Using Placement Scores for AP CSP in Chicago Public Schools

Willow Kelleigh[1]
The Learning Partnership
Chicago IL, USA
wkelleigh@thelearningpartnership.net

Onur Ramazan
Washington State University
Pullman WA, USA
onur.ramazan@wsu.edu

Steven McGee
The Learning Partnership
Chicago IL, USA
mcgee@lponline.net

Abstract

In Chicago Public Schools there is a need to provide guidance to schools on placing students into an intro-level CS class (ECS) or the more difficult AP CSP as a student's first CS class. Previous work created a placement exam based on the ECS curriculum to identify students prepared for AP CSP without taking ECS. This analysis found that after controlling for many variables including GPA, attendance at a selective enrollment school, and perceived value of CS, that the placement score was positively associated with the probability of a student passing the AP CSP exam.

CCS Concepts

• **Social and Professional Topics → Professional topics;** *Computing Education*; Student Assessment; K-12 Education; Computational Thinking

Keywords

AP Computer Science Principles, Exploring Computer Science, Generalized Mixed Model, Placement Scores, Chicago Public Schools

ACM Reference format:

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1 Introduction

Chicago Public Schools (CPS) enacted a computer science graduation requirement in 2016 to broaden computer science education in CPS [1]. Currently there is not a standardized method used to determine which CS class CPS students should take as their first high school CS class that fulfills the requirement: the higher-level AP CSP class or the standard introductory course, *Exploring Computer Science* (ECS). While both courses have been designed to support students with no prior experience in computer science, there is a need to better understand the extent to which prior computer science knowledge does contribute to success in the AP CSP exam over and above general academic performance. The use of GPA as the only indicator of AP preparedness can create bias, as student demographics have been found to correlate with general academic performance [2].

Previous research by McGee, Smith et al. [2021] created a placement exam based on the ECS curriculum to be used for informing schools on placing students directly into AP CSP, based on the likelihood that students would pass the AP CSP exam if they did well in the class. The placement exam questions were written by CPS teachers, who were trained in question writing for a computational thinking practices framework [4]. See McGee, Smith et al. [2021] for initial validation. Our analysis here focuses on whether these placement scores are correlated with AP CSP exam performance as a domain-specific proxy for whether students are prepared for AP CSP, after controlling for relevant variables related to general academic performance, such as GPA.

2 Theoretical Framework

The present study has been grounded in the CAPE Framework [5]. The CAPE framework frames equity in computer science education through four interconnected components: Capacity, Access, Participation, and Experience. Our prior work has examined how school Capacity factors correlate with Access to AP CSP in CPS [6], which found that the percentage of students with disabilities at a school is associated with a decreased probability of having Access to AP CSP.

In this study, we focus on CPS schools that provide Access to both ECS and AP CS. Schools need guidance on which course students should Participate in as their first Experience with CS. If students are placed into the AP class in lieu of ECS when they are not yet ready for AP coursework, it could be a negative Experience and reduce their interest in pursuing additional computer science [7, 8]. Alternatively, for students who are not ready for AP, they can take ECS and will likely be inspired to take additional coursework [9] and may be better prepared for AP coursework [10].

[1]Corresponding author

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This study is also grounded in Kolluri's [2018] research on equitable AP outcomes, which overlaps with the Experience dimension of the CAPE framework. The Experience dimension of the CAPE framework focuses on how students' experiences with AP coursework influence their cognitive and affective outcomes. Kolluri [2018] has developed three hypotheses from the literature that might explain why there are persistent disparities in AP performance by race/ethnicity. (1) Underrepresented students may not benefit from AP because they are not prepared for college-level work. (2) The quality of instruction may be lower for underrepresented AP students. (3) AP is a component of social reproduction in which low-income students do not have the family resources to be successful in AP, thus limiting their higher education opportunities. Kolluri [2018] has argued that "*More research is needed to determine which, if any, of the aforementioned interpretations of the challenges of AP aligns most closely with reality.*" (p. 32) Our research here primarily focuses on examining factors that predict success on the AP CSP exam that could be used as measures for preparedness. Having validated measures of preparedness would be essential for investigating Kolluri's [2018] 1st hypothesis related to preparedness for college-level work. Secondarily, after controlling for preparedness, we can identify demographic factors in which there are still differences in performance on the AP CSP exam that cannot be explained by preparedness. These results would point to factors that need further research to provide evidence related to Kolluri's [2018] 2nd and 3rd hypotheses.

3 Research Question

The following main research question has guided the present study:

RQ: After controlling for relevant variables such as GPA, CS attitudes, socioeconomic status, and student demographic background, do scores from the placement test described in McGee, Smith et al. [2021] predict AP CSP performance? In other words, can the placement exam be used as an indicator of preparedness?

4 Positionality Statement

The first author is a researcher primarily trained in statistical methods, identifies as a white woman, and has experienced both advantageous and disadvantageous bias in STEM and CS education. The second author is an ethnic and language minority who completed a doctoral degree in the United States as a first-generation college student. The third author is trained in the learning sciences and identifies as a Caucasian and Hispanic man.

The authors strived to undertake this study without bias or preconceptions affecting their decisions, but we acknowledge the possibility of this despite our efforts due to the inherent nature of past experiences shaping our current actions. We also acknowledge that this data is not ours, that it belongs to the CPS students, which CPS has generously allowed us to use, and that each number represents a student.

5 Research Methods

The present study examines the factors that are related to student success in the AP Computer Science Principles (AP CSP) exam with a particular focus on the placement score and students' perceived value of CS. A theory-based model was developed to assess whether these predictors remained statistically significant after controlling for variables such as GPA, absenteeism, socioeconomic status (SES), sex and race/ethnicity by using data from both the 2021-22 and 2022-23 school years. A Generalized Mixed Model (GMM) was employed to account for both student- and teacher-level variance.

5.1 Data Collection and Participants

The dataset spans the 2021-2022 and 2022-2023 academic years. Through a data share agreement, CPS provided the authors with the administrative data about students, teachers and schools used here. All scales, procedures and data on the demographic variables were determined and collected by CPS. As part of the validation of the placement exam, teachers voluntarily administered the exam at the beginning of their AP CSP class. The study initially included approximately 5,000 students but was reduced to a final sample due to missing placement score data and other constraints. The final analytic sample consisted of 1,723 students taught by 36 teachers across 24 high schools. The sample was not fully representative of the broader population of students taking AP Computer Science Principles (AP CSP) as indicated by a lower pass rate of 42% compared to the district-wide average of 56%, as well as differences in other variables such as attendance, several school services, and sex, among others.

5.2 Variables

The present study examined various student-level binary and continuous variables including GPA, placement scores, absenteeism, demographic characteristics and AP CSP performance, and one teacher-level variable concerning AP CSP PD. A school level variable was treated as being at the teacher-level (school type) due to the limited number of AP CSP teachers at each school. Some variables were excluded due to conceptual redundancy, insufficient data or model convergence issues. Among these variables were student SPED status, which could not be added due to model convergence issues. The primary focus was on the placement score and the value construct as key predictors of AP CSP exam success, which CPS defines as earning a score of 3 or higher on the exam.

To better understand the data used in the model, a summary of the averages of the variables used is listed below:

- Average cumulative weighted GPA of 4.23 (scale 0-6)
- On average absent 16.7 days
- Average CS value construct of 4.84 (scale 1-6)
- Average placement score of 16.01 (scale 0-25)
- On average received A's both semesters of CSP (50.3%)
- On average female (52.1%)
- On average receives foodservice (60.1%)
- On average not ESL (93.2%)
- On average Hispanic (plurality of 45.7%)
- On average has not taken ECS before (62.0%)
- On average has a teacher who has taken CSP PD (91.5%)

The extent to which students expect to do well in a particular subject and the extent to which they value that subject are both predictive of the probability that students will pursue a career in that domain [14]. The CS value construct controls for the student's level of motivation in CS. We excluded the expectancy construct from our analysis due to convergence issues. The sex variable dimensions are limited to either male, female, or not provided based on how CPS records that information for each student. At the time of this study, CPS did not provide options for other genders to be recorded. The foodservice variable is dummy coded as 1 if students are eligible for free or reduced priced lunch. This variable serves as a proxy for SES. English as a Second Language (ESL) is a district-level designation for students who are receiving bilingual services. Race/ethnicity is reported by CPS. A student is reported by CPS as belonging to one race/ethnicity or is reported as belonging to more than one race/ethnicity. CPS is an open choice district. Students can attend the high school within their attendance boundary or can apply to a school outside their attendance boundary. If a school outside their attendance boundary is oversubscribed, students are admitted on a lottery basis, except for eleven selective enrollment high schools that admit students based on test scores and eighth grade performance.

5.3 Data Operations

Data preprocessing involved variable type adjustments, factor consolidation, removal of duplicates. Checks for multicollinearity were conducted to reveal moderate correlations between weighted GPA and other variables such as absenteeism, race/ethnicity and selective school enrollment. However, since we included variables on a theoretical basis we proceeded with the analysis, as recommended by Kalnins and Praitis Hill [2023]. Variables were centered at the grand mean.

5.4 Data Analyses

The present study employed a Generalized Mixed Model (GMM) by using Jamovi software (version 2.5.7) to account for both fixed and random effects with teachers as a random variable to measure between-classroom differences. The analysis was conducted at both student and teacher levels to capture variance at different levels of the educational system.

A theory-based model was developed to assess the significance of placement scores and the value construct in predicting AP CSP exam success while controlling for other student and school-level variables.

6 Results

The null (i.e., unconditional) model revealed that 53.5% variance lied across the teachers (Fixed intercept = −0.830, $p < 0.001$; Random variance = 3.79, Residual variance = 3.29, ICC = 0.535; $R^2 = 0.535$). That is, the null model indicated that there was a significant clustering effect in the data. Thus, pursuing the multilevel modeling approach was supported.

The results of the multilevel binary logistic regression predicting whether a student passes the AP CSP exam are presented in **Table 1**. The full model revealed that 24% variance lied across the clusters (Fixed intercept = −1.36, p = 0.002; Random variance = 1.04, Residual variance = 3.29, ICC = 0.240; $R^2 = 0.704$). The full model (*AIC* = 1237.75, *BIC* = 1319.53, *Deviance* = 1207.75) showed better model fit than the null model (*AIC* = 8148.20, *BIC* = 8162.37, *Deviance* = 8144.20) and a significant amount of reduction in deviance.

The model intercept was significant ($\beta = -1.36$, $SE = 0.45$, $\text{Exp}(B) = 0.25$, $p = 0.002$) which could suggest a baseline log-odds of passing the exam when all predictors are at a grand mean of zero. The main predictor of interest was the placement scores as aforementioned. Placement score was positively associated with passing the AP CSP exam ($\beta = 0.16$, $SE = 0.02$, $\text{Exp}(B) = 1.00$, $p < 0.001$). That is, higher placement scores predicted an increased likelihood of success in AP CSP. In what follows, we report the results for the control variables. Sex was a significant predictor with male students being more likely to pass than female students ($\beta = 0.52$, $SE = 0.16$, $\text{Exp}(B) = 1.67$, $p = 0.001$). Selective school enrollment had a strong positive effect ($\beta = 1.95$, $SE = 0.45$, $\text{Exp}(B) = 7.02$, $p < 0.001$), suggesting that students attending selective schools are significantly more likely to pass. Additionally, earning all A's in AP CSP coursework significantly increased the odds of passing ($\beta = 1.47$, $SE = 0.19$, $\text{Exp}(B) = 4.36$, $p < 0.001$). Cumulative GPA was another significant predictor ($\beta = 1.29$, $SE = 0.19$, $\text{Exp}(B) = 3.64$, $p < 0.001$) which reinforces the role of overall academic performance in predicting success.

Hispanic or Latinx students were significantly less likely to pass compared to non-Hispanic students ($\beta = -0.36$, $SE = 0.18$, $\text{Exp}(B) = 0.71$, $p = 0.051$) although this effect was only marginally significant. The value construct was positively associated with passing ($\beta = 0.15$, $SE = 0.08$, $\text{Exp}(B) = 1.17$, $p = 0.046$). Lastly, students identified as English as a Second Language (ESL) learners

were significantly less likely to pass (β = −1.01, SE = 0.42, Exp(B) = 0.71, p = 0.051) although this effect was only marginally significant. The value construct was positively associated with passing (β = 0.15, SE = 0.08, Exp(B) = 1.17, p = 0.046). Lastly, students identified as English as a Second Language (ESL) learners were significantly less likely to pass (β = −1.01, SE = 0.42, Exp(B) = 0.37, p = 0.017). None of the other variables in the model significantly predicted passing the AP CSP exam (ps > 0.05).

The model's estimated impact of varying placement score is illustrated in **Figure 1**, with all other variables set to the sample average described in section 5.2. It is a graph showing placement score against the model's predicted probability of passing the AP CSP exam and depicts an increasing and slightly S-curved line where the minimum placement score of 0 corresponds to about an11% probability and the maximum score of 25 corresponds to about an 87% probability of passing.

Variable	***Label***	***Estimate***	***SE***	***Exp(B)***	***p***
Intercept	*Intercept*	-1.36	0.45	0.25	0.002
Sex	*Female vs Male*	0.52	0.16	1.67	0.001
Absent days	*Absent days*	-0.002	0.01	1.00	0.786
Selective enrollment	*False vs True*	1.95	0.45	7.02	<0.001
ECS class timing	*Not taken vs Taken*	0.21	0.18	1.23	0.239
All A's	*False vs True*	1.47	0.19	4.36	<0.001
Weighted cumulative GPA	*Weighted cumulative GPA*	1.29	0.19	3.64	<0.001
Hispanic/Latinx	*False vs True*	-0.36	0.18	0.71	0.051
Black/African American	*False vs True*	-0.31	0.31	0.70	0.252
Food service status	*False vs True*	-0.20	0.17	0.82	0.244
CSP professional development	*Not taken vs Taken*	-0.53	0.72	0.59	0.464
English language status (ESL)	*False vs True*	-1.01	0.42	0.37	0.017
EV value construct	*EV value construct*	0.15	0.08	1.17	0.046
Placement score	*Placement score*	0.16	0.02	1.18	<0.001

Table 1. Generalized Mixed Model Results

7 Discussion

Our findings show that the placement scores give valuable insight into the interaction between two of the CAPE dimensions: Participation and Experience. These results are informative for defining a preparedness construct that could be used to investigate Kolluri's [2018] 1st hypothesis related to underrepresented students not being prepared for AP coursework. The placement exam score is significantly positively correlated with the likelihood of passing the AP CSP exam even after accounting for other common variables schools have access to when placing students into AP classes, namely GPA and attendance.

Attendance was found to not correlate with AP CSP exam performance while GPA was found to correlate with AP CSP exam performance. Our findings suggest that GPA is useful alongside the placement exam when considering AP CSP placement. In other words, our model suggests that students with high general academic performance as measured by GPA and low domain-specific ability levels as measured by the placement exam, and students with low general academic performance but high domain-specific ability levels both have high probabilities of passing the AP CSP exam.

Furthermore, whether students had prior computer science exposure through ECS is not predictive of AP CSP exam success. These results provide evidence that AP CSP can be accessible to students with limited prior background in computer science. Similarly, teacher CSP PD was not found to correlate with AP CSP exam success, which could suggest that our findings are applicable across teacher-specific contexts. Prior research places importance on CSP PD, so our findings indicate future research is

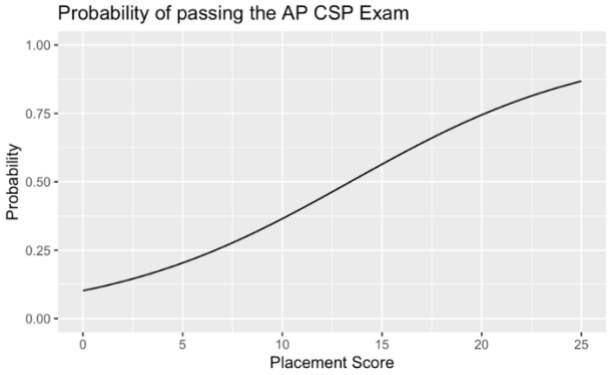

Figure 1. Probability of Passing the SP CSP Exam by Placement Score

needed to examine the relationship between the quality of teachers' PD experiences at AP CSP exam performance [16].

Our findings also show that a student's initial perceived value of CS is a predictor of AP CSP exam success after controlling for GPA and placement exam performance. This finding points to the importance of students' attitudes towards computer science in contributing to success in computer science. Overall, the combination of GPA, placement exam score, and perception of computer science value could serve as useful indicators of preparedness in deciding upon a students' first computer science course, as well as for future research disambiguating Kolluri's [2018] 1st hypothesis from the other hypotheses.

In this research, we did not focus on Kolluri's [2018] 2nd hypothesis related to the quality of the students' Experiences in the class. However, by controlling for indicators of preparedness, we can identify factors related to students' experiences that warrant further study. AP CSP class grades and the type of school a student attends is predictive of AP CSP exam success. Female students had lower AP CSP exam scores than male students. Hispanic/Latinx students, Black/African American students, and English Language Learners all had lower probability of AP CSP exam success. However, the difference for Black/African American students was not statistically significant and the result for Hispanic/Latinx students was marginally statistically significant. Since the model accounts for indicators of preparedness, these findings point to the possibility that the quality of the classroom experience is different for those groups of students.

There was one indicator of socioeconomic status that was included in the model that can provide evidence for Kolluri's [2018] 3rd hypothesis related to social reproduction. The results show that participation in the Free/Reduced Lunch program is not a statistically significant predictor of AP CSP exam success. These results do not provide evidence for Kolluri's 3rd hypothesis in this context.

7.1 Limitations and Future Directions

Every research has limitations, and the present study is not different. First, this study focused on schools that offered both an introductory CS class and AP CSP. The focus of the study is providing evidence to optimize the placement for a student's first computer science experience. It would be challenging to generalize these findings to contexts that only offer AP CSP, where the placement choice is between AP CSP or no computer science. Further research is needed to understand school decision making in the context of access to only AP CSP.

Second, this research was primarily focused on developing indicators of AP CSP preparedness. The results related to Kolluri's [2018] 2nd and 3rd hypotheses were secondary to the focus of this study and should be considered preliminary results that can inform future research. Furthermore, participation in the Free/Reduced Price lunch program is limited as an indicator of socioeconomic status [17]. It is possible that there may better indicators of SES than the use of FRL.

Third, the data used in the present research were temporally constrained, covering the period from the 2021–2022 school year to the 2022–2023 school year. Future research could incorporate additional data sources to provide a more complete picture of long-term trends.

Fourth, the analyses conducted in the present study are correlational in nature which limits the ability to infer causal relationships between variables. While significant associations may suggest meaningful patterns, they do not establish directionality or underlying mechanisms. Future research could employ experimental designs to better understand causal pathways and the potential mediating or moderating factors that may have been related to the observed relationships.

Fifth, the data used in the present study may not be fully representative of the broader student population, either in CPS or on a larger scale; given the unique context of a CS graduation requirement in CPS, this may limit the generalizability of these results to districts that do not have a CS graduation requirement. Future studies should consider using nationally representative samples or applying statistical techniques to adjust for potential biases to enhance the external validity of the results.

7.2 Relationship to Policy and Practice

As a work in progress, we are currently working with CPS to investigate how placement scores could be combined with GPA and measures of students' CS attitudes to inform schools on placing students in their first computer science class. We hope that in the future students may benefit from placement into a first CS experience that optimizes both their potential for success and the potential to be inspired to take more computer science classes.

We also want to highlight that students' initial perceived value of CS is predictive of success on the AP CSP exam. Our prior research has shown that helping students make connections between their CS course and their lives increases their perceived value of computer science [18]. Future research could examine whether spending classroom time developing students' perceptions of the value of CS also correlates with success on the AP CSP exam.

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