RESEARCH REPORT

The Effect of Advanced Placement Computer Science Course Taking on College Enrollment

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ABSTRACT

This study examines the effects of Advanced Placement Computer Science course taking on students' academic careers. Two large school districts in the United States (89 high schools and 59,592 graduates over two years) partnered with Code.org to pilot and implement a new computer science AP course called AP Computer Science: Principles to complement existing computer science offerings. This study provides estimates of the impact of AP Computer Science course taking on students' college enrollment, relative to students not participating in the program from the same schools, controlling for student academic achievement and background characteristics. We find that taking AP computer science courses has a positive and significant effect on increasing the likelihood of enrolling in college, despite the fact that very few students in either district took an AP Computer Science course in high school. However, we note that the two Advanced Placement courses predicted enrollment differently between the two districts. In one district, participation in Computer Science A was shown to relate to greater likelihood of college enrollment. In the other district, it was Computer Science Principles that showed enhanced college enrollment. Taken together, both courses in the combined sample successfully increased college enrollment by 24% to 34%. We also find that the impact of Computer Science A is greater for Hispanic and African-American students.

INTRODUCTION

This study provides direct evidence of the impact of an important initiative to improve student learning, reduce the digital divide, and enhance opportunities for all students. This initiative took place in two school districts on opposite sides of the country, District A on the East Coast and District B on the West Coast of the United States. Both are large urban districts serving diverse communities. In 2013, District A became the first school district in the nation selected by Code.org to participate in a unique partnership designed to increase access to computer science courses, curriculum and resources in schools. The program included a full curriculum, tools, and professional development for District A teachers. Since 2014, for the period in question, approximately 75 teachers in District A have undergone training for the AP CSP course, and many have become professional development facilitators for the program nationally. Similarly, District B launched the Code.org teacher training program in the 2015 academic year as part of a district instructional technology initiative. As with District A, District B was provided curricular materials for grades K-12, and professional development for high school educators for AP CSP. The Code.org Professional Learning Program provided both in-person and online support for teachers before and during their first year teaching the Code.org AP CSP curriculum. To date, about 100 teachers in District B have completed the program.

The purpose of this study is to examine the impact of this important initiative by estimating the post-secondary effects of taking Advanced Placement Computer courses in these two large districts. This study estimates the program's impact and efficacy in the schools in which participating teachers taught the course. After 4 years of implementation, many students who received the program have graduated into post-secondary life. This secondary data analysis project tracks students' post-secondary outcomes to estimate the effects of Computer Science course taking during the 2016-2017 and 2017-2018 academic years on higher rates of college attendance, controlling for student academic achievement and demographics. Student data was obtained from

the participating districts and college enrollment data was obtained from the National Student Clearinghouse via each district.

Despite the growing need for qualified workers in STEM fields, there remains a significant under-representation of females in STEM fields (Beede, et al., 2011) and specifically in Computer Science careers (Sax, et al., 2017). Similar gaps exist for minority students. Research has shown that targeted training of teachers to provide Computer Science courses can increase the number of minority students enrolled in advanced Computer Science courses (Goode, 2007). Goode argues that there is a critical need to provide professional development to support and encourage minority participation in Computer Science coursework.

Research also shows that students whose teachers have participated in the Code.org training have a greater likelihood of taking an AP Computer Science course (Brown & Brown, 2019) and students who take AP courses have a greater likelihood of attending college (Mattern, Marini, & Shaw, 2013). Mattern, et. al state, "… the odds of enrolling in a four-year institution increased by 171% for students who took one AP Exam compared with students who took no AP exams. Students participating in AP classes also earn better grades in college (Shaw, Marini, & Mattern, 2013), and have a greater likelihood of persisting in and graduating from college (Dougherty, Mellor, & Jian, 2006; Hargrove, Godin, & Dodd, 2008). This study aims to see if these benefits are also evident with respect to AP computer science courses.

Programs that give students the opportunity to take and master college-level work while still in high school have long been considered beneficial to students' post-secondary success (see Burham & Hewitt, 1967; Casserly, 1986; Chatman & Smith, 1998; Dodd, Fitzpatrick, De Ayala, & Jennings, 2002; Lively, 1993; Lord, 2000; Willingham & Morris, 1986; Windham, 1997). These programs typically have two aims. One is to allow students to earn college credit while still in high school, with the hope of shortening time to degree and saving time for the student and money for the student and the taxpayer. The second is to ease students' transition to college by exposing them to the content and structure of introductory college courses while still in high school, with the hope of increasing the number of students who do well in college and persist to a degree.

Arguably, the most popular and widespread of these programs is the College Board's Advanced Placement Program (AP). This program provides students with the opportunity to receive college credit for course work while they are still in high school. The College Board promotes AP as a tool for students to achieve their post-secondary goals. Specifically, the College Board suggests that participating in AP can give students an advantage in college admissions, can save students time and money and facilitate greater course taking flexibility in college by allowing them to enter college with college credits, and generally can "build the confidence to succeed" through exposure to college level coursework while still in high school (College Board, 2015). Interestingly, emerging research has found that AP participation and AP performance in math and science subjects are positively related to other desirable outcomes, occurring after high school and even in college (Brown & Choi, 2015). In addition, the AP program has grown significantly over the past decade, roughly doubling in size. Part of this expansion is due to increases in Computer Science offerings. As part of this growth, the AP population demographic has shifted. An open research question is whether and how the relationship between AP participation and performance in math and science subjects and particular outcomes has shifted – or not – over recent years.

A review of the current literature, combined with a consideration of the massive expansion of AP programs in the last decade, uncover three key drivers of the research objectives for this study. First, current research shows somewhat mixed results of the impact of AP programs on post-secondary outcomes, providing an opportunity to continue building evidence. Secondly, the recent expansions in AP programs have resulted in a changing population of AP participants, and related support initiatives indicate a changing AP environment, providing an opportunity to examine whether relationships previously observed between AP and student outcomes have changed. Lastly, researchers recognize the importance of controlling for as many student and school variables as possible to isolate the effect of AP, especially prior achievement, in establishing the links between AP participation and student outcomes.

A preponderance of evidence suggests that mastering AP course content relates to better post-secondary outcomes, even after controlling for relevant student pre-college entry attributes. Better scores on AP exams have been shown to relate to various college persistence measures, including persistence through the first and second years, as well as persisting through to earn a degree

(Dougherty, Mellor, & Jian, 2006; Eimers, 2003; Geiser & Santelices, 2004; Hargrove, Godin, & Dodd, 2008). Additionally, after controlling for relevant student pre-college entry attributes, there is evidence that AP exam scores relate to college performance. The better students score on AP exams, the more likely they are to have higher GPAs, to perform better in introductory courses, and in subsequent courses (Dodd, Fitzpatrick, De Ayala, & Jennings, 2002; Geiser & Santelices, 2004; Eimers, 2003; Hargrove et al., 2008; Sadler & Sonnert, 2010; Sadler & Tai, 2007). This is not to say that all evidence points to better outcomes for students who do well on AP exams. For example, Duffy (2010), noting that his findings contradict a number of other studies, found that getting college credit for an AP course provides no advantage in terms of likelihood to earn a college degree in 5 years or in terms of college GPA.

The research is mixed on whether just taking an AP course, without taking and/or passing the related AP exam, relates to post-secondary and post-graduate outcomes. Some studies suggest that, after controlling for relevant student pre-college entry attributes, there is a positive relationship between simply participating in AP courses and performance in college courses, (Sadler & Sonnert, 2010; Sadler & Tai, 2007) and students may be more likely to complete a science or math college degree if they have participated in a science or math AP course (Tai, Liu, Almarode, & Fan, 2010), but there seems to be little evidence that participation in AP courses impacts persistence in college. However, there are a number of studies that suggest that, after controlling for relevant student pre-college entry attributes, there is no evidence that participating in AP courses impacts college persistence or time to attain a degree (Dougherty, Mellor, & Shuling, 2006; Geiser & Santelices, 2004; Klopfenstein & Thomas, 2005; Klopfenstein & Thomas, 2009; Klopfenstein, 2010). Additionally, a number of studies suggest that just participating in AP courses does not impact college course GPA (Geiser & Santelices, 2004; Klopfenstein & Thomas, 2005; Klopfenstein & Thomas, 2009; Sadler & Sonnert, 2010).

Mastering the content of AP courses is the goal for students, and it is what logic dictates would most closely relate to student success in and after college. Why, then, continue to explore questions about the relationship between exposure to AP content (versus mastery of AP content) and student outcomes? This question is important given the massive expansion of AP programs over the last decade and the expansion of AP offerings, such as the introduction of AP Computer Science Principles. As

the AP gates open wide, it has been noted that more students who may not be prepared to tackle the content find themselves in AP classes (Dougherty & Mellor, 2010; Klopfenstein & Thomas, 2010; Lichten, 2010). There may be a benefit to these students in that just having AP courses on their transcripts can give them an advantage in college admissions typically accessible to a more privileged demographic (Geiser & Santelices, 2004; Sadler, 2010). While the goal for all students is to master the content, it is valuable to know if exposure to AP has an impact on outcomes. Findings in this area would be useful for colleges and universities that use AP course participation as a factor in admissions decisions. If AP exam performance continues to predict college success but AP participation does not, this is important for colleges and universities to know. For these reasons, we advocate for continuing to explore whether exposure to AP content to a broader audience of students is providing a benefit.

Even if the current research findings on the links between AP and student outcomes were consistent, the massive expansion of AP programs in the last decade makes it necessary to continually update the research (Klopfenstein, 2010; Tai et al., 2010). As AP programs have expanded, the population of AP participants is different than it was when much of the current research was conducted. Raw numbers of AP participants have increased, and with that, the demographic make-up of the group has shifted. Because student characteristics have been shown to relate to post-secondary and post-graduate outcomes, as the proportions of students with certain characteristics shift in the populations of interest, it is critical to determine whether the relationships between AP and student outcomes previously determined are changing with the changing population. With AP still growing, this argues for continued research that monitors these relationships over time.

From 2003 to 2013, the number of graduating seniors in the United States increased from 2,719,947 to 3,022,879 (College Board, 2005-2014). During that same time period, overall participation in AP (defined as a graduating senior having taken at least one AP exam) almost doubled from 514,163 to 1,003,430. The number of Black/African American AP participants more than tripled from 30,076 to 92,316, the number of Hispanic/Latino participants nearly tripled from 63,695 to 188,645, and the number of low-income participants defined by the College Board as those examinees granted exam fee reductions more than quadrupled from 8,489 to 275,864. These numbers have led to a shift in the demographic make-up of AP participants. From 2003 to 2013, the percentage of AP

participants who are Black/African American increased from 5.8% to 9.8%, the percentage who are Hispanic/Latino participants increased from 12.4% to 18.8%, and the percentage who are low-income participants increased from 11.4% to 27.5%.

Similarly, over the last decade, the number of students earning a qualifying score on at least one AP exam (defined as scoring three or higher on a five-point scale) increased greatly (College Board, 2005-2014). From 2003 to 2013, the overall number of AP exam passers increased from 331,734 to 607,505. The number of Black/African American AP passers almost tripled from 9,784 to 27,945, the number of Hispanic/Latino AP exam passers more than doubled from 43,021 to 102,668, and just from 2008 to 2013 (data unavailable for 2003) the number of low-income AP passers more than doubled from 61,698 to 131,911. As with AP participation, these numbers have led to a shift in the demographic make-up of AP exam passers. From 2003 to 2013, the percentage of AP passers who are Black/African American increased from 2.9% to 4.6%, the percentage of AP passers who are Hispanic/Latino increased from 13.0% to 16.9%, and just from 2008 to 2013 (data unavailable for 2003) the percentage who are low-income increased significantly from 13.4% to 21.7%.

The push that results in wider AP access creates two groups within the new test takers – those who did not have access before, but are prepared and motivated to succeed, and those who are less prepared and/or motivated to succeed (Dougherty & Mellor, 2010). We imagine that access will improve outcomes for typically underserved populations because it will help the former group, even just considering the advantage in the college admissions process (Sadler, 2010; Geiser & Santelices, 2004). However, as many people have recognized, a key thing is to support the latter group – those students who may now find themselves in AP courses unprepared. This has spurred many programs aimed at helping these underprepared students to succeed (e.g., AP STEM Access). This creates a truly dynamic and ever-changing landscape that deserves research attention. We cannot assume that previous findings will hold in perpetuity.

Due to the fact that there are many easily measurable (e.g., ethnicity, socioeconomic, academic achievement) and more difficult to measurable (e.g., motivation) factors related to post-secondary and post-graduate outcomes, there is still often doubt, even in the most well-constructed studies, that positive results indicate a causal link between AP and student outcomes. This is one of the most often cited limitations of studies comprising the current research on the relationship

between AP and student outcomes (Dougherty, et al., 2006; Dougherty, et al., 2006; Sadler, 2010; Duffy, 2010; Jackson, 2007, 2012, 2014; Klopfenstein & Thomas, 2010; Klopfenstein, 2010; Sadler & Sonnert, 2010; Tai et al., 2010;).

Descriptive statistics appear to provide a clear link between AP and student outcomes. One must consider, however, that typically it has been highly-motivated, highly-supported students taking AP who would have good post-secondary outcomes anyway. One way to satisfactorily control for these factors would be a randomized trial, but that is not feasible. However, it is feasible to employ statistical techniques to control for variables that may obscure the relationship between AP and outcomes. Methods such as regression (Duffy, 2010; Geiser & Santelices, 2004; Tai, et al., 2010), Hierarchical Linear Modeling (HLM; Dougherty et al., 2006; Sadler & Sonnert, 2010), and survival analyses (Klopfenstein, 2010) have been used.

The AP world is changing, and researchers must keep up. With the rapid expansion of AP programs comes a larger population and one that has a different demographic makeup – particularly a larger proportion of traditionally disadvantaged students – than in years past. Some of the new students in the AP population will be prepared for the challenge of AP; others will not. This fact has brought forth many programs and initiatives focused on getting more students to succeed in AP, and these programs will be at various stages of implementation with varying degrees of success, changing the overall landscape in addition to the student demographic changes.

This study contributes to the current body of research on the relationship between the College Board's Advanced Placement Program (AP) and post-secondary outcomes by showing how participation in a relatively new course impacts college enrollment as well as by showing the impact these courses have on enrollment for a relatively recent cohort of high school graduates, which may differ demographically from prior AP student populations.

Methodology

The primary research question this study seeks to address is, “What is the impact of Advanced Placement Computer Science participation on students’ post-secondary outcomes as measured by college enrollment?” We hypothesize that in districts that formed a close partnership to run high quality professional development for new computer science teachers, such as

Code.org's program for AP CS Principles, students who take an AP Computer Science course, such as AP Computer Science Principles or AP Computer Science A, in those districts will realize higher rates of college attendance, while controlling for prior academic achievement and student demographic variables.

Thus, we compared the post-secondary outcomes of graduated students who took a Computer Science course with those who did not take a Computer Science course from 89 schools where teachers that participated in the Code.org teacher training program taught a course in Computer Science (34 District A schools, 55 District B schools). The participating schools were selected based on their participation in the Computer Science teacher training program during the 2016-17 and 2017-18 academic years.

Design

This study employs a two-level hierarchical generalized linear regression model with a link function as the outcomes of interest are each binary outcomes. All models were estimated using the HLM8 software package (Raudenbush, Bryk, Cheong, Congdon, & du Toit, 2019). While the standard HLM uses a normal sampling model and an identity link function, we use a binomial sampling model and a logit link as the outcomes of interest are binary. This allows us to estimate the effect of program participation on the likelihood of attaining the desired post-secondary outcome of college enrollment. College enrollment was defined as having a record of enrollment in any college in the National Student Clearinghouse database.

Our analytic models feature two important aspects: (1) nested structure of data (i.e., students are nested within schools); and (2) outcomes of interest are binary. Given these assumptions a two-level hierarchical generalized linear model is an appropriate analytic model. We will begin our analysis with descriptive statistics. For example, we will calculate the percentage of binary outcomes by treatment conditions, year, schools, and student characteristics. Such detailed descriptive statistics along with corresponding graphics will provide an overall general picture of the data and will guide us to build a more sensible statistical model specification.

While the standard HLM uses a normal sampling model and an identity link function, we will use a binomial sampling model and a logit link as outcome of interest is binary. A binary response for student *i* in school *k*, Y_{ik}, takes a value of 1 if a student *i* in school *k* attained the binary outcome (e.g., enrolled in college), otherwise 0. We define the probability of the response equal to one as $\varphi_{ik} = \Pr(Y_{ik} = 1)$ and let φ_{ik} be modeled using a logit link function. The standard assumption is that Y_{ik} has a Bernoulli distribution. Thus, the Level 1 model is specified as follows:

$$\eta_{ik} = \log(\varphi_{ik}/(1-\varphi_{ik})) = \pi_{0k} + \pi_1 \mathrm{Trt}_k + \pi_2 \mathrm{Gender}, \qquad (1)$$

where η_{ik} is log-odd of achieving the binary outcome. We will include a set of student-level variables such as grade, gender, race, ethnicity, and so on. For simplicity, the above Level 1 model includes only a student gender (Gender: 1 for female, 0 for otherwise). Additionally, a treatment indicator variable Trt_k is coded 0 for students who did not take a Computer Science course and 1 for those that did. The key parameter of interest is π_1 in Equation 1 which captures the difference in log-odds of attaining the post-secondary outcome between the treatment and comparison students.

To address the primary research question, "What is the impact of Computer Science course taking on students' post-secondary outcomes?" we will be limited to exploring the impact of program participation to college enrollment. Due to the fact the data cover only two years post high school graduation, less than 0.5% had declared a major or graduated by Spring 2019. We are unable to estimate the program impact on more distal post-secondary outcomes such as major declaration or graduation. We will estimate the impact of program participation on college enrollment for the combined sample and for each district separately.

Sample

The dataset contained records for 59,592 graduated students in 89 participating high schools in two districts across two academic years: 2016-2017 and 2017-2018. The data included information regarding year of graduation, student demographics (gender, minority status, poverty status) student course taking in the computer science discipline, student grade point average, and student college attendance records as of March 2019. Thus, for students graduating high school in 2017, four semesters of college enrollment were possible (Fall 2017, Spring 2018, Fall 2018, and

Spring 2019). For 2018 graduates, only two semesters of college enrollment were potentially available (Fall 2018, Spring 2019).

Table 1. Descriptive Statistics for the Combined Sample

	Minimum	Maximum	Mean	Standard Deviation
Gender	0	1	0.52	0.500
GPA	0.57	4.66	2.936977	0.63614
CSP	0.00	1.00	0.0384	0.19215
CSA	0.00	1.00	0.0139	0.11698
Enrolled	0.00	1.00	0.6187	0.48570
Poverty	0.00	1.00	0.6533	0.47591
Minority	0.00	1.00	0.7592	0.42760
ANYAPCS	0.00	1.00	0.0504	0.21882

N = 59,592

The graduating students of these 89 high schools were predominantly Hispanic or African-American (75.9%) and economically disadvantaged (65.3%). In addition, computer science course taking was rather infrequent among the graduates Only about 5% of graduates took any Advanced Placement computer science course (AP Computer Science Principles or AP Computer Science during their high school careers. The greater portion of computer science course taking was participation in Advanced Placement Computer Science Principles (CSP), with rates of about 3.8%. In contrast, enrollment in Advanced Placement Computer Science A (CSA) was less than 1.4%.

Table 2. Demographics of CSA/CSP Enrollees and Non-Enrollees

	Enrolled in CSA	Not Enrolled in CSA	Enrolled in CSP	Not Enrolled in CSP
Pct Female	0.32	0.52	0.37	0.53
Pct Poverty	0.67	0.65	0.55	0.66
Pct Minority	0.60	0.76	0.65	0.76
Mean GPA	3.51	2.93	3.26	2.92

Note. N = 59592

The computer science course taking sample had higher average grade point average (3.51 for those taking CSA and 3.26 for those taking CSP) than those who did not take computer science courses (2.93 for CSA, 2.92 for CSP). Further, this sample was more male (68% vs 48% for CSA; 63% vs 47% for CSP), and less minority (60% vs 76% for CSA; 65% vs 76% for CSP). Finally, the AP course taking sample was slightly different in terms of poverty (67% vs 65% for CSA; 55% vs 66 % for CSP). As a result of these initial differences between the samples on these characteristics, each of these variables will be used as covariates in the analyses.

RESULTS

Initial investigation of the data structure suggests a multi-level model should be considered due to the clustering of students within schools. Using the 2017 academic year data, an intra-class coefficient (ICC) was calculated to estimate the amount of variation in the college enrollment outcome attributable to between-school differences. The ICC was calculated to be .44, suggesting that 44% of the variation in college enrollment was accounted for by between-school differences.

This suggests that a multi-level model should be employed to take this between-school clustering into account. Thus, multi-level procedures to estimate the effects and standard errors is justified.

Combined Sample

Any AP Computer Science

To estimate the effect of taking computer science courses on college enrollment, we first modeled college enrollment as a function of taking any AP Computer Science course (ANYAPCS) for the combined sample, while controlling for academic achievement (as measured by grade point average), gender, poverty, and minority status. The 2-level model did not include any level-2 predictors in the initial model. For these analyses, enrollment is defined as enrolling in either a two-year or four-year institution. We found that the vast majority of college enrollments were four-year enrollments, thus separating the outcomes into two-year or four-year had no effect. As a result, all analyses are for total college enrollment, regardless of two-year or four-year institution. The initial model for the impact of taking any Advanced Placement computer science course is defined as:

$$\text{Prob}(ENROLLED_{ij}=1|\beta_j) = \phi_{ij}$$

$$\log[\phi_{ij}/(1 - \phi_{ij})] = \eta_{ij}$$

$$\eta_{ij} = \beta_{0j} + \beta_{1j}*(GENDER_{ij}) + \beta_{2j}*(GPA_{ij}) + \beta_{3j}*(POVERTY_{ij}) + \beta_{4j}*(MINORITY_{ij}) + \beta_{5j}*(ANYAPCS_{ij})$$

Results from this model indicate that taking an Advanced Placement Computer Science Course (either AP Computer Science A or AP Computer Science Principles) had a significant impact on the likelihood of enrolling in college after controlling for academic achievement and other demographic variables. As can be seen in Table 3, the effect of taking an AP Computer Science course on college enrollment is positive and significant (β = 0.154; p = 0.001). Table 4 shows that the odds-ratio is estimated at 1.166, indicating a 17% increase in the likelihood of enrolling in college if a student took an AP CS course.

Table 3. Estimation of fixed effects for ANY AP CS on Enrollment

Fixed Effect	Coefficient	Standard error	*t*-ratio	Approx. *d.f.*	*p*-value
For INTRCPT1, β_0					
INTRCPT2, γ_{00}	0.417534	0.068826	6.067	88	<0.001
For SEX slope, β_1					
INTRCPT2, γ_{10}	0.137872	0.019082	7.225	59498	<0.001
For STATEFIN slope, β_2					
INTRCPT2, γ_{20}	1.185405	0.017150	69.121	59498	<0.001
For POVERTY slope, β_3					
INTRCPT2, γ_{30}	-0.107222	0.022082	-4.856	59498	<0.001
For MINORITY slope, β_4					
INTRCPT2, γ_{40}	0.095252	0.025756	3.698	59498	<0.001
For ANYAPCS slope, β_5					
INTRCPT2, γ_{50}	**0.153872**	**0.047758**	**3.222**	**59498**	**0.001**

Table 4. Estimation of Odds Ratios for ANY AP CS on Enrollment

Fixed Effect	Coefficient	Odds Ratio	Confidence Interval
For INTRCPT1, β_0			
INTRCPT2, γ_{00}	0.417534	1.518214	(1.324,1.741)
For SEX slope, β_1			
INTRCPT2, γ_{10}	0.137872	1.147829	(1.106,1.192)
For STATEFIN slope, β_2			
INTRCPT2, γ_{20}	1.185405	3.272013	(3.164,3.384)
For POVERTY slope, β_3			
INTRCPT2, γ_{30}	-0.107222	0.898326	(0.860,0.938)
For MINORITY slope, β_4			
INTRCPT2, γ_{40}	0.095252	1.099936	(1.046,1.157)
For ANYAPCS slope, β_5			
INTRCPT2, γ_{50}	**0.153872**	**1.166342**	**(1.062,1.281)**

Computer Science A

Likewise, we found positive effects for specific courses on college enrollment (Table 5). The effect estimate is positive and significant (β = 0.291; p = 0.001). We found that taking AP Computer Science A increased the likelihood of college enrollment by 34% while controlling for poverty, gender, minority status, and prior academic achievement (Table 6). For minorities

analyzed separately, this increase in odds was slightly higher at 38%. This finding was stronger than for taking any AP course, which suggests that there is a greater impact for taking CSA than any AP CS course.

Table 5. Estimation of fixed effects for AP CSA on Enrollment

Fixed Effect	Coefficient	Standard error	*t*-ratio	Approx. *d.f.*	*p*-value
For INTRCPT1, β_0					
INTRCPT2, γ_{00}	0.423874	0.068778	6.163	88	<0.001
For SEX slope, β_1					
INTRCPT2, γ_{10}	0.135268	0.019017	7.113	59498	<0.001
For GPA slope, β_2					
INTRCPT2, γ_{20}	1.187243	0.017090	69.471	59498	<0.001
For CSA slope, β_3	**0.290571**	**0.089939**	**3.231**	**59498**	**0.001**
INTRCPT2, γ_{30}					
For POVERTY slope, β_4					
INTRCPT2, γ_{40}	-0.107707	0.022082	-4.878	59498	<0.001
For MINORITY slope, β_5					
INTRCPT2, γ_{50}	0.094931	0.025749	3.687	59498	<0.001

Table 6. Estimation of Odds Ratios for AP CSA on Enrollment

Fixed Effect	Coefficient	Odds Ratio	Confidence Interval
For INTRCPT1, β_0			
INTRCPT2, γ_{00}	0.423874	1.527869	(1.333,1.752)
For SEX slope, β_1			
INTRCPT2, γ_{10}	0.135268	1.144843	(1.103,1.188)
For GPA slope, β_2			
INTRCPT2, γ_{20}	1.187243	3.278032	(3.170,3.390)
For CSA slope, β_3			
INTRCPT2, γ_{30}	**0.290571**	**1.337190**	**(1.121,1.595)**
For POVERTY slope, β_4			
INTRCPT2, γ_{40}	-0.107707	0.897890	(0.860,0.938)
For MINORITY slope, β_5			
INTRCPT2, γ_{50}	0.094931	1.099583	(1.045,1.157)

Computer Science Principles

We found similar, but less pronounced effects for taking the Computer Science Principles course. The effect estimate is positive and significant (β = 0.117; p = 0.032). Though not large an effect as was seen with Computer Science A, the odds-ratio was nonetheless significant. The likelihood of college enrollment increased by roughly 12% for those taking Computer Science Principles relative to those who did not, even while controlling for background variables and prior academic achievement (Table 8).

Table 7. Estimation of fixed effects for AP CSP on Enrollment

Fixed Effect	Coefficient	Standard error	*t*-ratio	Approx. *d.f.*	*p*-value
For INTRCPT1, β_0					
INTRCPT2, γ_{00}	0.423507	0.068759	6.159	88	<0.001
For SEX slope, β_1					
INTRCPT2, γ_{10}	0.135158	0.019054	7.093	59498	<0.001
For GPA slope, β_2					
INTRCPT2, γ_{20}	1.188819	0.017097	69.532	59498	<0.001
For CSP slope, β_3					
INTRCPT2, γ_{30}	**0.116721**	**0.054368**	**2.147**	**59498**	**0.032**
For POVERTY slope, β_4					
INTRCPT2, γ_{40}	-0.106943	0.022081	-4.843	59498	<0.001
For MINORITY slope, β_5					
INTRCPT2, γ_{50}	0.093461	0.025743	3.631	59498	<0.001

Table 8. Estimation of Odds Ratios for AP CSP on Enrollment

Fixed Effect	Coefficient	Odds Ratio	Confidence Interval
For INTRCPT1, β_0			
INTRCPT2, γ_{00}	0.423507	1.527308	(1.332,1.751)
For SEX slope, β_1			
INTRCPT2, γ_{10}	0.135158	1.144718	(1.103,1.188)
For GPA slope, β_2			
INTRCPT2, γ_{20}	1.188819	3.283202	(3.175,3.395)
For CSP slope, β_3	**0.116721**	**1.123806**	**(1.010,1.250)**
INTRCPT2, γ_{30}			
For POVERTY slope, β_4			
INTRCPT2, γ_{40}	-0.106943	0.898577	(0.861,0.938)
For MINORITY slope, β_5			
INTRCPT2, γ_{50}	0.093461	1.097968	(1.044,1.155)

District Specific Analyses

When we separate the samples by district, we see that taking an Advanced Placement computer science course had a positive impact in each of the districts, but the specific course driving the effect varied between districts. The overall effect of taking any AP computer science course was positive and significant for District A (β = 0.261; p = 0.003) as well as for District B (β = 0.11; p = 0.05). Odds of enrollment increased almost 30% in District A and roughly 12% in District B. However, this effect was driven by AP Computer Science Principles in District A (β = 0.277; p = 0.002) for an increased college enrollment likelihood of 32%, while it is driven by AP Computer Science A in District B (β = 0.342; p = 0.001) for an increased college enrollment likelihood of 41%. The effect estimate of AP Computer Science A in District A did not reach statistical significance (β = 0.178; p = 0.632). Similarly, the effect estimate for Computer Science Principles in District B did not reach significance (β = 0.00; p = 0.991). This disparate impact by course is likely due to different adoption rates for the specific courses between districts. For example, less than 0.3% of the students in District A took AP Computer Science A.

Figure 1. The Differential Effect of AP Participation on Enrollment by GPA

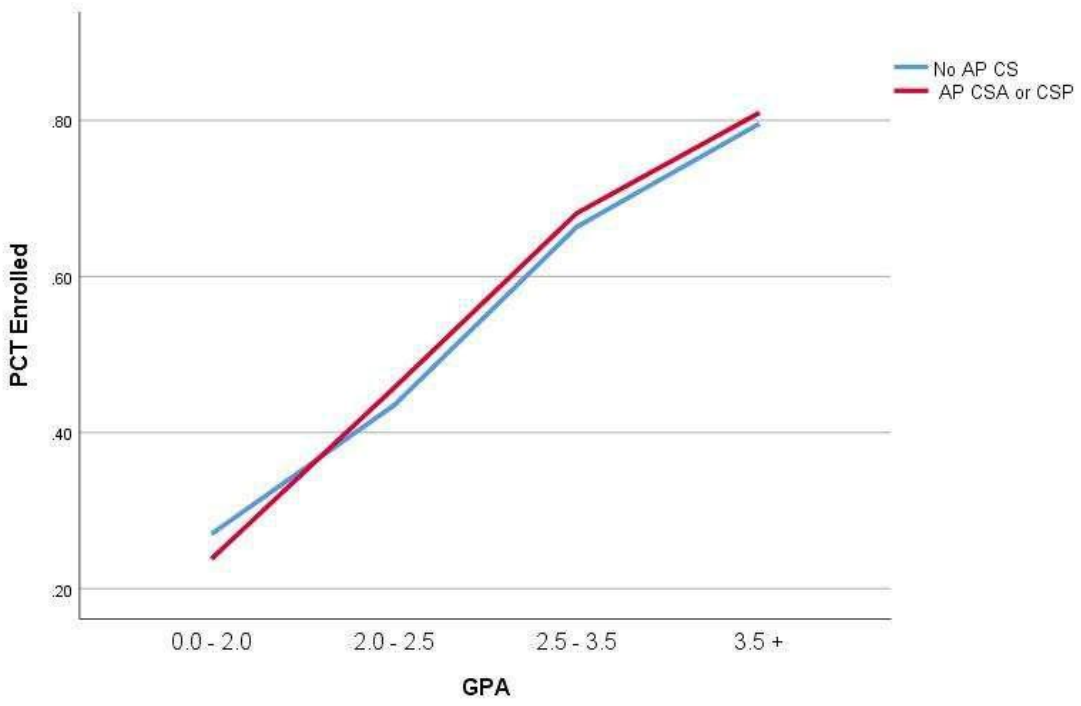


Figure 2. The Differential Effect of AP CSP Participation on Enrollment by GPA

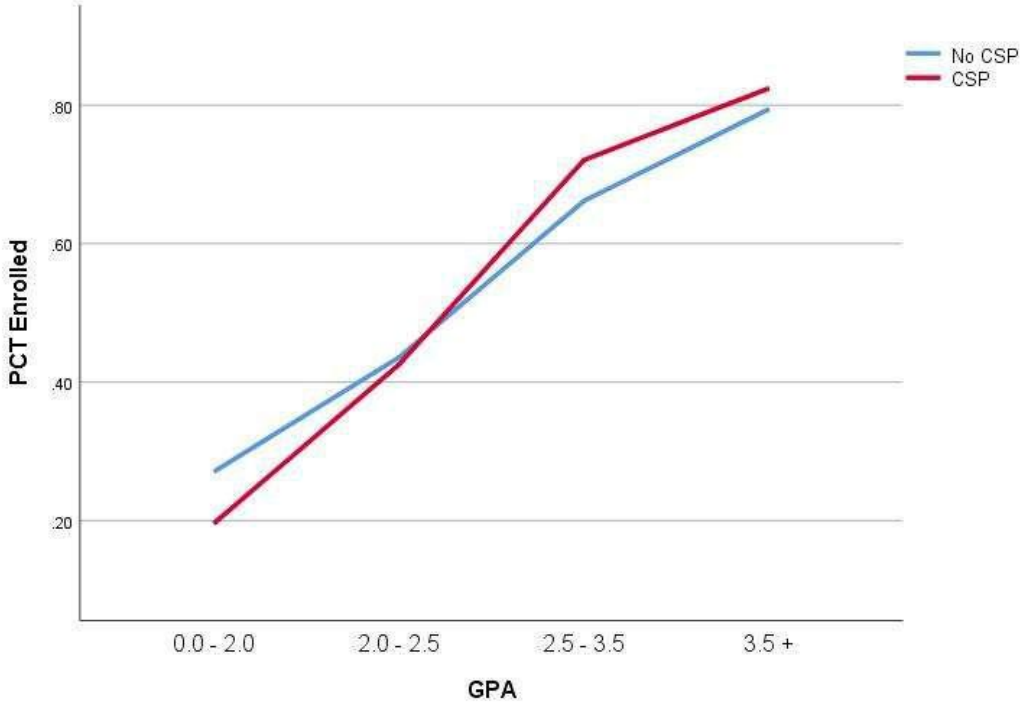
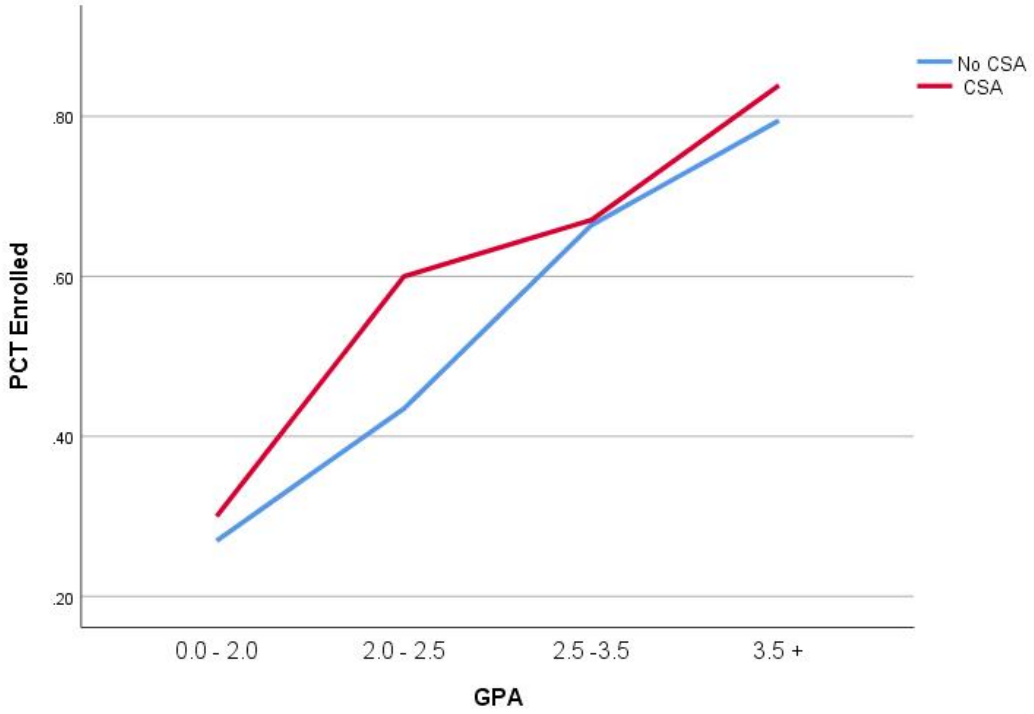


Figure 3. The Differential Effect of AP CSA Participation on Enrollment by GPA



In an attempt to better understand which students are predominately impacted by taking these AP courses, we separated students into four academic achievement levels based on cumulative grade point averages in high school. We then plotted the college enrollment probabilities for those who took specific AP computer science courses relative those who did not. Interestingly, when we look at students who took any AP computer science course (i.e., either CSA or CSP) the difference in college enrollment is relatively steady across GPA level (Figure 1). However, Figure 2 suggests that the greatest impact of taking Computer Science Principles occurs for students with higher mean grade point averages while Figure 3 suggests that taking Computer Science A has a greater effect for students with lower average academic achievement.

Table 9. Summary of Effects of AP Computer Science Course Taking on College Enrollment

	Significant	Odd-Ratio	N
Combined			59592
Any AP CS	YES	1.17	
CSA	YES	1.34	
CSP	YES	1.24	
District A			29588
Any AP CS	YES	1.30	
CSA	NO	N/A	
CSP	YES	1.32	
District B			30004
Any AP CS	YES	1.12	
CSA	YES	1.41	
CSP	NO	N/A	

DISCUSSION

The findings from this study provide support for the argument that training computer science teachers and increasing students' enrollment in computer science courses leads to positive post-secondary outcomes for students, even while controlling for overall academic achievement, student demographics, and school differences (summarized in Table 9). It is interesting to note the relatively high college enrollment rates generally, in excess of 60%. When larger proportions of students are enrolling in college, the impact that any given program can have on increasing enrollment is more limited. As the rate of college enrollment declines, programs such as this computer science teacher training program may be in a better position to effect change.

It is also interesting to note that the impact of taking a computer science course is not uniform across course offerings and districts. This suggests that how the districts emphasize course offerings can impact student post-secondary outcomes. AP Computer Science Principles was only introduced a few years ago, so it may take some time for students to become aware of and take advantage of it as part of their course selection. Perhaps, enhancement to college enrollment could be attributed to the AP Computer Science Principles course's focus on foundational concepts and how it impacts the world and that provides a greater interest for students compared to the narrower focus of Advanced Placement CSA. As College Board describes, AP Computer Science A is a more rigorous course and would make sense for students to progress from CS Principles to CSA. Evidence suggests that the participation rate for AP Computer Science Principles is increasing, which is a promising trend given these findings. This may also lead to increased participation in AP Computer Science A in the future, as students take AP Computer Science Principles first, then move on to AP Computer Science A. It would be advisable to encourage students to move toward taking AP Computer Science A and taking AP Computer Science Principles first may provide students with the foundation and confidence they need to undertake the more rigorous course. Lastly, it is noteworthy that the impact of taking Advanced Placement Computer Science courses on college enrollment was, with respect to AP CSA, more pronounced for minority students than for the overall population, especially since the sample was overwhelmingly minority.

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