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RESEARCH REPORT

# Modeling Longitudinal Effects of Computer Science Course Taking on Post-Secondary Outcomes

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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 28,453 graduates) partnered with Code.org to receive computer science teacher training in order to enhance Advanced Placement Computer Science course taking among their students. Using a path analytic modeling approach, this study provides estimates of the impact of taking an Advanced Placement Computer Science course (Advanced Placement-Computer Science A) on students' post-secondary outcomes, such as college enrollment, college persistence, and degree attainment, controlling for various student characteristics, including academic achievement. We find that taking AP Computer Science has an impact on degree attainment through college persistence. We also find that the impact is greater for certain subsets of students.

## INTRODUCTION

The purpose of this study is to model the impact of an important initiative by estimating the post-secondary effects of Computer Science course taking on students' academic careers. Since implementation began in the 2015-2016 school year, many of the graduated students who received the program moved on into post-secondary life and have had sufficient time since high school to have graduated from two and four-year institutions. This secondary data analysis project models students' post-secondary outcomes such as college enrollment, college persistence, and degree attainment to estimate the effects of Computer Science course taking on rates of college attendance, college persistence, and degree attainment, controlling for student academic achievement, free or reduced-price lunch status, and students from groups historically under-represented in Computer Science (URG) status. In this sample, URG is an indicator for Black/African-American or Hispanic students. College enrollment data were obtained from the National Student Clearinghouse (NSC) via the participating districts and matched to district data on course taking and relevant student demographic variables.

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), specifically in Computer Science

careers (Sax, et al., 2017). Similar gaps exist for under-represented students. Research has shown that targeted training of Computer Science teachers can increase the number of under-represented 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 under-represented 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). Further, students who take AP courses have a greater likelihood of attending college (Mattern, Marini, & Shaw, 2013), and it has been specifically shown that taking AP Computer Science courses positively impacts college enrollment and persistence (Brown & Brown, 2020). Mattern, et. al reported that 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).

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 & Mullen, 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 & Mullen, 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 math or science courses impacts persistence in college (Dougherty, Mellor, & Jian, 2006; Geiser & Santelices, 2004; Klopfenstein & Thomas, 2005; Klopfenstein & Thomas, 2009; Klopfenstein, 2010). This study addresses this issue by examining the post-secondary effects of taking advanced computer science courses on students' academic careers.

**Methodology**

The primary research question this study seeks to address is "How does Computer Science course taking impact students' post-secondary outcomes such as college-enrollment, college persistence, and college completion?" We hypothesize that students who took Advanced Placement Computer Science A will realize higher rates of college attendance, college persistence, and college completion. We modeled the post-secondary outcomes of graduates who took AP Computer Science A with those who did not in 89 schools in two districts. The participating schools were those whose teachers received Code.org's AP Computer Science Principles Professional Learning program during the 2015-16 academic year.

This study employs a path analytic modeling approach with all post-secondary outcomes as binary measures, thus the regressions are logistic in nature. All models were estimated using the Mplus software package (Muthen & Muthen, 1998-2017). This allows us to estimate the effect of program participation on the likelihood of attaining the desired post-secondary outcomes of college enrollment, college persistence, and degree attainment, both directly and indirectly. The standard model, shown below in Figure 1, proposes that college enrollment and college persistence are impacted by student characteristics such as gender, grade point average, free or reduced-price

lunch status, URG status, and computer science course-taking. This relationship is indicated by the paths from those student characteristic variables to the post-secondary outcome measures. Further, it is proposed that the likelihood of college degree attainment (grad) is impacted by these same student variables but also by college enrollment and college persistence. The double headed arrows between the student characteristic variables indicate that these variables are allowed to correlate with one another.

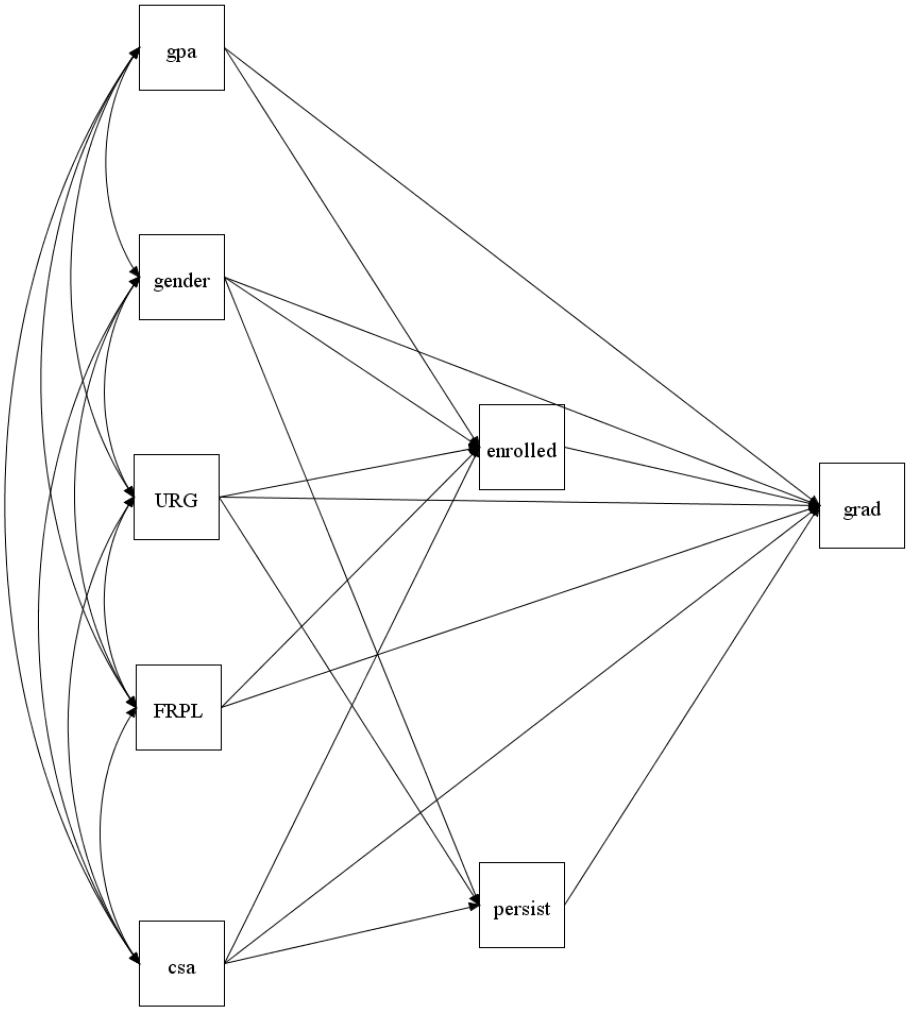


Figure 1. Proposed model of relationships

*Sample*

The dataset contained records for 27,824 graduated students in 89 participating high schools in the 2015-2016 academic year from two large coastal school districts. District A is on the West Coast

of the United States, and District B is on the East Coast of the United States. The data included information regarding student demographics (gender, URG status, poverty status) student course taking in the Computer Science discipline, student grade point average, and student college attendance records as of September 2021. Thus, for students graduating high school in 2016, eleven semesters of college enrollment were possible, excluding summer sessions (Fall 2016, through Spring 2021). Descriptive analysis of the data reveals the graduating students of these 89 high schools were predominately Hispanic or African-American (82.9% in District A; 65.9% in District B) and economically disadvantaged (79.0% in District A; 49.7% in District B). In addition, Computer Science course taking was very infrequent among the graduates. Only 3% of graduates in District A and 2.1% in District B took any Computer Science courses during their high school careers.

## RESULTS

We ran the models separately for the two districts to investigate whether the relationships were consistent across the two locations, or if each district demonstrated a unique set of relations among the variables. For the initial analyses, we ran the models for each district as specified in Figure 1 above. For both districts, the model estimation terminated normally and parameter estimates were obtained for each arrow in the model. For clarity of presentation, only statistically significant ($p < 0.05$) paths and parameter estimates will be shown. For each significant path, both the parameter estimates and standard error for that estimate will be shown. To get the odds ratios, the parameter estimates are exponentiated.

*District A – Full Population*

Model results for our West Coast district are presented in Figure 2. The results of this model indicate that college degree attainment is impacted by virtually all of the variables in the model, either directly or indirectly, positively or negatively. The greatest impact of student characteristics on college graduation, unsurprisingly, is student cumulative grade point average in high school. A one point increase in GPA increases the likelihood of earning a college degree by a factor of 3.7, or more than three and a half times the likelihood. Free or reduced-price lunch (FRPL) status and

under-represented group status also impact the likelihood of graduating college, but to a lesser extent. FRPL students (.82) and under-represented students (.67) have a reduced likelihood of graduating than their counterparts. We find that when controlling for demographic and background variables, there is a positive impact of taking a Computer Science course on college persistence, (odds ratio of 1.81), and that college persistence then dramatically increases the chances of earning a college degree (odds ratio of 7.4). That is, students who took AP Computer Science had an 81% greater likelihood of persisting in college which then led to a much greater likelihood of graduating from college. Thus, the effect of taking Computer Science on college persistence is a direct effect, but the effect of taking computer science on degree attainment is an indirect effect, mediated by college persistence.

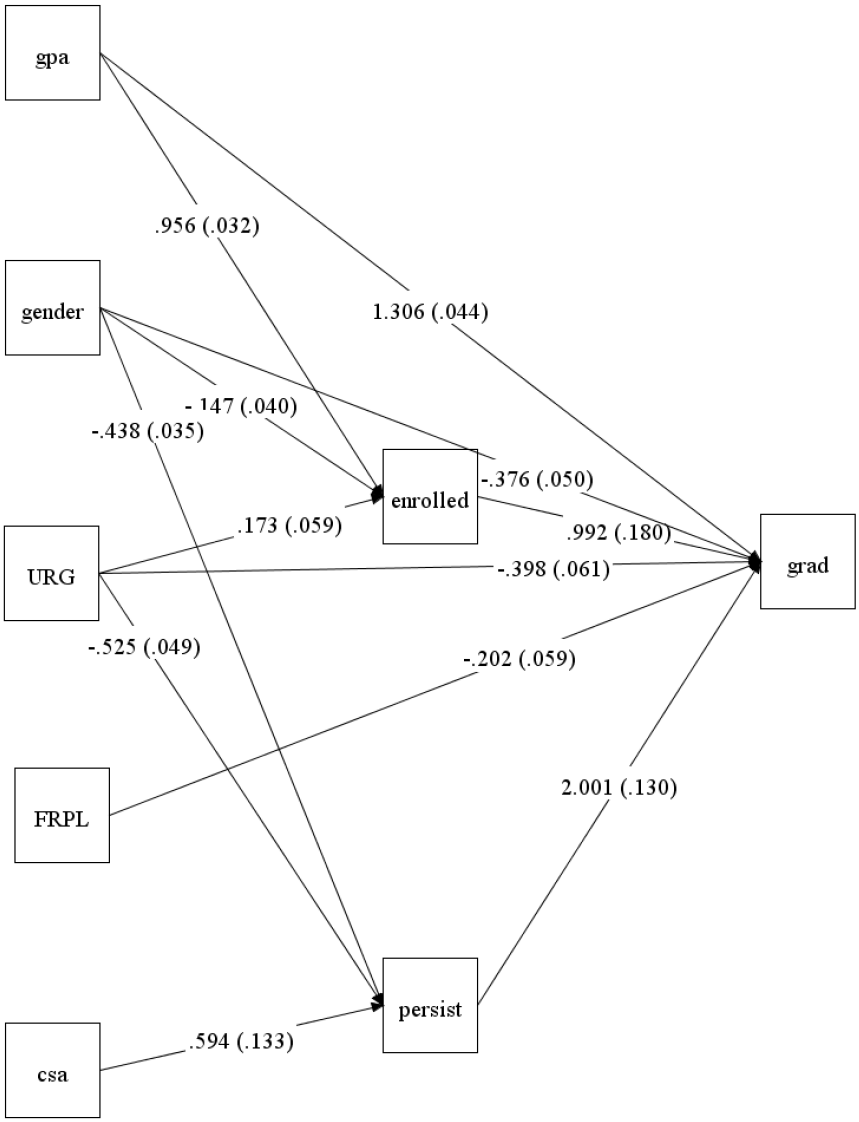


Figure 2. Model Results for District A – Full Population

*District B*

Similar results were found for our East Coast district (Figure 3). As with District A, the greatest impact of student characteristics on college graduation is from grade point average, with an odds ratio of 5.3, an even greater effect than was seen in District A where the odds ratio was 3.7. The indirect effect of Computer Science course taking on college degree attainment seen in District A was replicated in District B. In District B, the effect of taking AP Computer Science on college

persistence yielded an odds ratio of 2.7, meaning that students who took AP Computer Science were more than two and a half times as likely to persist in college than those who did not, then those who persisted in college were much more likely go on to earn a degree. The impact of taking Computer Science A on college persistence was greater in District B (2.7 odds ratio) than in District A (1.81 odds ratio). It would be interesting to extend these analyses to subsequent cohorts and explore the effect of taking AP Computer Science Principles, which was not offered to the students in the class of 2016.

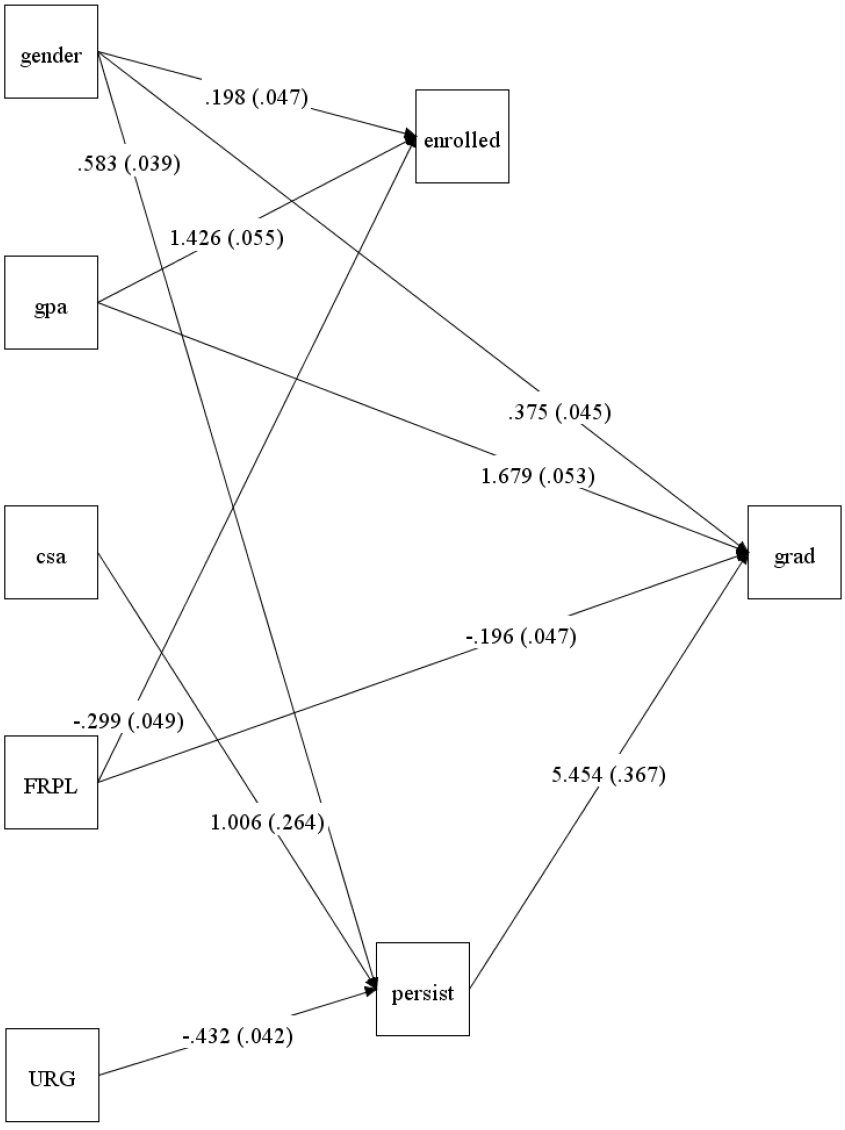


Figure 3. Model Results for District B – Full Population

*District A – URG Population*

The negative parameter estimates for the paths leading from the URG variable to the persistence and grad variables indicates that the likelihood of persisting in college and graduating from college is different for African-American and Hispanic students compared to their White and Asian counterparts. As a result, we sought to see how the model captures the relationships among the predictors and outcomes specifically for under-represented students. The results for District A URG students is presented in Figure 4. Again, taking AP Computer Science related to increased likelihood of persistence in college by an odds ratio of 1.89. Thus, African-American and Hispanic students who took AP Computer Science increased their likelihood of persisting in college by 89%. Subsequently, those that persisted in college had a much greater likelihood of earning a degree. This odds ratio is greater than what was obtained for the full population. That is, the effect of taking AP Computer Science on persistence in college is greater for URG students than non-URG students in this district.

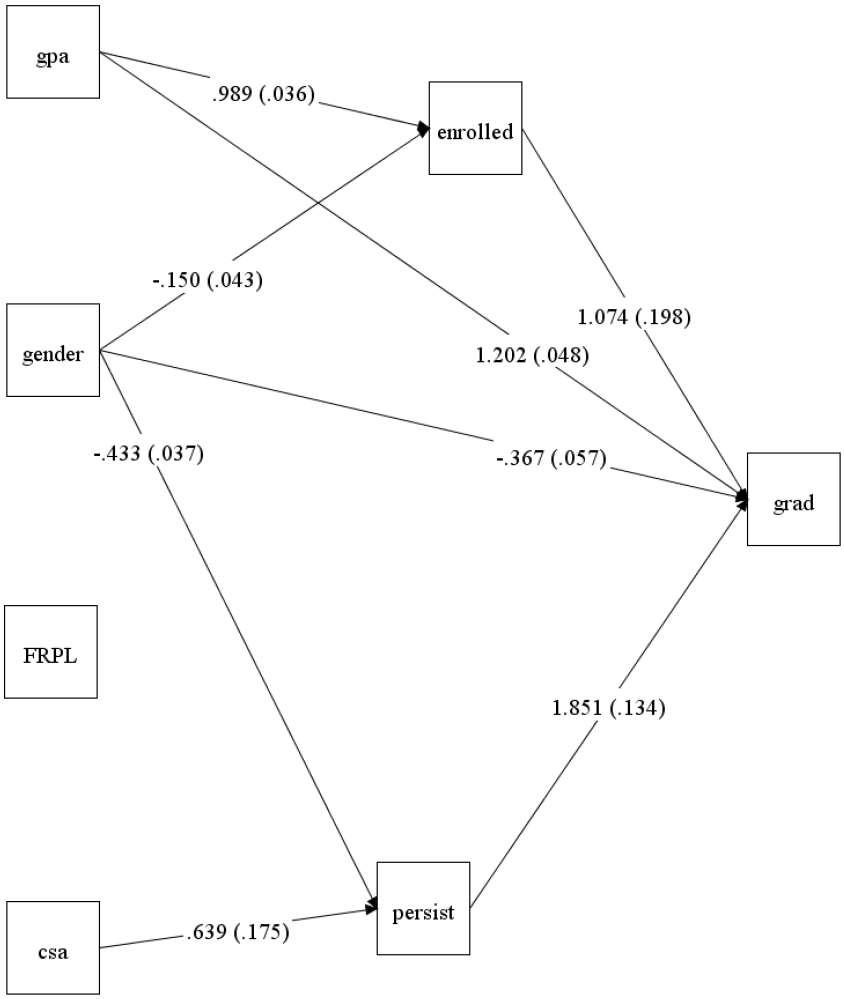


Figure 4. Model Results for District A –URG Students Only

Looking only at URG male students in District A, we found that taking AP Computer Science more than doubled the rate of degree attainment, while controlling for grade point average and poverty (Table 1) using a logistic regression model. This finding indicates that in some cases the impact of taking computer science courses has a direct effect on college graduation in addition to the indirect effect mediated by college persistence, even while controlling for poverty status and academic achievement as measured by grade point average.

| | B | S.E. | WALD | DF | SIG | EXP(B) |
|---|---|---|---|---|---|---|
| **FRPL** | -.102 | .115 | .798 | 1 | .372 | .903 |
| **AP-CSA** | .696 | .237 | 8.627 | 1 | .003 | 2.006 |
| **GPA** | 1.24 | .074 | 278.591 | 1 | <.001 | 3.455 |
| **CONSTANT** | -5.227 | .255 | 418.827 | 1 | <.001 | .005 |
| | | | | | | |

Table 1. Degree Attainment Predicted by FRPL, AP Computer Science, and GPA in District A – URG Male Students Only

*District B – URG Population*

Similarly, taking AP Computer Science increased college persistence for URG students in District B to a greater extent than in District A, as was seen in the general population of students. However, unlike in District A, the impact of taking computer science on persistence for URG students, though substantial, was less than for the general population. In the general population of students, the odds ratio was 2.7, but for the URG students only, the odds ratio was 2.4. This is still a very large effect, indicating that taking AP Computer Science more than doubles the likelihood of college persistence for URG students, but the effect was slightly greater in the general population.

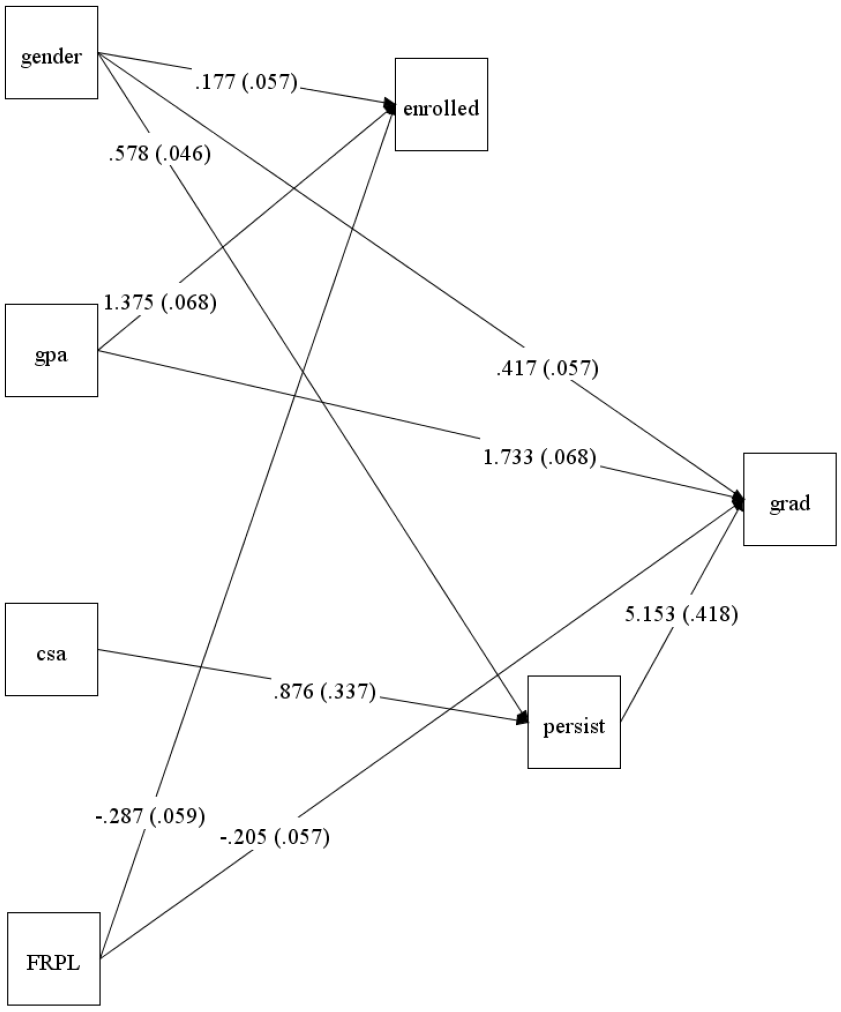


Figure 5. Model Results for District B – URG Students Only

Given the strong effect of GPA on college outcomes, we were particularly interested in understanding whether the impact of taking computer science on college persistence and college graduation held for different sets of students stratified by grade point average and poverty status. Thus, we first separated students into subsets based on cumulative GPA quartiles, and again based on Free or Reduced Price Lunch (FRPL) status, and modeled the relationships separately for each group.

We found that the results we saw in the general population and in the URG population did not necessarily hold for each of the student subsets. For example, the effect of taking computer science

on college persistence and subsequently on college graduation did not appear to be consistent for high and low GPA students. In District A, the mediated relationship held for higher GPA students, but not for lower GPA students. Figure 6 shows the significant paths in the model for those students who were in the upper half of cumulative grade point average. For these students, taking AP Computer Science increased their likelihood of college persistence 43%.

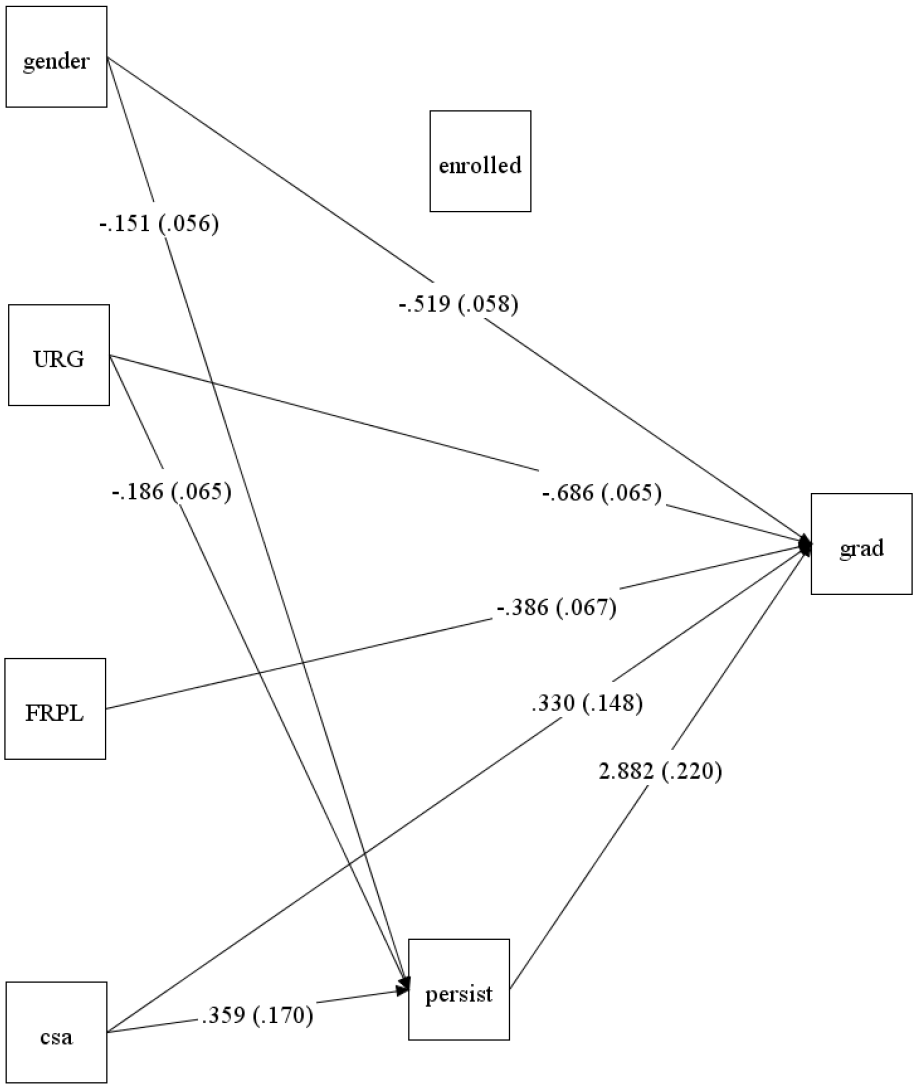


Figure 6. Model Results for District A – Upper Half GPA

Conversely, in District B, the mediated relationship held for only students in the first and second quartiles of cumulative grade point average, or those that were below average in grade point average (see Figure 7). Taking AP Computer Science did not significantly improve the likelihood of persisting in college or college degree attainment for students with higher GPA in District B, but tripled the likelihood of college persistence for lower GPA students. Thus, it appears that the students who benefit from taking AP Computer Science differ between the two districts. Or to state it differently, evidence suggests that taking AP Computer Science courses benefits specific subsets of students differently in varying contexts. This could be the due to the fact that District A has a longer history of offering AP Computer Science A, whereas District B only recently began offering the course more widely throughout the district after partnering for professional development training.

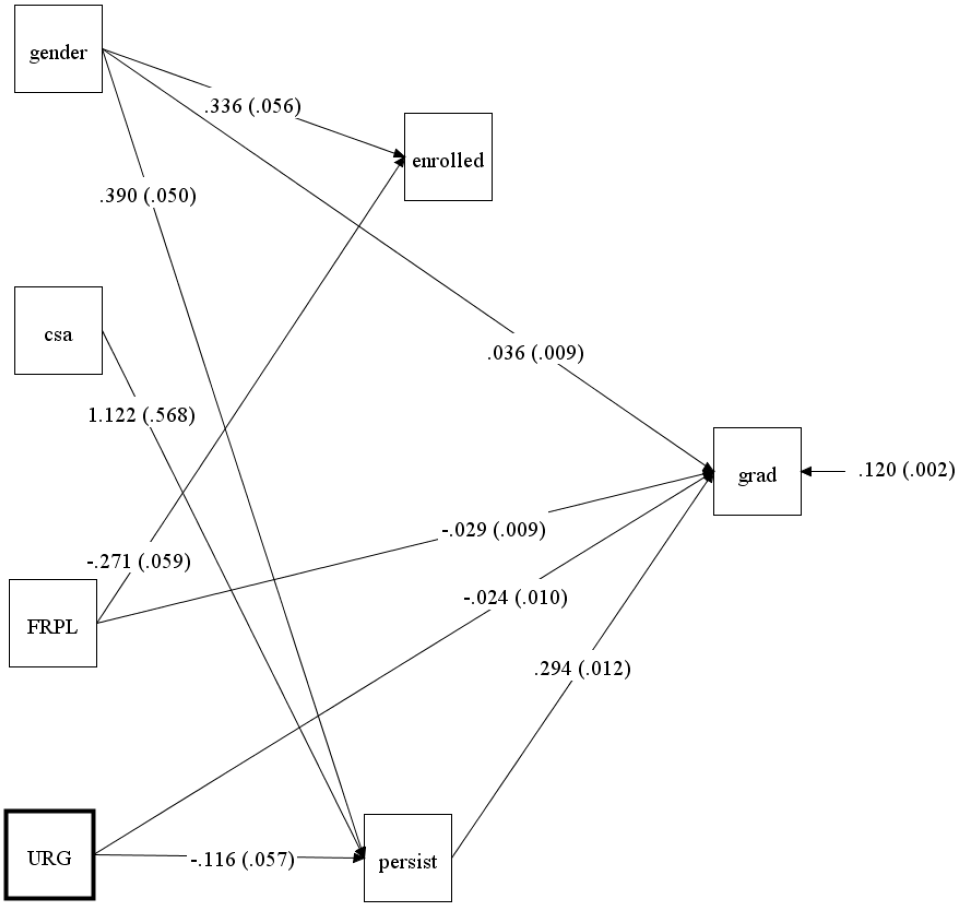


Figure 7. Model Results for District B – Lower Half GPA

When we run the models separately for FRPL students and non-FRPL students, we find differing results. In District A, only in the FRPL sample does taking AP Computer Science statistically improve the likelihood of college persistence, and it does so by a factor of over 2, meaning that FRPL students in District A who took AP Computer Science were twice as likely to persist in college than FRPL students who did not take AP Computer Science. For non-FRPL students in District A, the path from taking AP Computer Science to college persistence was not statistically significant. There was no difference between FRPL and not-FRPL students in District B.

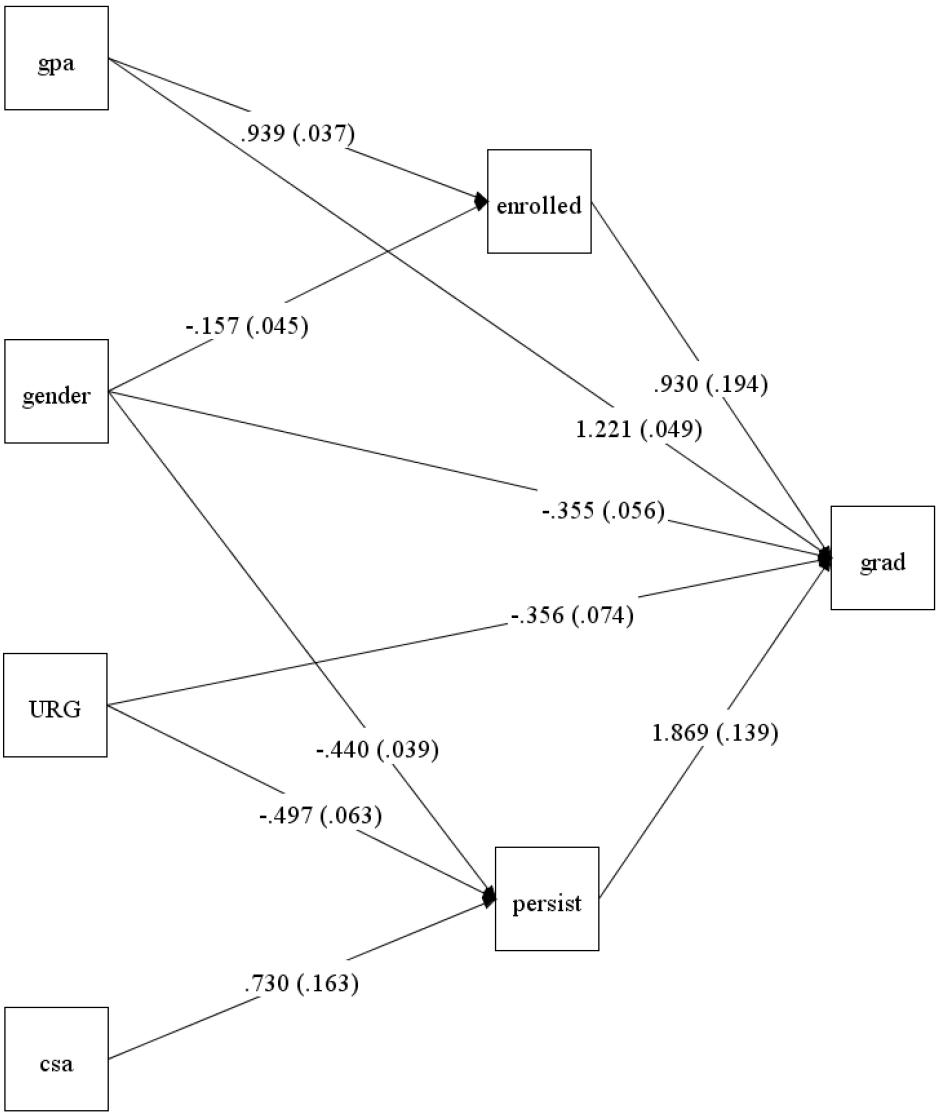


Figure 8. Model Results for District A – FRPL Students

## CONCLUSION

The findings from this study are somewhat mixed and vary by context but they do provide support for the argument that training computer science teachers and increasing students' enrollment in advanced computer science courses leads to positive post-secondary outcomes for students, even while controlling for overall academic achievement, student demographics, and school differences. We find that the impact of advanced coursework in computer science leads to greater persistence in college and ultimately greater likelihood of college degree attainment, but it operates differently for subsets of students in different educational contexts. In one district, the impact is greatest for higher achieving students while in another district, the impact is found for lower achieving students. This may have to do with how the districts recruit students into the courses or with how well the students are supported within the courses. It may also have to do with different histories of Computer Science course availability within each district. District A has a much longer and established history of providing Advanced Placement Computer Science courses to its students, whereas District B only recently began offering district-wide Advanced Placement Computer Science opportunities, mainly as a result of partnering with Code.org to train teachers in Advanced Placement Computer Science Principles and Exploring Computer Science. It would be interesting to delve further into how enrollment patterns for Advanced Placement Computer Science have changed and continue to change within and between these two districts with the introduction of Advanced Placement Computer Science Principles in 2017.

Similarly, the effect of advanced computer science courses was greater for under-represented students in one district, and less so in the other. This may be a sampling variation issue, as schools in District A were comprised of considerably more African-American and Hispanic students than were the schools sampled from District B. This study was limited to a single year of graduating high school seniors from two large districts. It would be helpful to explore the extent to which these relationships hold over other cohorts of students as more time allows for subsequent groups of students to matriculate to a college degree. Further, it is worthwhile to investigate whether and to what extent participation in specific AP Computer Science courses (Computer Science A and/or Computer Science Principles) similarly or differentially impacts post-secondary outcomes, and

how those impacts vary among subsets of students and between districts with different strategies, histories, and practices for enrollment. As post-secondary outcome data for students graduating since 2017 become available in the coming years, the analyses presented here could be extended to address these important questions and gain a better understanding of how Computer Science course-taking affects students' collegiate experience.

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## REFERENCES


Beede, D. N., Julian, T. A., Langdon, D., McKittrick, G., Khan, B., and Doms, M. E., Women in STEM: A Gender Gap to Innovation (August 1, 2011). Economics and Statistics Administration Issue Brief No. 04-11. Available at SSRN: https://ssrn.com/abstract=1964782 or http://dx.doi.org/10.2139/ssrn.1964782

Brown, R., & Brown, E. A. (2019). Estimating the effect of a teacher training program on Advanced Placement outcomes. *International Journal of Computer Science Education in Schools*, 2 (4), 3-21.

Brown, E. A. & Brown, R. (2020). The Effects of Advanced Placement Computer Science Course Taking on College Enrollment. West Coast Analytics Research Report. Fort Worth, TX.

Dodd, B.G., Fitzpatrick, S.J., De Ayala, R.J., & Jennings, J.A. (2002). *An investigation of the validity of AP grades of 3 and a comparison of AP and non-AP student groups* (College Board Research Report No. 2002-9). New York: College Board.

Dougherty, C., Mellor, L. & Jian, S. (2006). The relationship between Advanced Placement and college graduation. (National Center for Educational Accountability: 2005 AP Study Series, Report 1). Austin, TX: National Center for Educational Accountability.

Eimers, M.T., & Mullen, R. (2003). *Dual credit and Advanced Placement: Do they help prepare students for success in college?* Paper presented at the 43rd annual Association of Institutional Research Fall Conference, Tampa, FL.

Geiser, S., & Santelices, V. (2004). *The role of advanced placement and honors courses in college admissions*. Berkley, CA: Center for Studies in Higher Education.

Goode, J. (2007). If You Build Teachers, Will Students Come? The Role of Teachers in Broadening Computer Science Learning for Urban Youth. *Journal of Educational Computing Research*, 36(1), 65-88.

Hargrove, L., Godin, D., Dodd, B. (2008). College outcomes comparisons by AP and non-AP high school experiences (College Board Research Report 2008-3). New York: The College Board.

Klopfenstein, K. (2010). Does the Advanced Placement program save taxpayers money? The effect of AP participation on time to college graduation. In P. Sadler, G. Sonnert, R. Tai, K. Klopfenstein (Eds), *AP: A Critical Examination of the Advanced Placement Program* (pp. 189-218). Cambridge, Massachusetts: Harvard Education Press.

Klopfenstein, K., & Thomas, M.K. (2005). *The Advanced Placement performance advantage: Fact or fiction?* American Economic Association. Retrieved from https://www.aeaweb.org/assa/2005/0108_1015_0302.pdf.

Klopfenstein, K., & Thomas, M.K. (2009). The link between Advanced Placement experience and early college success. *Southern Economic Journal, 75(3)*, 873-891.

Mattern, K.D., Marini, J.P., & Shaw, E.J. (2013). The relationship between AP Exam performance and college outcomes. (College Board Research Report 2009-4) New York: The College Board.

Murphy, D., & Dodd, B. (2009). A comparison of college performance of matched AP and non-AP student groups. (College Board Research Report No. 2009-6). New York: The College Board.

Muthen, L.K., and Muthen, B.O. (1998-2017). Mplus User's Guide. Eighth Edition. Los Angeles, CA: Muthen & Muthen.

Sadler, P. & Sonnert, G. (2010). High school Advanced Placement and success in college coursework in the sciences. In P. Sadler, G. Sonnert, R. Tai, K. Klopfenstein (Eds), *AP: A Critical Examination of the Advanced Placement Program* (pp. 119-137). Cambridge, Massachusetts: Harvard Education Press.

Sadler, P., & Tai, R. (2007). Accounting for advanced high school coursework in college admission decisions. *College and University, 82(4)*, 7-14.

Sax, L. J., Lehman, K. J., Jacobs, J. A., Kanny, M. A., Lim, G., Monje-Paulson, L., & Zimmerman, H. B. (2017). Anatomy of an Enduring Gender Gap: The Evolution of Women's Participation in Computer Science, *The Journal of Higher Education*, 88:2, 258-293, DOI: 10.1080/00221546.2016.1257306

Shaw, E. J., Marini, J. P., & Mattern, K.D. (2013). Exploring the utility of Advanced Placement participation and performance in college admission decisions. *Educational and Psychological Measurement*, 73, 229-253.

Tai, R., Liu, C, Almarode, J., & Fan, X. (2010). Advanced Placement course enrollment and long-range educational outcomes. In P. Sadler, G. Sonnert, R. Tai, K. Klopfenstein (Eds), *AP: A Critical Examination of the Advanced Placement Program* (pp. 109-118). Cambridge, Massachusetts: Harvard Education Press.