The Causal Effect of the School Day Schedule on the Academic Achievement of Adolescents

Teny Maghakian Shapiro *   Kevin M. Williams†

Abstract

How a student's classes are scheduled throughout the day is often determined by necessity, but can have a meaningful impact on academic performance. Acknowledging student's internal clocks and making small changes to scheduling patters could be a relatively low-cost method for administrators to improve performance. This paper builds on literature that has shown the negative effects of early morning classes to consider the influence the school-day schedule has throughout the day. Our data is five cohorts of college freshman at the United States Air Force Academy who face randomized scheduling and largely take a common set of classes. We find the largest impact of the schedule is in the early morning, but also find evidence of academic fatigue and asymmetric effects among STEM, non-STEM, and physical education courses that vary over the day.

JEL: I23, J13, J24

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*Santa Clara University; tshapiro@scu.edu

†University of California, Davis; kmwilliams@ucdavis.edu

1 Introduction

Learning is a complex and cognitively taxing task that depends on a multitude of factors, including the context of a student's school and classes. Many recent, often expensive, educational reform proposals support this idea by focusing on *how* students learn rather than what they learn. We look at the context of the school day schedule and find that there may be potential to improve student performance at relatively low costs by reorganizing the school day. Previous research has shown the benefits of similar academic contexts such as the impacts of later start time, longer school days, and longer school years on academic achievement (Carrell et al. 2011, Bellei 2009, Marcotte 2007, Hansen 2013). The findings from these studies imply that the way in which the school day or school year is organized is an important aspect of the education production function. Although the benefits of alternate school organization have been well established across many disciplines and dimensions (Boergers et al. 2014, Wahlstrom et al. 2014), school administrators have been hesitant to make changes. Even relatively low-cost changes, such as start times, haven't occurred due to constraints caused by bussing schedules and after-school sports practices and jobs. Given the reluctance to change the way in which the school year or school day is scheduled, we seek to determine whether the way that students' courses are scheduled *within* the school day has any affect on their academic achievement. By understanding the role of course organization throughout the day, school administrators may have the opportunity to improve student outcomes with a very low cost intervention– reorganizing the time in which courses are offered. Similarly, students with some control over their own schedule could take matters into their own hands and follow a few rules-of-thumb to put themselves in the best position to succeed.

To determine how the organization of students' course schedules affects their academic achievement, we use data from the United States Air Force Academy (USAFA) and take advantage of the random assignment of students to courses, instructors, and schedules at USAFA. Random assignment, mandatory attendance, along with extensive background data on students allow us to examine how the scheduling of classes throughout the day affects student achievement without worrying about confounding factors or self-selection issues that would make such an analysis at traditional high schools or colleges difficult. Additionally, USAFA's grading structure for core courses allows for a consistent measure of student achievement. Faculty members teaching the same course in each semester use an identical syllabus, give the same exams during a common testing period, and assign course grades jointly with other instructors, allowing for standardized grades within a course-semester.

Despite our use of university-level data, we believe our findings are applicable to the high school student population as well. We consider only freshmen in their first semester at USAFA, who are adolescents and have the same biological sleep patters and preferences as those in their earlier teens. However, we recognize that USAFA students are not the average teenager; they were high-achievers in high school and chose to attend a military service academy. Although we do not know for certain if school schedules affect high-achievers or military-types differently than teenagers in the general population, we have no reason to believe that the students in our sample would be *more* adversely affected by differences in course schedules. Because the students in our study self-selected into a regimented and morning-oriented lifestyle, we believe our estimates may be a lower bound of the effect for the average adolescent.

Consistent with what is known about adolescents' internal clocks, we find that students perform better in afternoon and late-morning classes than they do earlier in the morning. However, performance in later-period classes is also affected by fatigue from having had a number of classes earlier in the day. We also find that the negative effects of having a morning class are strongest for STEM classes and dissipate by afternoon. Additionally, we are able to estimate the effects of having PE and breaks early in the school day, which both lead to improved academic performance in subsequent classes. Many of these effects differ across course-type and student characteristics.

2 Background

While determining the role of school day organization is new to economics, there has been a great deal of related research done in other disciplines finding that the time of day that students take a class may affect their achievement in the class. To fully understand how the organization of the school can influence academic achievement, it is important to have a basic understanding of the biology of sleep and wakefulness. The biological rhythm that governs our sleep-wake cycle is called the circadian rhythm, a hard-wired "clock" in the brain that controls the production of the sleep-inducing hormone melatonin. During adolescence, there are major changes in one's circadian rhythm. More adult-like patterns of REM sleep develop, there are increases in daytime sleepiness, and there is a shift in the circadian rhythm toward a more own-like tendency for later bed and wake-up times Cardinali (2008), Crowley et al. (2007), Carskadon et al. (1993), Wolfson & Carskadon (1998). The adolescent body does not begin producing melatonin until around 11 p.m. and continues in peak production until about 7 a.m., then stops at about 8 a.m. In contrast, adult melatonin levels peak at 4 a.m. School schedules affect adolescent sleep patterns by imposing earlier wake-up times that are asynchronous with the circadian rhythm. That is, the way that most high schools are currently scheduled requires students to wake up and be alert and focused at a time at which their body wants to be asleep.

There are two main sleep factors that affect mental performance. The first is the duration; that is, the number of hours of sleep. Early start times causes students to be sleep deprived. Several studies find an inverse relationship between sleep and academic performance at both the secondary and post-secondary level (Curcio et al. 2006, Wolfson & Carskadon 1998, Trocket et al. 2000). Correlational studies comparing sleep-wake patterns and academic outcomes for early versus late starting schools find that students attending later starting schools self-report more hours slept, less daytime fatigue, and less depressive feelings (Owens et al. 2010, Boergers et al. 2014). The second sleep factor is the time of day one is expected to function. Regardless of the duration of sleep, there are times of the day when a person is more and less alert, which is related to their circadian timing (Blake 1967). For adolescents, alertness begins in the late morning, drops off mid-afternoon, and peaks again in the early evening. The way that classes are currently scheduled may be forcing students to learn at a time that is asynchronous with their preferred time of day. If learning of certain subjects is less adversely affected by being done when tired or out of sync with one's circadian rhythm than other subjects, then there exists an opportunity to rearrange the class schedule to improve overall achievement.

A number of studies have explored the role of school start times on academic achievement. Using student-level data from Clemson University, Dills & Hernandez-Julian (2008) find that even when controlling for student and course characteristics, students perform better in classes that meet later in the day. Wahlstrom (2002) examined the effect of the start time change at Minneapolis Public School district from 7:15 a.m. to 8:40 a.m. She finds that the policy change had a positive effect on attendance and an insignificant improvement on grades. Hinrichs (2011) takes advantage of the same policy change, instead comparing the outcomes of students to those in St. Paul (Minneapolis' twin city) where start times were not changed. His results suggest no effect of school start time on academic achievement. Edwards (2012) studied the effect of start times on middle school students and found that a one hour delay in start times leads to a three percentile point gain in both math and reading test scores for the average student. Finally, Carrell et al. (2011) study the role of school start times at USAFA by utilizing two policy changes in the daily schedule during a three year period. They find that starting the school day 50 minutes later increases overall academic achievement by about one-tenth of a standard deviation and that performance throughout the day is affected by early start times.

Another related set of studies has focused on productivity in the workplace. The most relevant of this research is the work on changes in productivity and safety between day and night shifts (Smith et al. 1994). Folkard & Tucker (2003) find that productivity and safety declines during the night shift and is relatively constant for day shifts and that the likelihood of sustaining an injury is

23 percent higher at night. Additionally, many studies have found that sleep deprivation in medical residents decreases their performance (Veasey et al. 2002). Philibert (2005) finds as much as one standard deviation decrease in performance due to high levels of sleep deprivation. However, no research has been done on how productivity varies within a given shift.

Two studies have assessed the differential impact of morning classes on achievement across course subjects. Cortes et al. (2012) utilize the essentially random variation between students in the ordering of classes over the day at Chicago Public High Schools and find that having a class first period significantly reduces grades in that course, and that having math in first period reduces test scores in all subjects and reduces grades in future math classes as well. In a similar vein, Pope (2014) uses data from Los Angeles County schools to determine how secondary-school students perform in morning versus afternoon courses. He finds that learning monotonically decreases throughout the school day and that having a morning instead of afternoon math or English class increases a student's GPA by 0.072 and 0.032 points, respectively.

We build on these literatures by looking at the causal relationship between student achievement, arguably productivity, and the scheduling of classes throughout the day. Because of USAFA's very structured and regimented academic environment, we can estimate these effects free from the selection bias and issues with non-standardized grading that plague most studies. While many studies have suggested changes to make to school schedules based on knowledge about adolescents' circadian rhythm and time preferences, no study has been able to assess how these scheduling differences actually affect students in practice.

3 Data

Data for this study come from the United States Air Force Academy (USAFA). USAFA is a fully accredited post-secondary institution with annual enrollment of approximately 4,500 students, offering 32 majors within the humanities, social sciences, basic sciences, and engineering. Students are required to graduate within four years and typically serve a minimum five year commitment as a commissioned officer in the United States Air Force following graduation. Despite its military setting, USAFA is comparable to other selective colleges and universities in the United States. Like other selective post-secondary schools, USAFA faculty hold graduate degrees from high quality programs in their fields. Approximately 40 percent of classroom instructors have terminal degrees, similar to large universities where graduate students teach introductory courses. However, class size at USAFA is rarely larger than 25 students, and students are encouraged to interact with faculty members in and out of the classroom. Therefore, the learning environment at USAFA is similar to that of small liberal arts colleges. Students at USFAFA are high achievers, with average math and verbal SAT scores at the 88^{th} and 85^{th} percentiles of the nationwide SAT distribution, respectively. Only 14 percent of applicants where admitted to USAFA in 2007. Students are drawn from each Congressional district in the US by a highly competitive admission process than ensures geographic diversity. The school day at USAFA is highly structured, which is atypical of most universities, but very similar to a high school setting There are four 53 minute class periods each morning and three each afternoon after an 85 minute lunch break. All students are required to attend a mandatory breakfast 25 minutes before first period. In this study, we exploit give important features of the school day structure at USAFA. First, students in their freshman year at USAFA are required to take a series of core course in which attendance in their assigned section is mandatory. Second, students are randomly assigned to course sections and cannot choose which periods they take their classes or with which instructors. Third, students are not assigned a class for every class period. Fourth, we exploit the fact that USAFA runs on an M/T schedule. On M days, students have one set of classes and on T days they have a different set of classes. The M/T schedule runs every other day. Thus, the same student has two different class schedules within the same semester. Finally, we exploit two distinct policy changes in the USAFA class schedule. Prior to academic year 2006-2007 (AY 2006), the class schedule started at 7:30 AM. In AY 2006 the school day was moved 30 minutes earlier, starting at 7 AM. In AY 2007, the start time was moved to 7:50 AM.

Table 1: **Class Schedule at the U.S. Air Force Academy**

Period	AY1996 - AY2005	AY2006	AY2007 - AY2009
1	7:30	7:00	7:50
2	8:30	8:05	8:50
3	9:30	9:10	9:50
4	10:30	10:15	10:50
5	13:00	13:00	13:30
6	14:00	14:05	14:30
7	15:00	15:10	15:30

Table 1 shows the academic day schedule across the years of our sample. These unique features of our dataset enable us to cleanly identify the causal average treatment effect of different components of the school schedule on academic achievement using both within-student and across-student/cohort variation. Because of all the rich, random variation the academic environment at USAFA offers, we are able to identify how different elements of the school schedule affects achievement.

3.1 The Dataset

Our dataset consists of 4,816 first-year students from the entering classes of 2004 to 2008. For each student we have pre-treatment demographic data and measures of their academic, athletic, and leadership aptitude. Academic aptitude is measured through SAT verbal and math scores and an academic composite computed by the USAFA admissions office, which is a weighted average of an individual's high school GPA, class rank, an the quality of the high school they attended. The measure of pre-treatment athletic aptitude is a score on fitness test require by all applicants prior to entrance. The measure of pre-treatment leadership aptitude is a leadership composite also computed by the USAFA admissions office, which is a weighted average of high school and community activities. Other individual-level controls include indicators for whether a student is Black, Hispanic, Asian, female, a recruited athlete, whether they attended a military preparatory school, and the number of class credits students have on that schedule day. We measure academic performance using students' final percentage score earned in a course. To account for differences in course difficulty or grading across years, we normalize all scores to a mean of zero and a variance of one within a course-semester. We refer to this measure as the student's normalized grade. Students at USAFA are required to take a core set of approximately 30 courses in mathematics, basic sciences, social sciences, humanities, and engineering. In this study, we focus primarily on the mandatory introductory courses in mathematics chemistry, engineering, computer sciences, English, and history. We refer to these as the required courses. Because grades in the humanities courses (English and history) are mostly determined by papers and assignments done outside the classroom, whereas grades in STEM (science, technology, engineering, and math) courses are based on performance on common exams, we examine the effects of STEM and non-STEM course timing separately to see if the effects differ across course type. Tables 2 and 3 show summary statistics for our sample. In Table 2 we show the mean characteristics of students enrolled in the required courses (Column (1)), STEM courses (Column (2)). Students enrolled in STEM classes are very similar to those in all requires courses. This makes us confident that there is no selection into STEM courses by higher achieving students. The last three columns show the characteristics of students by start-time cohort. Students whose first period began at 7:00 a.m. started at USAFA in AY 2006. We'll refer to this as the early start time. Those whose first period began at 7:30 a.m. started at USAFA before AY 2006 (the middle cohort), while those with the 7:50 a.m. first period started at USFAFA in AY 2007 and 2008 (the late cohort). We do note some differences in pre-treatment academic variables across our cohorts. Students from the middle cohort have higher SAT, academic composite, and fitness scores, on average. The late cohort has the lowest academic composite scores and has the highest fraction of minorities and females. Even if small differences between cohort exist, we do not expect them to affect our results as we make within course by year comparisons and control for all observable background characteristics as well as classroom peer characteristics.

Prior to the start of freshman year, students take placement exams in mathematics, chemistry, and select foreign languages. Scores on these exams are used to place students into the appropriate starting courses (e.g., remedial math, Calculus I, Calculus II, etc.). Conditional on course placement, athlete status, and gender, the s USAFA registrar randomly assigns students to required course sections. Thus, students have no ability to choose the class period or their professors in the required core courses. Professors teaching the same course in each semester use an identical syllabus and give the same exams during a common testing period. These unique institutional characteristics assure there is no self-selection of students into (or out of) courses, towards particular class periods, or toward certain professors.

To verify that assignment to different class periods is random with respect to student ability, we plot the mean academic composite score of students across class periods and M/T schedule days for the three different start-time cohorts in Figure 1. The first panel shows means for all required courses, the second for required STEM courses, and the third for required non-STEM courses. Overall, mean academic composite scores are very similar across class periods. As expected from the student summary statistics, mean academic composite scores are a bit lower for the late cohort than for the early or middle cohorts. The randomness of student assignment across different class periods allows us to utilize this variation to determine the causal impact of course scheduling on achievement. Carrell et al. (2010) show that student assignment to required courses at USAFA is random with respect to peer characteristics and professor experience, academic rank, and terminal degree status. They also find no correlation between student characteristics and professor gender. Nonetheless, we also careful to control for classroom-level peer characteristics to address differences in peers across classes and control for professor characteristics by including instructor fixed effects.

4 Analysis

4.1 Time of Day

Thanks to the unique institutional characteristics of USAFA, including random assignment of students to their classes and standardized grading, we can cleanly identify the causal effect of course scheduling on academic achievement. The first aspect of course scheduling we examine is what we'll refer to as the "period effect," that is, the relationship between the period a student takes a class and their academic achievement in that class. We begin simply by looking at mean performance across class periods in Figure 2. These numbers are also summarized in rows 5-11 of Table 3. The first panel shows the average grade earned in the required courses across all class periods. The second panel shows the average grade for STEM and non-STEM courses separately, while the third panel shows differences across the three different start-times regimes. A few patterns emerge. First, grades in first period are among the lowest in the day. Second, there appears to be a dip in grades during 4^{th} and 7^{th} periods and a peak during 2^{nd} and 6^{th} periods. Finally, there appear to be some differences in average performance across the periods for STEM and non-STEM classes as well as across the different start-time regimes.

While looking at means gives us some insight into patterns that may exist, the means also reflect differences in courses offered during different class periods, differences in professor quality, and the accumulating effects of fatigue throughout the day. Using regression framework, we are able to disentangle the time of day effect from all other attributes of the student and their schedule on academic achievement. We estimate the following equation:

$$Grade_{icjtsp} = \alpha + \theta_p + \delta_1 X_{ict} + \delta_2 \frac{\sum\limits_{k \neq i} X_{kcjtsp}}{n_{cjtsp} - 1} + \phi_{cts} + \gamma_{jt} + \rho_i + \epsilon_{icjtsp} \tag{1}$$

where $Grade_{icjtsp}$ is the normalized grade for student i in course c with instructor j on schedule day s in period p in year t. θ_p is a vector of indicator variables for all periods of the school day, excluding first period. The coefficient on each indicator variable will tell us the effect of having a class in that period, relative to first period. The vector X_{ist} includes the following student characteristics: SAT math and SAT verbal test scores, academic and leadership composites, fitness score, race, gender, the number of credit hours the student has on that schedule day, whether the student was recruited as an athlete, and whether s/he attended a military preparatory school. To control for classroom peer effects, we include $\frac{\sum_{k \neq i} X_{kcjtsp}}{n_{cjtsp}-1}$, the average pre-treatment characteristics of all students in the section q except for individual i. ϕ_{cst} are course by year by schedule day fixed effects and are included in all specifications to control for unobserved mean differences in academic achievement or grading standards across courses, years, and schedule days. In subsequent specifications we add professor by year fixed effects, γ_{jt}, to control for fixed differences in instructor quality within a given year. A third specification adds individual student fixed effects, ρ_i, to exploit the within-student variation in daily schedules across schedule days. Standard errors are clustered by student. Estimates from Equation 1 are shown in the first three columns of Table 4. Including instructor and individual fixed effects both increases the magnitude of the point estimates and improves their precision. Student performance is higher in every class period than it is in first period. Students taking a class during 7^{th} period, for example, perform about two-tenths of a standard deviations better than in a 1^{st} period class, controlling for all attributes of the student, class, instructor, and peers.

While our estimates show that students perform better in later period classes, the estimates in the first three columns of Table 4 capture two things. First is the effect of having a class during that time of day. The second is any accumulating effects of fatigue from having taken a number of classes previous to that one. The institutional setting at USAFA allows us to disentangle these two effects, because students are not assigned to classes during all periods on each schedule day. There is random variation both in the number of classes a student has had before a given class without a break (consecutive classes) as well as the number of total classes a student has had before a given class period (cumulative classes). The number of consecutive and cumulative classes can vary both across students and within students because of the M/T schedule days. For example, student A may have classes during 2^{nd}, 4^{th}, and 6^{th} periods on one schedule day, while student B has classes during 1^{st}, 2^{nd}, 5^{th}, and 6^{th} periods . By 6^{th} period, student A has had two cumulative classes, but zero consecutive classes (since he had 5^{th} period off), while student B has had three cumulative classes and one consecutive class. If students are fatigued by classes throughout the day, A and B's performance in 6^{th} period will be affected by both the timing of the class as well as the number of classes they have had that day, both consecutive and cumulative.[1] We will be able to determine the magnitude of the "fatigue effect" and whether the number of cumulative or consecutive classes matter more for performance. We add the consecutive and cumulative class variables to Equation 1 and show estimates in Columns (4) - (6) of Table 4. In all specifications, adding the fatigue variables increased the magnitude of the estimates, suggesting that the estimates in the first three columns actually understate the benefits of taking a class later in the day. Performance increases throughout the school day until 7^{th} period. This is in line with sleep research which finds that adolescent alertness improves throughout the morning, but begins the dip between 2:00 and 5:00 p.m. Consistent with the change in the period coefficients, the estimates on both the effect of the number of consecutive and cumulative classes are negative and mostly statistically significant. When including individual fixed effects, only the number of cumulative classes has an effect on grades. Each additional class a student has taken that day prior to their current class decreases performance by 0.04 standard deviations.[2] We explore the fatigue effects further in Section 4.3 when we assess the causal effects of breaks within the day on achievement.

To asses whether the time of day effect differs across start-times, we estimate Equation 1 for the different start time regimes separately. The first three columns of Table 5 show the estimates

[1] All students are assumed to have lunch period "free" and so 5th period classes are always given a previous-consecutive-classes value of 0.

[2] We have tested the non-linearity of the fatigue effect in alternate specifications by including variables for the number of consecutive and cumulative classes squared. Estimates on those coefficients were very small and statistically insignificant, suggesting that the fatigue effect is actually linear.

from the analysis. The difference in performance across the day is amplified the earlier that first period begins. Additionally, the fatigue effect captured by the number of cumulative classes a student has had is stronger the earlier that first period begins. The fatigue effect is not statistically significant for the later start-time. The next two columns of Table 5 show the time of day effect of STEM and non-STEM courses separately. While the magnitudes of the period effects are similar for both types of classes, they are only statistically significant for the STEM classes as is the fatigue effect, which is larger for STEM courses. However, the lack of precision in the non-STEM class estimates may be attributed to the smaller sample of those classes. We explore differences between STEM and non-STEM classes further in Section 4.2. Columns (6) and (7) of Table 5 look at differences across gender. The effect is much stronger and more precisely estimated for males, which may again be attributed to sample size since women only make up 20 percent of the USAFA population. We next look at the effect on minority students.[3] No strong patterns emerge for minority students. Finally, we look at differences for high and low ability students. High-ability students are those whose academic composite scores are in the top tercile. Low-ability students are those in the bottom tercile.[4] The time of day effects are very similar for both groups, although the fatigue effects are larger for the high-ability students.

4.2 Breaking Down the Morning

The time of day analysis shows that first period is the worst time to have a class on that course's grade and that performance improves throughout the day. Carrell et al. (2011) find that performance in classes throughout the day is affected by having a first period class and that the effect is magnified the earlier first period starts. We expand on their analysis by determining which classes are worst to have first period, both on the first period grade and on follow-on grades, as well as

[3]All Black, Hispanic, and Asian students are classified as minority.

[4]Because USAFA is a highly selective university, students at the bottom tercile of achievement at USAFA are still higher-achieving than the average high school student.

which classes later in the day are most adversely affected by having had a first period class. To determine the effect of first period classes, we being by estimating the following equation:

$$Grade_{icjtsp} = \alpha + \beta_1 NonSTEM\_F_{ictsp} + \beta_2 STEM\_F_{ictsp} + \delta_1 X_{ict} + \delta_2 \frac{\sum_{k \neq i} X_{kcjtsp}}{n_{cjtsp} - 1} + \phi_{cts} + \gamma_{jts} + \rho_i + \epsilon_{icjtsp} \quad (2)$$

where $NonSTEM\_F$ is an indicator variable equal to one if a student has a non-STEM first period class on the same schedule day as course c and $STEM\_F$ equals one if a student has a STEM first period class on that schedule day.[5] β_1 and β_2 measure the average effect of having a first period STEM class and first period non-STEM class on academic performance throughout the day, respectively. Estimates from the regression are shown in Columns (1) - (3) of Table 6. Each column shows a different specification, each adding additional fixed effects. Estimates show that having a STEM course first period negatively affects average achievement throughout the schedule day by 0.10 standard deviations. While the estimates for non-STEM first period courses are negative, they are not statistically different from zero. To determine whether the adverse effects of having a first period class vary by the time that first period begins, we interact the treatment variables, $NonSTEM\_F$ and $STEM\_F$ with indicator variables for whether there were early (7:00 a.m.), middle (7:30 a.m.), or late (7:50 a.m.) start times that year. Columns (4) - (6) of Table 6 show these estimates. In Column (6), we see that when including individual fixed effects, the negative first period effect is strongest for the earliest start time and comes through for both STEM and non-STEM courses.

We next want to know which class periods are most adversely affected by having had a first period class on that schedule day. To do this, we interact the treatment variables, $NonSTEM\_F$ and $STEM\_F$, with indicator variables for whether that course was during first period, 2^{nd}- 4^{th}period,

[5] STEM classes are classified as those in math, physics, chemistry, biology, engineering, and computer science. Non-STEM classes are those not in the STEM subjects. We do not limit these definitions to required courses.

or 5^{th}-7^{th} period. These estimates are shown in Columns (7) - (9) of Table 6. The negative effects of having a first period class are strongest on achievement in the first period class itself and are similar for STEM and non-STEM classes, both seeing a reduction in achievement of about 0.16 standard deviations. Having a first period STEM class also has a negative effect on performance on 2^{nd}- 4^{th}period course performance. However, the magnitude of this effect is smaller than for the first period class (0.11 standard deviations). The point estimates of having a non-STEM first period class on subsequent class performance are negative, but statistically insignificant. The negative effects of having a first period class dissipate by afternoon for both types of first period classes.

Table 7 explores differences from having a first period class for different subgroups. The regressions are estimates just as in Table 6, with each panel showing estimates from a different regression for each subgroup. There are two valuable patterns that emerge. First, low-ability students appear to be more adversely affected by having had a first period STEM class than high-ability students. Second, we observe differences between students in the top tercile of fitness scores (high-fitness) and those in the bottom tercile (low-fitness). The effects are statistically significant and much larger in magnitude for low-fitness students. Low-fitness students who have a first period course perform 0.25 standard deviations worse in that class, both for STEM and non-STEM, than students who do not have a first period class.

We next look at which classes are most adversely affected by having had a first period class. To do this, we interact the treatment variables, $NonSTEM\_F$ and $STEM\_F$, with indicator variables for whether that class was during first period, 2^{nd}- 4^{th}period, or 5^{th}-7^{th} period as well as indicator variables for whether the class was a STEM course or non-STEM course. For instance, if a student has a 3^{rd} period history class on the same day as a 1^{st} period math class, they will fall under the category of STEM 1st Per X 2nd-4th Per. Class X Non-STEM. This allows us to distinguish the heterogeneous effects of having a first period class on different times of the day as well as on different types of courses. We will be able to determine if STEM classes are more or less adversely affected by an early morning start and whether the effects on STEM classes differ across the day. These estimates are shown in Table 8. We focus on Column (3), which shows the estimates when including individual fixed effects. A few interesting patterns emerge. First, performance in afternoon classes, periods 5-7, remain unaffected by having had any type of first period class. Second, grades in morning STEM classes are negatively affected by having any type of first period class. Finally, while performance in non-STEM morning classes are not affected by having a first period non-STEM class, they *are* negatively affected by having a first period STEM class.

To better understand the magnitude of these effects and which part of the ability distribution is most affected by having a morning class, we consider three additional outcomes besides the student's normalized grade in a course. The first is their raw score– the percent of points earned in the course. The second is whether they "aced" the class by earning an A or A-. We also look at whether they "failed" the class by earning a D or F. We show the estimates in Tables 10, 11, and 12 in the appendix. While the effects on the students raw score seem moderate (students with a 1^{st} period STEM class score 1.3 percentage points lower in the course than those without a first period class), we observe effects both on the margin of acing and failing the course. Having a 1^{st} period STEM course reduces the likelihood of acing that class by about four percentage points and increases the likelihood of failing it by about five percentage points. Thus we see that the negative impacts of having a morning class aren't clustered only at one end of the grade distribution and that students of all levels are susceptible to the effects of early morning schedules.

4.3 Organizing the Day

We have gained some more insight on first period classes and their effects throughout the day, but we also need to understand how to best organize the rest of the day to maximize achievement. At USAFA, like at most high schools, students have different combinations of breaks, required courses, physical education, and elective courses. We exploit this random variation in course scheduling to determine the best ordering of classes.

An important policy question that arises from the start time debate is what classes, if any, we should be held in the morning. We are especially interested in the effect of having physical education (PE) in the morning compared to having an academic class, or no class at all. At USAFA, PE is a two period long class to allow students enough time to change their clothes and shower. Because of this, PE is only offered during first, third, and fifth periods. We next assess how a student's performance in courses differs depending on the course they just had. Each section of a class acts as it's own small pseudo-experiment where treatments are the different possible lead-ups. We'll refer to these as the lead-up scenarios. There are four possible lead-up scenarios: having a STEM class, a non-STEM class, no class, or PE. We estimate the following equation:

$$Grade_{icjtsp} = \alpha + \sum_{p=2}^{7} \sum_{l \in L} \beta_{pl}(Period = p) * (LeadUp = l) + \delta_1 X_{ict} + \delta_2 \frac{\sum_{k \neq i} X_{kcqt}}{n_{cqt} - 1} + \phi_{cts} + \gamma_{jts} + \epsilon_{icjts} \tag{3}$$

where L ={STEM class before, break before, or PE before}. Having a non-STEM class before is the omitted category. Because PE is a two-period long class, we can only estimate the effect of PE as a lead-up class for 3^{rd}, 5^{th}, and 7^{th} periods. We exclude individual fixed-effects from this specification to allow for more statistical precision in our estimates. We show the estimates graphically in Figure 3. The first panel of the figure shows estimates for all required courses. The second panel shows estimates for STEM courses and the third panel for non-STEM courses. The estimates show how performance in each period differs by lead-up relative to having a non-STEM class before. Overall, students perform better in their classes after having had a break or having had PE, with the exception of 7^{th} period STEM courses. Importantly, students who had PE before their 3^{rd} period class do better than with any other lead-up scenario. While having a STEM class as a lead-up has negative effects for morning classes, by late afternoon, the effects are positive, especially for non-STEM courses.

Table 9 show differences in lead-up course effects across subgroups. While the effects of lead-up classes are fairly similar across genders, some differences emerge by race. Minority students (shown in Column (4)) benefit more from having PE before their 3^{rd} period class and having a break during 1^{st} period than white students do, while white students benefit more from having a break during 5^{th} period. Some differences across student ability also emerge. Columns (5) and (6) show estimates for low- and high-ability students, respectively. Low-ability students benefit greatly from having PE before their 3^{rd} period class, while the effect for high-ability students is small and statistically insignificant. Low-ability students are also more adversely affected by having PE before their 7^{th} period class.

We expand this analysis by looking at how the *two* courses preceding a class impacts achievement. This is especially important to do since both chemistry and PE are two-period long classes and comparisons to regular length classes may be unfair since students may be additionally fatigued from the longer classes. There are five possible two-period lead-up scenarios that we explore: having two academic classes[6], having two free periods, having PE, having a free period followed by an academic class, and having an academic class followed by a free period. We adjust Equation 3 accordingly and estimate the following equation:

$$Grade_{icjtsp} = \alpha + \sum_{p=3}^{7} \sum_{l \in L2} \beta_{pl} (Period = p) * (LeadUp2 = l) + \delta_1 X_{ict} + \delta_2 \frac{\sum_{k \neq i} X_{kcjtsp}}{n_{cjtsp} - 1} + \phi_{cts} + \gamma_{jts} + \epsilon_{icjtsp} \tag{4}$$

where L2 ={PE before, free period-free period, free period-class, class-free period}. Having two academic classes before is the omitted category. The two period lead-up analysis begins at 3^{rd} period. Once again, because PE can be only offered during certain periods, PE is a lead-up class only for 3^{rd}, 5^{th}, and 7^{th} periods. Estimates are shown graphically in Figure 4. Again, we observe

[6]Since Chemistry is a two-period long class, it is classified as being equivalent to two academic classes.

benefits of having PE before a class, especially for STEM classes. Specifically, students who have PE before their 3^{rd} period class perform about 0.13 standard deviations better than those who have two academic courses in those periods. The exception is for 7^{th} period STEM classes in which students perform worse if they had PE or a two period break than if they had two consecutive classes. The negative effect of having two period off before 7^{th} period also appears for non-STEM classes. This suggests that while breaks are good early in the school day, they can actually be harmful at the end when students are either switching their focus away from their classes or entering their afternoon slump in wakefulness (National Sleep Foundation 2014). In almost all instances, having a combination of a class and a break in a two-period interval perform better in their class than if they had just had two consecutive classes.

5 Discussion and Conclusions

Findings from this study shed light on a number elements within a student's daily schedule that can affect their academic achievement. Two similar students taking the same classes with the same teachers, but with different schedules could be expected to get grades as different as two-tenths of a standard deviation (approximately a B- to a B+ difference) in certain scenarios. With each finding, we discuss administrative action that could be taken to better optimize the school schedule. Schools face multitudes of different constraints when it comes to scheduling, but many of our suggestions are quite broad and could be achieved using standard scheduling software. STEM classes are more adversely affected by being scheduled in the morning than non-STEM classes. This could be due to more of non-STEM work (e.g. writing assignments) being done outside of the classroom or greater amounts of new in-class material in STEM classes. These results are consistent with Goldstein et al. (2007) who find that for adolescents, scores on intelligence tests are significantly lower during the early morning hours. At USAFA, all students enrolled in a course in a given semester take the exams during a common testing period so the effects that we measure are not coming from students doing poorly on exams in the morning relative to their counterparts who take the exams during the afternoon. Subgroup analysis shows that low-ability students are more adversely affected by early morning STEM classes. We are unable to establish why this is the case; however, one hypothesis is that this may be because high-ability students can overcome what they miss in the classroom by teaching themselves the material. In a best-case scenario, fewer STEM classes overall would be scheduled in the early morning, but perhaps a more reasonable policy to enact would be putting STEM classes for the more advanced students early in the morning.

Our findings regarding physical education further support the idea of shifting STEM classes away from the morning. We find positive effects, which are especially strong for low-ability students, of having P.E. in the morning. This is in line with Lambourne & Tomporowski (2010), Tomporowski et al. (2011)'s review of studies that have explored the effects of both overall physical fitness and acute exercise. Once again this suggests shifting away (especially for lower-ability students) from morning STEM classes and towards morning physical education to wake students up. Some of our highest point-estimates are of the negative impact of having P.E. just before the last period of the day. We interpret this as a sort of mental "checking-out" whereby it is hard for students to reengage their minds for a final class late in the afternoon. Depending on the facilities at a school, P.E. could be a class where more students could be active in the morning by increasing morning class sizes without requiring more instructors or sections offered.

Academic fatigue, measured by both total and consecutive classes seems to adversely affect performance. Spacing out free periods can help reduce fatigue. Now, it's hardly reasonable for us to advocate later start times (or not having a first period class) in addition to then having multiple spaced-out free periods during the day. High school students are often taking six, sometimes seven classes. However, one takeaway is that free periods during the last period of the day are effectively a waste. They don't help with start time or fatigue. Sports commonly dictate that students have their last period free because of scheduling conflicts, but our evidence suggests that giving students their last period free should be avoided whenever possible.

The variation in start time across our USAFA cohorts falls in line with the literature that suggests 7:00am is of peak importance for adolescent sleep. The one cohort that had classes starting as 7:00am had stronger morning effects across the board than those in the 7:30am and 7:50am cohorts. Differences between the 7:30am and 7:50am cohorts were less statistically significant, despite larger samples, and also generally closer to each other than to the 7:00am cohort. This suggests that later start times are better, but also that the improvement is non-linear and will fade out after a point. We can't suggest a universal best start time. In our college setting, students don't have long commutes or so-called zero-period classes (ones that occur before the normal academic school day begins) to deal with. A 7:30am start time at USAFA may be equivalent to an 8:45am start time at one high school or a 9:30am start time at another depending on the scheduling and commuting patterns.

While most of our discussion has been around what administrators or schedulers could do to better optimize the school schedule, there is also the potential for student optimization. In a setting where a student has some control over which classes they take, they may be able to do themselves a favor by forcing themselves to be active in the morning, spacing out their breaks and not taking too many consecutive classes.

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6 Figures

Figure 1: Randomness of Student Class Assignment Across Periods, Cohorts, and Schedule Days

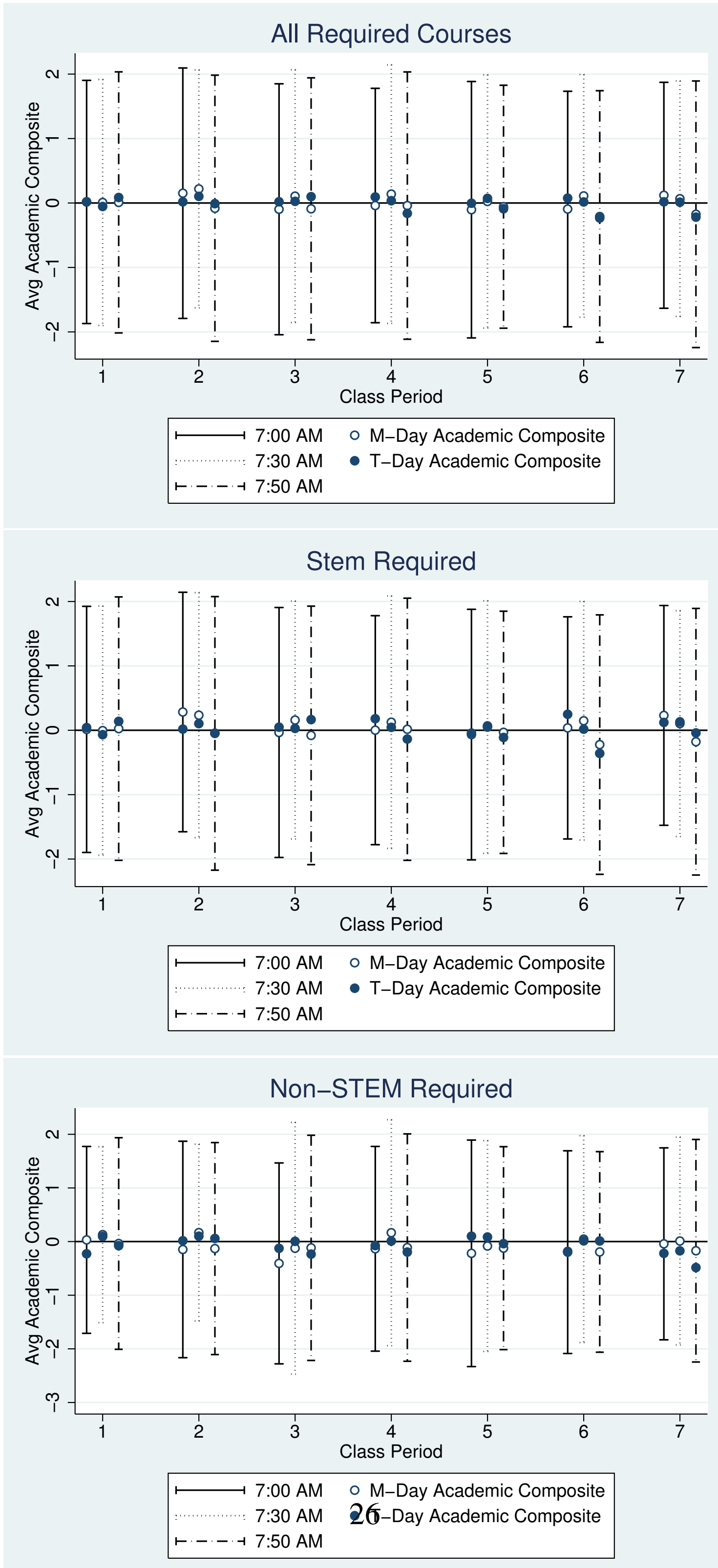


Figure 2: Mean Performance in Required Courses Across Periods

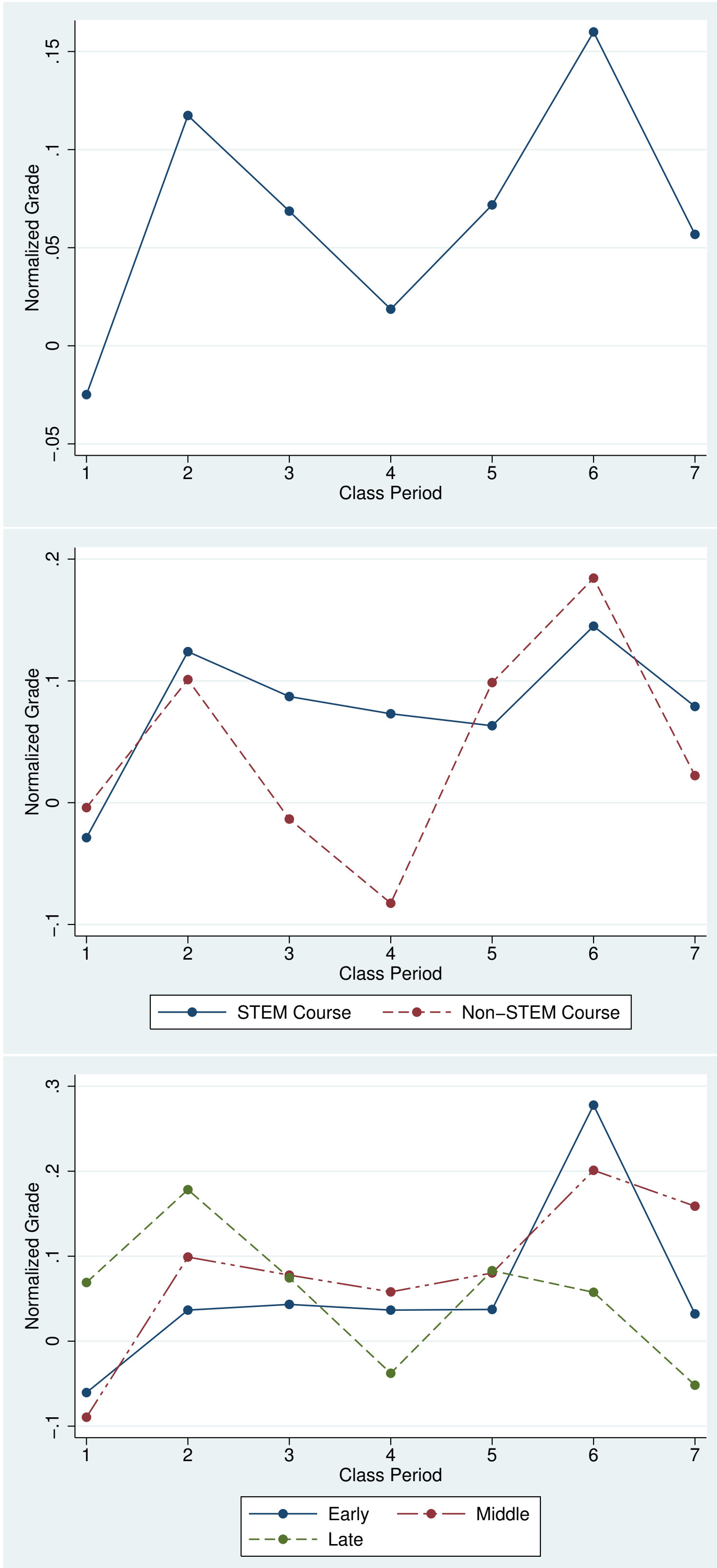


Figure 3: Impact of Course-Before on Current Course Performance

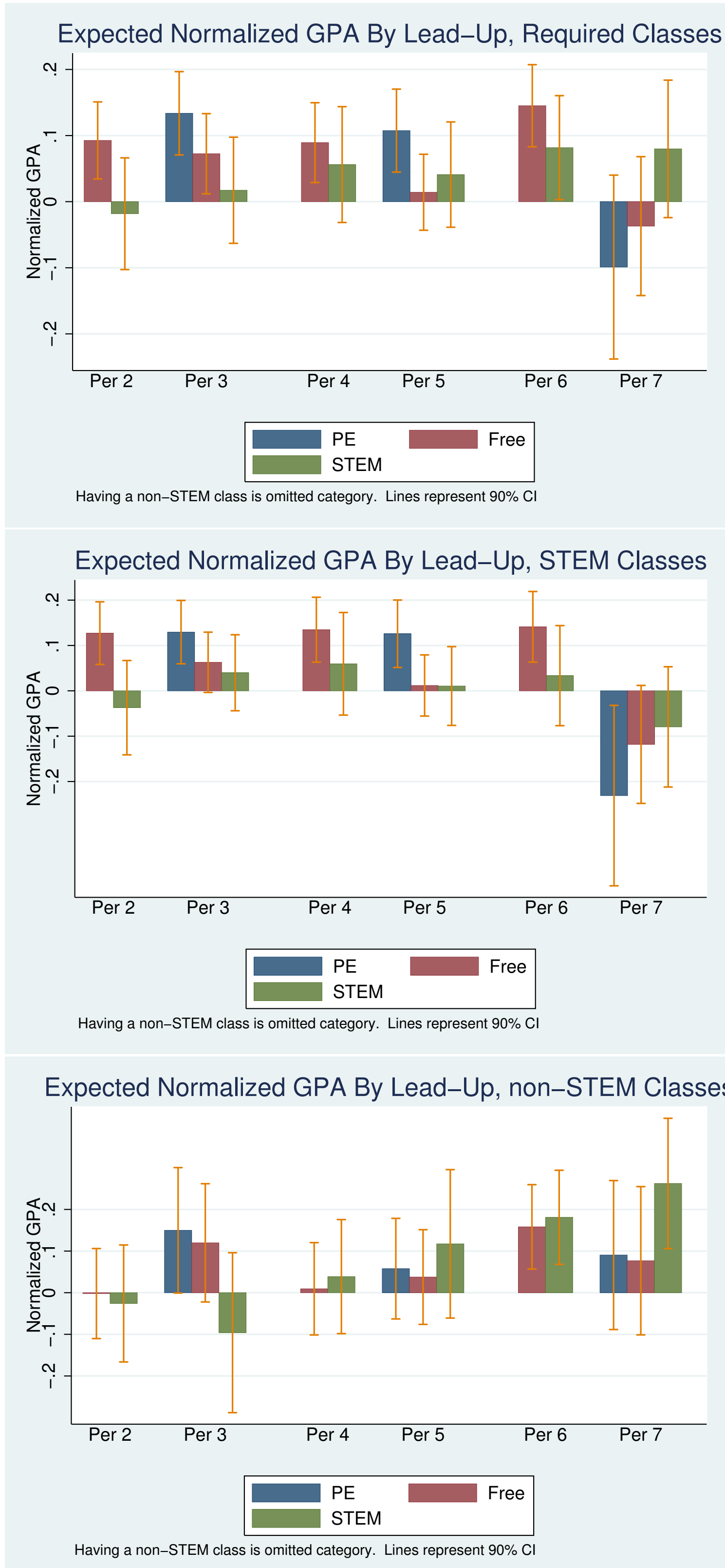
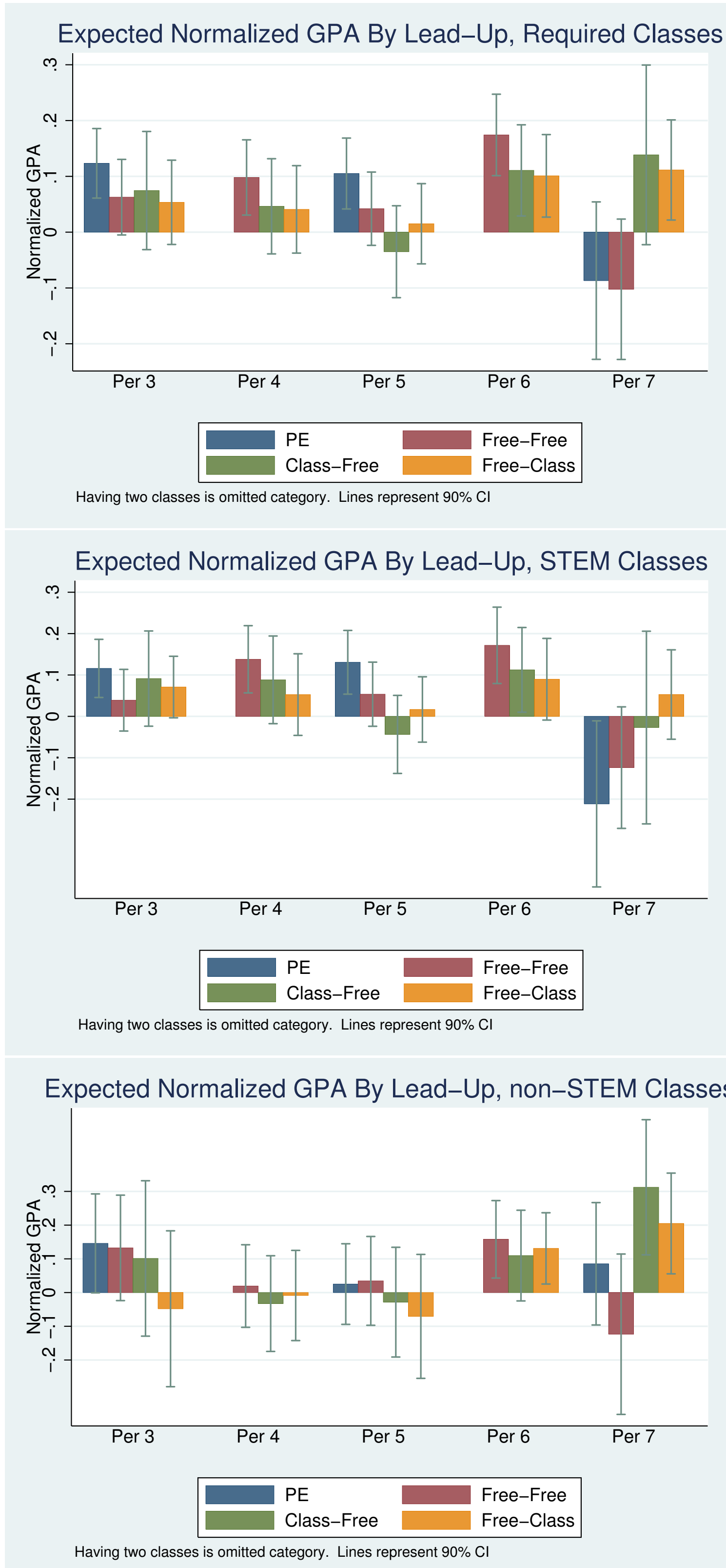


Figure 4: Impact of Course-Before on Current Course Performance



7 Tables

Table 2: Summary Statistics-Students

	(1) Required	(2) STEM	(3) 7:00 am	(4) 7:30 am	(5) 7:50 am
Prep School	0.161	0.169	0.114	0.182	0.164
Black	0.0342	0.0345	0.0285	0.0351	0.0365
Hispanic	0.0805	0.0790	0.0824	0.0661	0.0965
Asian	0.0962	0.0979	0.108	0.0872	0.100
Female	0.188	0.189	0.185	0.171	0.209
Fitness Level	4.075	4.102	3.649	4.549	3.764
Academic Comp.	13.20	13.25	13.20	13.31	13.06
Leadership Score	17.37	17.38	17.38	17.39	17.35
Sat Verbal	6.452	6.460	6.420	6.506	6.407
Sat Math	6.697	6.706	6.699	6.754	6.627
Credits/Day	8.314	8.242	8.304	8.282	8.359
Raw Score	79.27	77.99	77.62	79.00	80.57
Grade	0.0643	0.0688	0.0436	0.0765	0.0621
Observations	16168	11885	3472	6916	5780

Table 3: Summary Statistics-Classes

	(1) All Cohorts	(2) 7:00 AM	(3) 7:30 AM	(4) 7:50 AM
Number of Students	4816	987	1933	1896
Number of Sections	1056	224	445	387
Number of Courses	32	7	14	11
Avg Section Size	16.56	16.72	17.03	15.89
Period 1 Avg	-0.0249	-0.0605	-0.0895	0.0690
Period 2 Avg	0.117	0.0365	0.0990	0.178
Period 3 Avg	0.0686	0.0432	0.0777	0.0745
Period 4 Avg	0.0187	0.0366	0.0580	-0.0378
Period 5 Avg	0.0718	0.0373	0.0803	0.0830
Period 6 Avg	0.160	0.278	0.201	0.0575
Period 7 Avg	0.0568	0.0321	0.159	-0.0518

Table 4: Class Period Effects

	(1)	(2)	(3)	(4)	(5)	(6)
	Grade	Grade	Grade	Grade	Grade	Grade
2nd Period	0.110***	0.0738**	0.118***	0.132***	0.0998***	0.143***
	(0.0273)	(0.0343)	(0.0360)	(0.0280)	(0.0350)	(0.0370)
3rd Period	0.0722***	0.0605*	0.102***	0.140***	0.127***	0.157***
	(0.0231)	(0.0309)	(0.0315)	(0.0276)	(0.0346)	(0.0363)
4th Period	0.0660**	0.0651	0.149***	0.146***	0.140***	0.219***
	(0.0288)	(0.0397)	(0.0418)	(0.0333)	(0.0433)	(0.0466)
5th Period	0.0223	0.0584	0.129***	0.112**	0.132**	0.220***
	(0.0324)	(0.0478)	(0.0491)	(0.0434)	(0.0559)	(0.0617)
6th Period	0.111***	0.179***	0.245***	0.223***	0.276***	0.357***
	(0.0395)	(0.0570)	(0.0604)	(0.0505)	(0.0653)	(0.0739)
7th Period	0.0536	0.115*	0.195***	0.197***	0.244***	0.333***
	(0.0421)	(0.0625)	(0.0685)	(0.0562)	(0.0731)	(0.0857)
Credits/Day	-0.00547	-0.00503	-0.0102***	0.00245	0.00269	-0.00392
	(0.00347)	(0.00347)	(0.00343)	(0.00377)	(0.00383)	(0.00385)
Consecutive Classes				-0.0243*	-0.0341**	-0.00931
				(0.0147)	(0.0148)	(0.0157)
Cumulative Classes				-0.0451***	-0.0370***	-0.0387**
				(0.0132)	(0.0136)	(0.0159)
Teacher FEs	No	Yes	Yes	No	Yes	Yes
Indv FEs	No	No	Yes	No	No	Yes
N	16119	16119	16119	16119	16119	16119
R-Square	0.190	0.249	0.717	0.191	0.251	0.717

Standard errors in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < .01$

Table 5: Class Period Effect for Different Subgroups

	(1) Early	(2) Middle	(3) Late	(4) STEM	(5) Non-STEM	(6) Males	(7) Females	(8) Minority	(9) High Ability	(10) Low Ability
2nd Period	0.139*	0.122*	0.158***	0.132***	0.115	0.150***	0.140	0.213**	0.124*	0.172**
	(0.0738)	(0.0710)	(0.0582)	(0.0485)	(0.349)	(0.0412)	(0.0861)	(0.0894)	(0.0631)	(0.0764)
3rd Period	0.236***	0.191***	0.113*	0.167***	0.0387	0.157***	0.180**	0.127	0.110*	0.221***
	(0.0783)	(0.0593)	(0.0659)	(0.0425)	(0.533)	(0.0417)	(0.0821)	(0.0891)	(0.0623)	(0.0722)
4th Period	0.389***	0.191**	0.188**	0.206***	0.119	0.222***	0.221**	0.222**	0.220***	0.248***
	(0.0971)	(0.0774)	(0.0857)	(0.0574)	(0.573)	(0.0535)	(0.112)	(0.110)	(0.0751)	(0.0949)
5th Period	0.268*	0.296***	0.0823	0.218***	0.122	0.238***	0.147	0.0526	0.286***	0.214*
	(0.140)	(0.0922)	(0.117)	(0.0734)	(0.893)	(0.0707)	(0.144)	(0.142)	(0.103)	(0.123)
6th Period	0.487***	0.429***	0.189	0.355***	0.388	0.390***	0.166	0.0958	0.393***	0.362**
	(0.165)	(0.112)	(0.143)	(0.0886)	(1.006)	(0.0840)	(0.185)	(0.169)	(0.122)	(0.150)
7th Period	0.430**	0.377***	0.213	0.296***	0.436	0.377***	0.236	0.246	0.348**	0.319*
	(0.185)	(0.128)	(0.169)	(0.103)	(1.112)	(0.0980)	(0.207)	(0.198)	(0.138)	(0.181)
Consecutive Classes	0.0238	-0.00351	-0.0362	-0.00273	-0.0518	-0.00979	-0.0621	-0.0363	0.0247	-0.0270
	(0.0309)	(0.0241)	(0.0277)	(0.0184)	(0.162)	(0.0174)	(0.0409)	(0.0368)	(0.0253)	(0.0332)
Cumulative Classes	-0.0696**	-0.0522**	-0.0152	-0.0527***	-0.0268	-0.0433**	-0.0138	-0.0227	-0.0583**	-0.0270
	(0.0330)	(0.0232)	(0.0292)	(0.0191)	(0.284)	(0.0179)	(0.0415)	(0.0383)	(0.0278)	(0.0319)
Teacher FEs	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Indv FEs	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N	3445	6894	5780	11851	4268	13088	3031	3397	5373	5376
R2	0.741	0.700	0.726	0.818	0.959	0.724	0.775	0.764	0.739	0.721

Standard errors in parentheses
* $p < 0.10$, ** $p < 0.05$, *** $p < .01$

Table 6: Effect of First Period Across the Day

	(1) Grade	(2) Grade	(3) Grade	(4) Grade	(5) Grade	(6) Grade	(7) Grade	(8) Grade	(9) Grade
Non-STEM 1st Period	-0.0145	-0.00996	-0.0384						
	(0.0213)	(0.0217)	(0.0244)						
STEM 1st Period	-0.0739***	-0.0407	-0.100***						
	(0.0231)	(0.0251)	(0.0306)						
7am Non-STEM 1st Period				-0.0202	-0.0302	-0.112**			
				(0.0481)	(0.0478)	(0.0509)			
7am STEM 1st Period				-0.138***	-0.110**	-0.188***			
				(0.0465)	(0.0483)	(0.0584)			
7:30am Non-STEM 1st Period				-0.0132	-0.0100	0.0100			
				(0.0316)	(0.0324)	(0.0386)			
7:30am STEM 1st Period				-0.0731**	-0.0211	-0.0659			
				(0.0337)	(0.0364)	(0.0460)			
7:50am Non-STEM 1st Period				-0.00481	0.00485	-0.0494			
				(0.0329)	(0.0329)	(0.0356)			
7:50am STEM 1st Period				-0.0251	-0.0162	-0.0742			
				(0.0389)	(0.0408)	(0.0543)			
Non-STEM 1st Per. X 1st Per. Class							-0.121**	-0.110*	-0.162**
							(0.0525)	(0.0608)	(0.0684)
STEM 1st Per. X 1st Per. Class							-0.132***	-0.107***	-0.172***
							(0.0274)	(0.0354)	(0.0384)
Non-STEM 1st Per. X 2nd-4th Per. Class							0.000483	-0.00692	-0.0389
							(0.0265)	(0.0276)	(0.0302)
STEM 1st Per. X 2nd-4th Per. Class							-0.0724**	-0.0571*	-0.113***
							(0.0327)	(0.0343)	(0.0401)
Non-STEM 1st Per. X 5th-7th Per. Class							0.0129	0.0170	-0.000853
							(0.0276)	(0.0274)	(0.0305)
STEM 1st Per. X 5th-7th Per. Class							0.0299	0.0502	0.00143
							(0.0375)	(0.0374)	(0.0438)
Teacher FEs	No	Yes	Yes	No	Yes	Yes	No	Yes	Yes
Indv FEs	No	No	Yes	No	No	Yes	No	No	Yes
N	16119	16119	16119	16119	16119	16119	16119	16119	16119
R2	0.190	0.249	0.716	0.190	0.250	0.716	0.191	0.250	0.717

Standard errors in parentheses

* p<0.10, ** p<0.05, *** p<0.01

Table 7: Effect of First Period Across the Day for Different Subgroups

	(1) Male	(2) Female	(3) Minority	(4) High-Ability	(5) Low-Ability	(6) High-Fitness	(7) Low-Fitness
Non-STEM 1st Period	-0.0422	-0.0327	-0.0399	-0.0163	-0.0313	-0.0507	-0.0502
	(0.0271)	(0.0640)	(0.0607)	(0.0426)	(0.0479)	(0.0461)	(0.0447)
STEM 1st Period	-0.101***	-0.0592	-0.0596	-0.0295	-0.120*	-0.0318	-0.176***
	(0.0348)	(0.0722)	(0.0724)	(0.0476)	(0.0658)	(0.0563)	(0.0568)
7am Non-STEM 1st Period	-0.102*	-0.239*	-0.0258	-0.0647	-0.130	-0.0260	-0.151*
	(0.0567)	(0.142)	(0.117)	(0.0809)	(0.105)	(0.150)	(0.0777)
7am STEM 1st Period	-0.171**	-0.245*	-0.110	-0.0410	-0.281**	-0.0197	-0.235***
	(0.0669)	(0.139)	(0.132)	(0.0871)	(0.113)	(0.143)	(0.0884)
7:30am Non-STEM 1st Period	0.0102	-0.0136	-0.0153	-0.0405	0.128*	-0.0258	0.148
	(0.0423)	(0.104)	(0.108)	(0.0672)	(0.0755)	(0.0544)	(0.0955)
7:30am STEM 1st Period	-0.0661	-0.0118	-0.0813	-0.0496	0.00655	-0.00532	-0.0956
	(0.0521)	(0.113)	(0.122)	(0.0723)	(0.0968)	(0.0649)	(0.130)
7:50am Non-STEM 1st Period	-0.0660	0.0340	-0.0663	0.0395	-0.109	-0.150	-0.0598
	(0.0406)	(0.0866)	(0.0883)	(0.0643)	(0.0702)	(0.0931)	(0.0592)
7:50am STEM 1st Period	-0.0920	-0.000271	-0.000852	0.00795	-0.108	-0.144	-0.150*
	(0.0631)	(0.114)	(0.116)	(0.0796)	(0.132)	(0.152)	(0.0840)
Non-STEM 1st Per. X 1st Per. Class	-0.125	-0.299*	-0.265	-0.126	-0.191	-0.193	-0.252**
	(0.0765)	(0.162)	(0.188)	(0.119)	(0.143)	(0.137)	(0.121)
STEM 1st Per. X 1st Per. Class	-0.182***	-0.129	-0.145	-0.0850	-0.238***	-0.105	-0.250***
	(0.0439)	(0.0862)	(0.0919)	(0.0652)	(0.0785)	(0.0686)	(0.0715)
Non-STEM 1st Per. X 2nd-4th Per. Class	-0.0458	-0.00774	-0.0131	0.00879	-0.0592	-0.0393	-0.0552
	(0.0337)	(0.0790)	(0.0720)	(0.0506)	(0.0614)	(0.0560)	(0.0604)
STEM 1st Per. X 2nd-4th Per. Class	-0.116**	-0.0292	-0.0472	0.0119	-0.154*	-0.0388	-0.174**
	(0.0462)	(0.0969)	(0.0955)	(0.0585)	(0.0881)	(0.0731)	(0.0784)
Non-STEM 1st Per. X 5th-7th Per. Class	-0.00800	0.0157	-0.0111	-0.0121	0.0469	-0.0218	0.000715
	(0.0331)	(0.0851)	(0.0772)	(0.0558)	(0.0583)	(0.0563)	(0.0557)
STEM 1st Per. X 5th-7th Per. Class	0.000913	0.0619	0.0561	-0.00239	0.0595	0.0694	-0.0861
	(0.0485)	(0.110)	(0.112)	(0.0722)	(0.0884)	(0.0837)	(0.0807)
Teacher FEs	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Indv FEs	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N	13088	3031	3397	5373	5376	5270	5487
R2	0.723	0.774	0.763	0.738	0.721	0.744	0.739

Standard errors in parentheses

* p<0.10, ** p<0.05, *** p<0.01

Table 8: Effect of First Period Across the Day for Different Courses

	(1) Grade	(2) Grade	(3) Grade
Non-STEM 1st Per. X 1st Per. Class	-0.0941*	-0.0898	-0.156**
	(0.0545)	(0.0637)	(0.0711)
STEM 1st Per. X 1st Per. Class	-0.141***	-0.114***	-0.176***
	(0.0277)	(0.0357)	(0.0385)
Non-STEM 1st Per. X 2nd-4th Per. Class X Non-STEM	0.0810	0.0765	0.0633
	(0.0510)	(0.0528)	(0.0614)
Non-STEM 1st Per. X 2nd-4th Per. Class X STEM	-0.0264	-0.0337	-0.0693**
	(0.0284)	(0.0297)	(0.0314)
STEM 1st Per. X 2nd-4th Per. Class X Non-STEM	-0.0644	-0.0427	-0.150**
	(0.0535)	(0.0555)	(0.0678)
STEM 1st Per. X 2nd-4th Per. Class X STEM	-0.0731**	-0.0613	-0.0919**
	(0.0360)	(0.0382)	(0.0412)
Non-STEM 1st Per. X 5th-7th Per. Class X Non-STEM	0.0830*	0.0547	0.0507
	(0.0454)	(0.0451)	(0.0533)
Non-STEM 1st Per. X 5th-7th Per. Class X STEM	-0.0167	0.000908	-0.0245
	(0.0312)	(0.0312)	(0.0338)
STEM 1st Per. X 5th-7th Per. Class X Non-STEM	0.0723	0.0527	-0.0137
	(0.0519)	(0.0522)	(0.0662)
STEM 1st Per. X 5th-7th Per. Class X STEM	0.00819	0.0507	0.0122
	(0.0450)	(0.0449)	(0.0485)
Teacher FEs	No	Yes	Yes
Indv FEs	No	No	Yes
N	16119	16119	16119
R2	0.191	0.250	0.717

Standard errors in parentheses
* p<0.10, ** p<0.05, *** p<0.01

Table 9: Effect of Period Before on Performance by Subgroup

	(1) Male	(2) Female	(3) White	(4) Minority	(5) Low Ability	(6) High Ability
Per. 3 PE Before	0.131***	0.172*	0.122***	0.240***	0.174*	0.0551
	(0.0435)	(0.0940)	(0.0437)	(0.0909)	(0.0943)	(0.0706)
Per. 5 PE Before	0.0790*	0.193*	0.138***	0.0108	0.0800	0.0977
	(0.0417)	(0.110)	(0.0429)	(0.0880)	(0.0841)	(0.0738)
Per. 7 PE Before	-0.121	-0.0853	-0.114	0.0583	-0.353**	-0.107
	(0.0922)	(0.235)	(0.0920)	(0.244)	(0.158)	(0.185)
Per. 2 Free Before	0.0915**	0.0814	0.0747*	0.177**	0.118	0.0845
	(0.0394)	(0.0890)	(0.0409)	(0.0819)	(0.0853)	(0.0644)
Per. 3 Free Before	0.0740*	0.0799	0.0868**	0.106	0.0933	-0.0460
	(0.0414)	(0.0870)	(0.0424)	(0.0862)	(0.0815)	(0.0684)
Per. 4 Free Before	0.0456	0.206**	0.0706*	0.166**	0.0351	0.116*
	(0.0414)	(0.0864)	(0.0422)	(0.0825)	(0.0864)	(0.0653)
Per. 5 Free Before	0.00905	0.0625	0.0359	-0.0561	-0.0492	-0.0349
	(0.0396)	(0.0837)	(0.0396)	(0.0793)	(0.0745)	(0.0641)
Per. 6 Free Before	0.114***	0.263***	0.195***	0.0309	0.0972	0.0506
	(0.0418)	(0.0965)	(0.0428)	(0.0913)	(0.0818)	(0.0724)
Per. 7 Free Before	-0.0584	0.159	-0.0619	0.0764	0.124	-0.177
	(0.0712)	(0.159)	(0.0754)	(0.125)	(0.146)	(0.109)
Per. 2 STEM Before	-0.00874	0.0272	-0.0303	0.0532	-0.0352	0.0685
	(0.0603)	(0.101)	(0.0588)	(0.105)	(0.143)	(0.0794)
Per. 3 STEM Before	0.0112	0.0286	-0.0361	0.124	0.0846	0.0322
	(0.0553)	(0.109)	(0.0556)	(0.0985)	(0.113)	(0.0856)
Per. 4 STEM Before	0.0673	0.0425	0.0353	0.104	0.245*	-0.0496
	(0.0599)	(0.124)	(0.0594)	(0.135)	(0.129)	(0.0916)
Per. 5 STEM Before	0.0378	0.0355	0.0518	0.0467	-0.0540	0.0303
	(0.0521)	(0.143)	(0.0533)	(0.124)	(0.124)	(0.0955)
Per. 6 STEM Before	0.0777	0.111	0.125**	-0.0715	0.0430	-0.00301
	(0.0505)	(0.205)	(0.0531)	(0.119)	(0.115)	(0.100)
Per. 7 STEM Before	0.134**	0.0229	0.114	0.0416	0.0909	0.0447
	(0.0678)	(0.175)	(0.0728)	(0.144)	(0.138)	(0.120)
Teacher FEs	Yes	Yes	Yes	Yes	Yes	Yes
Indv FEs	No	No	No	No	No	No
N	13088	3031	12722	3397	3946	4162
R2	0.255	0.373	0.246	0.375	0.279	0.344

Standard errors in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < .01$

Table 10: Effect of First Period Across the Day on Raw Score

	Raw Score	Raw Score	Raw Score	Raw Score	Raw Score	Raw Score	Raw Score	Raw Score	Raw Score
Non-STEM 1st Period	-0.0851	-0.0713	-0.190						
	(0.177)	(0.183)	(0.211)						
STEM 1st Period	-0.551***	-0.394*	-0.736***						
	(0.196)	(0.216)	(0.261)						
7am Non-STEM 1st Period				-0.181	-0.262	-0.925**			
				(0.405)	(0.405)	(0.456)			
7am STEM 1st Period				-0.976**	-0.942**	-1.519***			
				(0.392)	(0.415)	(0.503)			
7:30am Non-STEM 1st Period				-0.102	-0.0687	0.320			
				(0.273)	(0.282)	(0.338)			
7:30am STEM 1st Period				-0.514*	-0.242	-0.390			
				(0.294)	(0.322)	(0.402)			
7:50am Non-STEM 1st Period				0.0286	0.0573	-0.337			
				(0.263)	(0.265)	(0.293)			
7:50am STEM 1st Period				-0.266	-0.194	-0.555			
				(0.322)	(0.340)	(0.442)			
Non-STEM 1st Per. X 1st Per. Class							-0.898**	-0.857*	-1.224**
							(0.403)	(0.472)	(0.578)
STEM 1st Per. X 1st Per. Class							-0.962***	-0.985***	-1.312***
							(0.241)	(0.325)	(0.346)
Non-STEM 1st Per. X 2nd-4th Per. Class							-0.0185	-0.0582	-0.163
							(0.223)	(0.236)	(0.262)
STEM 1st Per. X 2nd-4th Per. Class							-0.588**	-0.473	-0.791**
							(0.272)	(0.291)	(0.340)
Non-STEM 1st Per. X 5th-7th Per. Class							0.162	0.162	0.0882
							(0.230)	(0.230)	(0.260)
STEM 1st Per. X 5th-7th Per. Class							0.221	0.321	0.0401
							(0.310)	(0.309)	(0.365)
Observations	16119	16119	16119	16119	16119	16119	16119	16119	16119

Standard errors in parentheses
* p¡0.10, ** p¡0.05, *** p¡0.01

Table 11: Effect of First Period Across the Day on Likelihood of Earning an A or A- in the Class

	Ace	Ace	Ace	Ace	Ace	Ace	Ace	Ace	Ace
have_nonstem1_mtday	-0.00865	-0.00727	-0.0141						
	(0.00871)	(0.00898)	(0.0126)						
have_stem1_mtday	-0.0336***	-0.0190*	-0.0294*						
	(0.00950)	(0.0103)	(0.0154)						
p1nonstemday_early				-0.0166	-0.0304*	-0.0397*			
				(0.0178)	(0.0180)	(0.0241)			
p1stemday_early				-0.0466***	-0.0381**	-0.0616**			
				(0.0177)	(0.0184)	(0.0261)			
p1nonstemday_middle				-0.00922	-0.00351	-0.00329			
				(0.0136)	(0.0139)	(0.0207)			
p1stemday_middle				-0.0324**	-0.00891	-0.0141			
				(0.0143)	(0.0155)	(0.0240)			
p1nonstemday_late				-0.00282	0.000623	-0.0117			
				(0.0132)	(0.0136)	(0.0185)			
p1stemday_late				-0.0249	-0.0175	-0.0245			
				(0.0156)	(0.0166)	(0.0259)			
p1nonstemday_p1class							-0.0221	-0.0298	-0.0435
							(0.0220)	(0.0264)	(0.0349)
p1stemday_p1class							-0.0465***	-0.0290*	-0.0396**
							(0.0115)	(0.0150)	(0.0195)
p1nonstemday_p234class							-0.0145	-0.0139	-0.0245
							(0.0111)	(0.0118)	(0.0158)
p1stemday_p234class							-0.0359***	-0.0261*	-0.0323*
							(0.0137)	(0.0144)	(0.0191)
p1nonstemday_p567class							0.00393	0.00419	0.000547
							(0.0121)	(0.0120)	(0.0160)
p1stemday_p567class							-0.0120	-0.00351	-0.0221
							(0.0166)	(0.0164)	(0.0229)
Observations	16119	16119	16119	16119	16119	16119	16119	16119	16119

Standard errors in parentheses
* p¡0.10, ** p¡0.05, *** p¡0.01

Table 12: Effect of First Period Across the Day on the Likelihood of Earning a D or F in the Class

	Failed	Failed	Failed	Failed	Failed	Failed	Failed	Failed	Failed
have_nonstem1_mtday	-0.000353	0.000388	-0.00315						
	(0.00554)	(0.00589)	(0.00799)						
have_stem1_mtday	0.0104*	0.0100	0.0184*						
	(0.00616)	(0.00705)	(0.0102)						
p1nonstemday_early				-0.00651	-0.00871	0.00498			
				(0.0136)	(0.0139)	(0.0187)			
p1stemday_early				0.0165	0.0175	0.0422**			
				(0.0133)	(0.0146)	(0.0210)			
p1nonstemday_middle				0.00431	0.00542	-0.0123			
				(0.00835)	(0.00879)	(0.0125)			
p1stemday_middle				0.00951	0.00907	0.0103			
				(0.00928)	(0.0103)	(0.0157)			
p1nonstemday_late				-0.00308	-0.00141	0.000724			
				(0.00794)	(0.00840)	(0.0109)			
p1stemday_late				0.00668	0.00591	0.00953			
				(0.00940)	(0.0103)	(0.0151)			
p1nonstemday_p1class							0.0147	0.00907	0.0150
							(0.0114)	(0.0141)	(0.0195)
p1stemday_p1class							0.0300***	0.0404***	0.0492***
							(0.00867)	(0.0125)	(0.0156)
p1nonstemday_p234class							0.00119	0.00363	-0.00293
							(0.00761)	(0.00824)	(0.0107)
p1stemday_p234class							0.00374	0.00438	0.0153
							(0.00862)	(0.00933)	(0.0132)
p1nonstemday_p567class							-0.0109	-0.00962	-0.0139
							(0.00727)	(0.00754)	(0.00979)
p1stemday_p567class							-0.0144	-0.0123	-0.0128
							(0.00937)	(0.00963)	(0.0133)
Observations	16119	16119	16119	16119	16119	16119	16119	16119	16119

Standard errors in parentheses
* p¡0.10, ** p¡0.05, *** p¡0.01