day courses per student, course schedule difficulty, and course grade level.

Table 6: Heterogeneous impact of Laptop Requirements on GPA

	Sex		Race/Ethnicity		GPA	
	Required	Prohibited	Required	Prohibited	Required	Prohibited
Laptop Policy	-0.062**	0.114***	-0.047**	0.066**	-0.091***	0.088*
	(0.026)	(0.045)	(0.020)	0.028	(0.028)	(0.046)
Female	0.040***	0.044***	–	–	–	–
	(0.010)	(0.010)	–	–	–	–
Female*Policy	0.015	-0.104**	–	–	–	–
	(0.032)	(0.054)	–	–	–	–
Non-white	–	–	-0.040***	-0.042***	–	–
	–	–	(0.013)	(0.013)	–	–
Non-white*Policy	–	–	-0.034	-0.058	–	–
	–	–	(0.084)	(0.084)	–	–
High GPA	–	–	–	–	0.348***	0.359***
	–	–	–	–	(0.013)	(0.013)
High GPA*Policy	–	–	–	–	0.090***	-0.090*
	–	–	–	–	(0.030)	(0.052)
R-squared	0.426	0.426	0.425	0.425	0.450	0.450
Class/semester FE	yes	yes	yes	yes	yes	yes
Class Difficulty	yes	yes	yes	yes	yes	yes
Major FE	yes	yes	yes	yes	yes	yes
Grade Level FE	yes	yes	yes	yes	yes	yes
Sample size	32946	32946	32946	32946	32946	32946

Estimates in terms of grade points. Robust Standard errors in parentheses, clustered by individual (5570 clusters). Stars indicate whether coefficients are statistically significantly different from zero at conventional levels as follows: *** $p<0.01$, ** $p<0.05$, * $p<0.1$. Laptop required variable is an indicator for the student having at least one class on the same day that requires laptop use. Laptop prohibited variable is an indicator for the student having at least one class that bans laptop use on the same day.

Table 7: Falsification Test
Impact of Laptop Policies on Opposite Day Grades

	(1)	(2)	(3)	(4)
Opposite day required	-0.003	-0.002	–	–
	(0.017)	(0.017)	–	–
Opposite day prohibited	–	–	0.012	-0.033
	–	–	(0.035)	(0.024)
R-squared	0.154	0.555	0.154	0.556
Demographic controls	no	yes	no	yes
Class/semester FE	yes	yes	yes	yes
Major FE	no	yes	no	yes
Grade Level FE	no	yes	no	yes
Sample size	17750	17750	19007	19007

Estimates in terms of grade points. Robust Standard errors in parentheses, clustered by individual (3689 in columns 1 and 2 and 3836 clusters in columns 3 and 4). Stars indicate whether coefficients are statistically significantly different from zero at conventional levels as follows: *** $p<0.01$, ** $p<0.05$, * $p<0.1$. The Sample in columns 1 and 2 consists of all student-class observations from students in laptop-allowed classes that do not have any laptop required classes on class days. The sample in columns 3 and 4 consists of all student-class observations from students in laptop-allowed classes that do nat have any laptop-banned classes on class days. Opposite day required variable is an indicator for the student having at least one class on an alternate day that requires laptop use. Laptop prohibited variable is an indicator for the student having at least one class that bans laptop use on the same day.

Table 8: Impact of Laptop Policies on Grades
Within Student Estimates

	Panel A: Laptops Required		
	(1)	(2)	(3)
Laptop required	-0.028*	-0.011	-0.020
	(0.016)	(0.017)	(0.017)
R-squared	0.437	0.441	0.568
	Panel B: Laptops Prohibited		
	(1)	(2)	(3)
Laptop prohibited	0.016	0.036	0.052*
	(0.032)	(0.032)	(0.029)
R-squared	0.437	0.441	0.568
Sample size	32946	32946	32946
Schedule vars	no	yes	yes
Class FE	no	no	yes
Student FE	yes	yes	yes

Estimates in terms of grade points. Robust Standard errors in parentheses. Standard are clustered at the individual level. Stars indicate whether coefficients are statistically significantly different from zero at conventional levels as follows: *** $p<0.01$, ** $p<0.05$, * $p<0.1$. Laptop required variable is an indicator for the student having at least one class on the same day that requires laptop use. Laptop prohibited variable is an indicator for the student having at least one class that bans laptop use on the same day. Schedule variables include Schedule variables term fixed effects, same-day course schedule difficulty, and same-day number of courses.

Table A1: Reduced Form Estimates of Laptop Requirements on Outcomes

	(1)	(2)	(3)	(4)
Laptop required	-0.038*	-0.043**	-0.048***	-0.054***
	(0.022)	(0.018)	(0.019)	(0.019)
Asian	–	-0.012	-0.014	-0.025
	–	(0.027)	(0.026)	(0.027)
African American	–	-0.113**	-0.108**	-0.110**
	–	(0.052)	(0.053)	(0.055)
Hispanic or Latino	–	-0.041**	-0.042***	-0.042***
	–	(0.017)	(0.017)	(0.017)
	–	-0.045*	-0.045*	-0.036
	–	(0.026)	(0.026)	(0.027)
Age	–	-0.002**	-0.003***	-0.003***
	–	(0.001)	(0.001)	(0.001)
Lagged GPA	–	1.085***	1.079***	1.072***
	–	(0.016)	(0.016)	(0.016)
Number of same-day courses	–	–	-0.008	-0.004
	–	–	(0.009)	(0.009)
Course difficulty	–	–	0.138***	0.098***
	–	–	(0.020)	(0.021)
R-squared	0.215	0.418	0.421	0.426
Class/semester FE	yes	yes	yes	yes
Grade Level Fe	no	no	yes	yes
Major FE	no	no	no	yes
Sample size	32946	32946	32946	32946

Estimates in terms of grade points. Robust Standard errors in parentheses, clustered by individual (5570 clusters). Stars indicate whether coefficients are statistically significantly different from zero at conventional levels as follows: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. Laptop required variable is an indicator for the student having at least one class on the same day that requires laptop use. Laptop prohibited variable is an indicator for the student having at least one class that bans laptop use on the same day.

Table A2: Reduced Form Estimates of Laptop Prohibitions on Outcomes

	(1)	(2)	(3)	(4)
Laptop Prohibited	0.092***	0.053*	0.061**	0.054**
	(0.033)	(0.028)	(0.028)	(0.028)
Asian	–	-0.012	-0.014	-0.025
	–	(0.027)	(0.026)	(0.027)
African American	–	-0.111**	-0.106**	-0.109**
	–	(0.052)	(0.053)	(0.055)
Hispanic or Latino	–	-0.041**	-0.042***	-0.043***
	–	(0.017)	(0.017)	(0.017)
	–	-0.046*	-0.046*	-0.037
	–	(0.026)	(0.026)	(0.027)
Age	–	-0.002**	-0.003***	-0.003***
	–	(0.001)	(0.001)	(0.001)
Lagged GPA	–	1.084***	1.079***	1.072***
	–	(0.016)	(0.016)	(0.016)
Number of same-day courses	–	–	-0.012	-0.007
	–	–	(0.009)	(0.009)
Course difficulty	–	–	0.140***	0.100***
	–	–	(0.020)	(0.021)
R-squared	0.216	0.418	0.421	0.426
Class/semester FE	yes	yes	yes	yes
Grade Level Fe	no	no	yes	yes
Major FE	no	no	no	yes
Sample size	32946	32946	32946	32946

Estimates in terms of grade points. Robust Standard errors in parentheses, clustered by individual (5570 clusters). Stars indicate whether coefficients are statistically significantly different from zero at conventional levels as follows: *** p<0.01, ** p<0.05, * p<0.1. Laptop required variable is an indicator for the student having at least one class on the same day that requires laptop use. Laptop prohibited variable is an indicator for the student having at least one class that bans laptop use on the same day.

Appendix Table 3: Reduced Form Estimates of Laptop Policies on GPA
Excluding Students who Never have Laptop-Required or Prohibited Courses

	Panel A: Laptops Required			
	(1)	(2)	(3)	(4)
Laptop required	-0.068***	-0.061***	-0.060***	-0.058***
	(0.022)	(0.019)	(0.019)	(0.019)
R-squared	0.220	0.434	0.436	0.443

	Panel B: Laptops Prohibited			
	(1)	(2)	(3)	(4)
Laptop prohibited	0.073**	0.041	0.054*	0.051*
	(0.034)	(0.029)	(0.029)	(0.028)
R-squared	0.219	0.433	0.436	0.443
Sample size	21943	21943	21943	21943
Demographic vars	no	yes	yes	yes
Schedule vars	no	no	yes	yes
Major FE	no	no	no	yes
Class/semester FE	yes	yes	yes	yes

Robust Standard errors in parentheses, clustered by individual (5570 clusters). Stars indicate whether coefficients are statistically significantly different from zero at conventional levels as follows: *** $p<0.01$, ** $p<0.05$, * $p<0.1$. Laptop required variable is an indicator for the student having at least one class on the same day that requires laptop use. Laptop prohibited variable is an indicator for the student having at least one class that bans laptop use on the same day. Demographic variables include sex, race, and lagged GPA. Schedule variables include number of same-day courses per student, course schedule difficulty, and course grade level.

Table A4: Reduced Form Estimates of Laptop Policies on GPA
Redesignating Courses without Laptop Policies as Laptop-Optional

	Panel A: Laptops Required			
	(1)	(2)	(3)	(4)
Laptop required	-0.027	-0.043***	-0.049***	-0.058***
	(0.019)	(0.016)	(0.016)	(0.016)
R-squared	0.197	0.386	0.389	0.395

	Panel B: Laptops Prohibited			
	(1)	(2)	(3)	(4)
Laptop prohibited	0.092***	0.067***	0.072***	0.068***
	(0.029)	(0.025)	(0.025)	(0.025)
R-squared	0.197	0.386	0.389	0.395
Sample size	48679	48679	48679	48679
Demographic vars	no	yes	yes	yes
Schedule vars	no	no	yes	yes
Major FE	no	no	no	yes
Class/semester FE	yes	yes	yes	yes

Robust Standard errors in parentheses, clustered by individual (5570 clusters). Stars indicate whether coefficients are statistically significantly different from zero at conventional levels as follows: *** $p<0.01$, ** $p<0.05$, * $p<0.1$. Laptop required variable is an indicator for the student having at least one class on the same day that requires laptop use. Laptop prohibited variable is an indicator for the student having at least one class that bans laptop use on the same day. Demographic variables include sex, race, and lagged GPA. Schedule variables include number of same-day courses per student, course schedule difficulty, and course grade level.

B Appendix B: Supplimentary Materials

Instructor Laptop Survey

1. What is your policy for students using laptops in your classes?
   a) Laptop are <u>not</u> allowed
   b) Students may use laptops if they choose
   c) Students <u>must</u> use laptops
   d) Depends on class/Other (please explain)

2. What is your policy for students using computer tablets (i.e. iPads) and other technology?
   a) Laptop are <u>not</u> allowed
   b) Students may use laptops if they choose
   c) Students <u>must</u> use laptops
   d) Depends on class/Other (please explain)

3. What fraction of your students use laptops in class?
   a) None/close to none
   b) About ¼
   c) About ½
   d) About ¾
   e) All/close to all

4. From your perspective, how does laptop use in class impact **student learning**?
   a) Laptops *significantly decrease* learning
   b) Laptops *slightly decrease* learning
   c) Laptops have *no impact* on learning
   d) Laptops *slightly increase* learning
   e) Laptops *significantly increase* learning

5. From your perspective, how does laptop use in class impact **student participation**?
   a) Laptops *significantly decrease* student participation
   b) Laptops *slightly decrease* student participation
   c) Laptops have *no impact* on student participation
   d) Laptops *slightly increase* student participation
   e) Laptops *significantly increase* student participation

Free Response Questions

6. From your perspective, what are the most significant **advantages** of students using laptops in class?

7. From your perspective, what are the most significant **disadvantages** of students using laptops in class?

8. What do you think could be done to improve the way computers are used in class?

Student Laptop Use Survey   **ClassID_____**

*The purpose of this survey is to collect information for research study investigating laptop use and student performance. Your participation in this survey is entirely voluntary. You may refuse to take this survey or skip any questions you wish not to answer. Your participation will not affect your current or future relationship with ***********. Any personally identifiable information we collect will be kept confidential.*

email/Student ID (either):_____

1) Did you bring a Laptop to use in class today?   _____ Yes   _____ No

2) How often do you use a laptop computer during this class?
____ Every day in class/Close to every day in class
____ About ¾ of the days in class
____ About ½ of the days in class
____ About ¼ of the days in class
____ Never/Close to never

3) When you bring a laptop to use in this class, around how much time is your laptop open and turned on?

_____Hours _____Minutes   Circle Here if Not Applicable

4) Do any classes in your schedule **today** (before or after this class) **REQUIRE** you to bring a laptop to class? _____Yes _____No   If yes, how many _____
What days (if any) do you have at least one class that **requires** you to bring a laptop to class?
   ☐   ☐   ☐   ☐   ☐
Monday   Tuesday   Wednesday   Thursday   Friday

5) Do any classes in your schedule **today** (before or after this class) **NOT ALLOW** you to bring a laptop to class? _____Yes   _____No   If yes, how many?_____
What days (if any) do you have at least one class that **does not allow** you to bring a laptop to class?
   ☐   ☐   ☐   ☐   ☐
Monday   Tuesday   Wednesday   Thursday   Friday

6) Did you know the laptop policies of any of your classes before enrolling?
_____Yes   _____No   If yes, for how many?_____

7) When deciding which classes to take, how important were the class laptop policies?
___ Not at all important to my decision
___ Somewhat important to my decision
___Very important to my decision

Laptop Required Courses

Abnormal Psychology
Academic Orientation for Internationals
Academic Reading & Writing
Academic Reading/Writing Internationals
Adv Grammar Vocabulary Internats
Adv. Epidemiology and Biostat.
Advanced Flight
Advanced Flight Lab I
Advanced Flight Lab II
Advanced Health Assessment
Advanced Medical-Surgical Nursing
Aircraft Systems
Aircraft Systems I
Aircraft Systems II
Algorithms and Data Structures
Anesthesia Principles I
Anesthesia Principles III
Anesthesia Seminar I
Anthropology of Globalization
Applications of Cognitive Behavioral
Applied Data Analysis
Applied Statistics and Student
Artificial Intelligence
Assessment for English Learners
Astrobiology
Auditing and Attestation II
Beginning Drawing,LE
Beginning Painting,LE
Business Plan Development
Business Regulation
Chemistry and Physics for Nurse
Child Development
College Media: Forum
Commercial Flight Lab II
Communicating Across Cultures
Communication & Interpersonal Skills
Communication Across Cultures
Community Placement Thesis
Composition and Research,LE
Computer Architecture
Computer Graphics
Computer Networks
Computer Science Principles
Computer Security
Computer Systems and Programming
Counseling Ethics

Cultural Anthropology
Database Systems
Directed Studies
Diversity and Learning
E-Commerce
Ecology and Lab
Education in a Diverse Society
Effective Presentations
Elementary Statistics, LE
Emerging Scholars
English Learners
English Learners, Family & Community
English Learners, Family and Community
Entrepreneurship
Environmental Anthropology
Environmental Biology, LE
Environmental Health
Environmental Psychology
Epidemiology
Executive Development
Executive Financial Decision Making
Exploring Student Leadership
Facilitating Services Across Discipli..
Financial Design & Analysis
Financial Report & Control III
Financial Reporting and Control I
Flight Theory
Foundations of Education in a Diverse
Fundamental of Entrepreneurship
Geographic Information Systems
Gerontological Nursing
Google Code Jam
Group Therapy
Health Assessment
Health Care and Health Promotion of
History and Systems of Psychology
Human Evolution and Archaeology
Human Factors in Flight
Independent Research Thesis
Indigenous Peoples of the Us
Infectious and Chronic Diseases
Info Lit Intensive Internat
Information Literacy for International
Information Technology in the Business
Internal Reporting and Business Control
International Context Tour

Laptop Required Courses, continued

Intro to Anthropology,LE	Psychopathology and the DSM
Intro. to Academic Writing	Public Health Capstone Project
Introduction to Computer Science	Public Presentations,LE
Introduction to Data Structures	Qualitative Research Methods
Introduction to Ecology	Quantitative Research Methods
Introduction to Education	Research Methodologies
Introduction to Environmental Studies	Research Methods
Introduction to Professional Nursing	Research Project
Introduction to Psychology,LE	Research in the Practice Setting
Introduction to Public Health	Research/Development Seminar in
Justice Studies Thesis	Rhetorical Theory and Practice
Leadership Communication	Roles of the Special Educator
Leadership Development, LE	Sales Management
Leadership for Social Change	Scientific Computing
Making Sense of Films, LE	Seminar in Professional Roles
Managing People	Senior Capstone
Marketing New Ventures	Senior Project I, II
Masters Project/Thesis	Senior Project Proposal Writing
Measuring Human Traits and Behavior	Senior Seminar
Medical-Surgical Nursing	Service Learning in Psychology
Meteorology	Social Entrepreneurship
Methods of Instruction and Curriculum	Social Neuroscience
Middle Eastern History	Social Psychology
Mineral, Chemical, Spectacle	Software Engineering
Modern World History, LE	Special Education Assessment
Myth, Magic and the Supernatural	Special Topics
Nursing Theory and Research	Special Topics Seminars
Operating Systems	Specialized Education Services
Organisms and Evolution	Statistics for the Sciences
Organizational Behavior	Student Teach SPED: Mild/Mod
Organizational Communication	Survey of Latin American Culture
Pharmacology	Teaching & Research Seminar
Portfolio Development	Teaching with Technology
Prin/Applic's SPED Assessment	Technology and Teaching
Principles of Genetics	The Child in the Family
Principles of Management	The Information Age, LE
Professional Aspects II	The Nonprofit Organization
Professional Flight I	Theoretical Foundations of Advanced
Professional Flight I Lab	Thesis Research
Professional Flight II	Thinking & Writing for Psych
Professional Flight II Lab	Transitioning to College
Professional Writing	Undergraduate Research
Professional and Technical Writing	Undergraduate Teaching
Psychology Field Experience	United States History,LE
Psychology Lab Skills	Western Civilization,LE

Laptop Prohibited Courses
British Classicism to Victorianism
Business Finance
Composition and Research,LE
Contemporary Latin American Culture and
Directed Studies
Introduction to Literature,LE
Investments and Analysis
Literary Criticism and Research Methods
Meditation As Environmental Study
Personal Finance and Investing, LE
Spanish I
Spanish II
Spanish IV
Studies in British Literature
Studies in Method, Theory, & Genre
Survey of Latin American Culture
Survey of Peninsular Spanish Culture ..
Yoga for Wellness
Yoga for Wellness Level 2