School-level Predictors of Offering AP CSP in Chicago Public Schools over Time: A Multilevel Approach

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Abstract

The present study examines trends and factors related to the likelihood of offering Advanced Placement Computer Science Principles courses in the Chicago Public Schools from the 2016-2017 to 2022-2023 school years. The number of schools offering Advanced Placement Computer Science Principles courses increased significantly during this period from 12 schools in the 2016-2017 school year to 34 in the 2022-2023 school year. A multilevel binary logistic regression analysis was conducted to examine the contributions of school demographics and school capacity to the likelihood of offering Advanced Placement Computer Science Principles courses. The findings showed that schools with a higher percentage of Asian students were more likely to offer Advanced Placement Computer Science Principles courses while schools with a higher percentage of special education students, students eligible for free or reduced lunch and Hispanic or Latinx students were less likely to offer Advanced Placement Computer Science Principles courses. In terms of school capacity, the presence of qualified Advanced Placement Computer Science Principles or Exploring Computer Science teachers, larger school size and strong teaching practices significantly increased the likelihood of offering Advanced Placement Computer Science Principles courses. Conversely, higher family involvement was found to slightly reduce the likelihood of offering Advanced Placement Computer Science Principles courses. The implications for policymakers as well as the limitations and future directions are discussed.

Keywords: Advanced Placement Computer Science Principles; School demographics; School capacity; Chicago Public Schools, Multilevel Modeling

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1 Introduction

Each year, about 18,000 students in the Chicago Public Schools graduate with one year of high school computer science credit in fulfillment of the district's computer science graduation requirement. This accomplishment was the culmination of over a decade of work by the Chicago Public Schools in collaboration with university computer science faculty and educational researchers. In 2012, the Chicago Public Schools was the first school district to adopt the Exploring Computer Science curriculum and professional development program outside of Los Angeles, where it originated. After four years of pilot implementation, less than half of the schools in the Chicago Public Schools offered any computer science course. Nevertheless, the Chicago Public Schools introduced a high school computer science graduation requirement in 2016 with the Exploring Computer Science serving as the foundational course for the requirement. After four years of implementation of the graduation requirement policy, all the Chicago Public Schools high schools in the Chicago Public Schools offered enough sections of computer science, mainly the Exploring Computer Science so that all students could fulfill the graduation requirement [13]. The Exploring Computer Science course instilled a desire in many students to take additional coursework [12]. However, less than half of the high schools in the Chicago Public Schools offer additional coursework to fulfill this desire.

While Advanced Placement Computer Science Principles course was developed to attract broader participation of students underrepresented in computer science coursework, access to the Advanced Placement Computer Science Principles course within the Chicago Public Schools remains limited despite the existence of the Exploring Computer Science in every high school in

the Chicago Public Schools. Unfortunately, there are too many of the Chicago Public Schools' schools where students do not have access to additional computer science courses. This is particularly acute for Advanced Placement computer science, where, like other Advanced Placement subject areas, racial and ethnic disparities remain in terms of access and outcomes. Eight of the eleven specialized, selective enrollment Chicago Public Schools high schools offer the Advanced Placement Computer Science Principles course. In contrast, only about one quarter of the 82 Chicago Public Schools neighborhood high schools offer the Advanced Placement Computer Science Principles course and these schools serve higher percentages of Black or African American and Hispanic or Latinx students than the selective schools do [1, 6, 14].

1.1 Theoretical Framework

The present study has been grounded in the CAPE (Capacity for, Access to, Participation in and Experiences of Computer Science education) framework [5] to understand how the context of Advanced Placement implementation fosters or impedes equity in access and outcomes for Advanced Placement Science, Technology, Engineering and Mathematics in the Chicago Public Schools. Disparities in Advanced Placement participation can in many cases be explained by disparity in Access to the range of Advanced Placement courses available at schools. As discussed above, Black students are less likely to attend a high school that offers Advanced Placement computer science [11]. Access to Advanced Placement coursework is dependent upon the Capacity of a school to offer the courses. Prior research has shown that some of the factors that influence the capacity to offer AP include (a) school size, with larger schools being more likely to offer [17], (b) average 8th grade standardized test performance of the high school student body, with higher average performance associated with higher likelihood of

offering Advanced Placement [7] and (c) the number of qualified teachers being associated with offering Advanced Placement [11].

1.2 Review of Relevant Literature

Within the Chicago Public Schools, the Chicago Alliance for Equity in Computer Science (CAFÉCS) research has found that the relationship between taking either a non-Advanced Placement introductory computer science class, like Exploring Computer Science, or taking Advanced Placement Computer Science Principles and the probability of majoring in computer science is similar [10]. For students who took only Exploring Computer Science or Advanced Placement Computer Science Principles, there is a statistically significant probability of majoring in computer science, but the predicted probability is below the national average of computer science bachelor's degrees. However, taking both Exploring Computer Science and Advanced Placement Computer Science Principles increases the probability of completing a bachelor's degree in computer science above the national average.

Research on Advanced Placement Computer Science A has shown a strong relationship with majoring in computer science [15, 16]. However, Advanced Placement Computer Science A is one of the least diverse Advanced Placement courses, with primarily white and Asian males taking the class. Given the preponderance of evidence that successful completion of AP courses is predictive of selection and completion of a Science, Technology, Engineering and Mathematics college major, it is important to understand the factors that contribute to inequities in access to and success in Advanced Placement Science, Technology, Engineering and Mathematics courses in high schools.

The implementation of the computer science graduation requirement has also led to an expansion of Advanced Placement computer science within the Chicago Public Schools,

particularly Advanced Placement Computer Science Principles. However, less than half of the high schools in the Chicago Public Schools offer any advanced computer science coursework beyond the required introductory course. The Chicago Public Schools' Hispanic or Latinx students participate in Advanced Placement Computer Science Principles at a rate similar to their overall district representation [14]. However, Black or African American students are underrepresented in Advanced Placement Computer Science Principles.

The College Board, in collaboration with the computer science education community, developed the Advanced Placement Computer Science Principles course as a means to broaden participation in Advanced Placement computer science.

1.3 Present Study

Grounded in the CAPE Framework, the present study aims to examine the factors that are related to the likelihood of the offering of Advanced Placement Computer Science Principles courses in the Chicago Public Schools across the 2016-2017 to 2022-2023 school years. Specifically, the present study focuses on two primary areas: (1) how school demographics including racial/ethnic composition, socioeconomic status, bilingual status and special education status are associated with the likelihood of offering Advanced Placement Computer Science Principles course and (2) how school capacity factors such as teacher qualifications, school size and school climate contribute to the likelihood of the offering of Advanced Placement Computer Science Principles courses. To address these questions, a multilevel binary logistic regression approach is employed to account for the nested structure of the data with schools nested within school years. Therefore, the following research questions have guided the present study:

RQ1: To what extent are the school-level demographic factors associated with the likelihood of the offering of Advanced Placement Computer Science Principles courses in the Chicago Public Schools?

RQ2: To what extent are the school-level capacity factors associated with the likelihood of the offering of Advanced Placement Computer Science Principles courses in the Chicago Public Schools?

2 Methods

2.1 Data

Through a data share agreement, the Chicago Public Schools provided the data for the use in the present study. The data used in the present study comprised 110 schools in the Chicago Public Schools in the school years ranging from 2016-2017 to 2022-2023. As such, the schools were nested within the 7 school years. In terms of the school type, 66.4% were neighborhood schools (N = 73), 10% were selective schools (N = 11), 11.8% were Officer Candidate Schools (N = 13), 8.2% were Science, Technology, Engineering and Mathematics schools (N = 9) and 3.6% were specialty schools (N = 4).

2.2 Variables

Dependent Variable. The primary dependent variable of the present study was offering Advanced Placement Computer Science Principles courses in the Chicago Public Schools. It was dummy-coded into two main categories (0 = *School did not offer an Advanced Placement Computer Science Principles course*; 1 = *School offered an Advanced Placement Computer Science Principles course*).

Variables in school demographics model. The school demographics model consisted of the demographic information of the schools in the Chicago Public Schools. All variables in this

model were continuous. More specifically, the following race/ethnicity variables were included in the school demographics model: the percentage of White students (M = 5.47, SD = 10.34), the percentage of Hispanic/Latinx students (M = 42.41, SD = 38.18), the percentage of Native American/Alaskan students (M = 0.23, SD = 0.31), the percentage of Asian/Pacific Islander students (M = 0.01, SD = 0.05), the percentage of Black/African American students (M = 34.25, SD = 32.79), the percentage of Multiracial students (M = 0.73, SD = 1.01), the percentage of Asian students (M = 2.35, SD = 4.97), the percentage of Hawaiian/Pacific Islander students (M = 0.12, SD = 0.24), and the percentage of not reported race/ethnicity students (M = 0.34, SD = 1.11). Additionally, the following status-related variables were included in the school demographics model: the percentage of bilingual students (M = 0.12, SD = 0.13), the percentage of special education students (M = 0.22, SD = 0.18) and finally the percentage of students who were eligible for free or reduced lunch (M = 0.82, SD = 0.17) where this variable was used as a proxy for the schools' socioeconomic status. The reported means and standard deviations represented all schools across all school years.

Variables in school capacity model. The school capacity model included variables that represented the structural, instructional and resource-based capacity of schools to offer Advanced Placement Computer Science Principles courses in the Chicago Public Schools. School size was a continuous variable and was measured as the total student enrollment (M = 751.12, SD = 751.80). The presence of qualified computer science teachers was captured using two binary variables: whether a school had at least partially qualified Exploring Computer Science (ECS) teachers (0 = *Absence* [N = 190], 1 = *Presence* [N = 554]) and whether it had at least partially qualified Advanced Placement Computer Science Principles teachers (0 = *Absence* [N = 354], 1 = *Presence* [N = 390]). To be considered at least partially qualified, the Exploring Computer

Science and Advanced Placement Computer Science Principles teachers must have at least attended the summer workshop related to the course. To be considered fully qualified, the teachers must have attended all of the subsequent school year in addition to the summer workshop or if they were endorsed in computer science. Additionally, the school capacity model incorporated several continuous measures derived from the 5Essentials framework [2] which assessed key aspects of school climate. These variables included effective leaders (M = 52.37, SD = 15.78), collaborative teachers (M = 57.49, SD = 14.79), involved families (M = 56.47, SD = 19.92), supportive environment (M = 52.85, SD = 14.09) and ambitious instruction (M = 59.73, SD = 15.59). These variables were used to evaluate the extent to which school capacity contributed to the likelihood of offering Advanced Placement Computer Science Principles courses across different school years. The 5Essentials variables are scaled on a rage of 0 to 100. The reported means and standard deviations represented all schools across all school years.

2.3 Data operations

As aforementioned, the data used in the present study was provided by the Chicago Public Schools. Following obtaining the data, a data cleaning and management procedure was applied. For instance, some of the continuous variables (e.g., the number of at least partially qualified Advanced Placement Computer Science Principles teachers) were re-coded as binary categorical variables (e.g., 0 = *Absence of at least partially qualified Advanced Placement Computer Science Principles teachers*; 1 = *Presence of at least partially qualified Advanced Placement Computer Science Principles teachers*). Missing cases in the dataset were imputed by using a Fully Conditional Specification [4] with a single iteration and 10 imputations. This method was selected as it is an appropriate missing data imputation method for multilevel data as well as both categorical and continuous variables [4]. Finally, the predictor variables were

centered prior to multilevel modeling analyses in order to obtain a meaningful and interpretable zero point [3].

2.4 Data analysis

Two main analytical approaches were pursued in the present study: (1) A descriptive approach, and (2) A multilevel approach.

Descriptive approach. The descriptive approach aimed to provide a general overview and trend of Advanced Placement Computer Science Principles course offerings across schools in the Chicago Public Schools from the 2016-2017 to 2022-2023 school years. Frequency counts were utilized to summarize the number of schools offering and not offering Advanced Placement Computer Science Principles across school years. A bar chart was generated to depict changes in course availability across the years to visually represent these trends. Finally, A Pearson chi-squared test (χ^2) was conducted to examine the association between school years and the offering of Advanced Placement Computer Science Principles courses. This test determined whether the observed trends in Advanced Placement Computer Science Principles course offerings over time were statistically significant and assessed the strength of association using the Phi coefficient as the effect size measure. The analyses in the descriptive approach were performed in SPSS v25 [8].

Multilevel approach. A multilevel binary logistic regression analysis was conducted to account for the nested structure of the data (i.e., schools within school years). This approach allowed for the examination of year-level variance in the likelihood of offering Advanced Placement Computer Science Principles courses. An unconditional model (i.e., null model) was first fit to estimate the baseline variance attributed to school years. The null model provided an intraclass correlation coefficient (ICC) to assess the extent of clustering in the data. Two

conditional models were subsequently specified to identify predictors of Advanced Placement Computer Science Principles course offerings. Two separate conditional models were fitted: (1) school demographics model and (2) school capacity model. It is because school demographics and school capacity are distinct dimensions that are related to educational offerings. Demographic variables (such as racial/ethnic composition, socioeconomic status, and special education enrollment) reflect the student population's characteristics while school capacity variables (such as teacher qualifications, school size, and school climate) reflect the school's resources and infrastructure. By keeping these factors in separate models, we ensure a clearer understanding of how each dimension independently contributes to the likelihood of offering Advanced Placement Computer Science Principles courses. Additionally, we can more accurately evaluate the unique contributions of each set of predictors while minimizing potential collinearity between them by modeling the demographic and capacity variables separately. School demographics and school capacity may be highly correlated and including both in a single model could lead to issues of multicollinearity which would complicate interpretation of the coefficients.

First, the school demographics model examined the role of demographic variables such as racial/ethnic composition, socioeconomic status (e.g., percentage of free/reduced lunch), and percentage of bilinguals and students in special education. Second, the school capacity model included variables related to school capacity such as teacher qualifications, school size, and school climate indicators (e.g., 5Essentials measures). Both conditional models were evaluated for fit using Akaike Information Criterion (AIC), Bayesian Information Criterion (BIC) and deviance reduction compared to the unconditional model. Fixed effects were interpreted to determine the significance and direction of predictors while random effects assessed residual

variance across school years. The analyses in the multilevel approach were performed in Jamovi v2.3.28 [9].

3 Results

3.1 Preliminary Results

Descriptive statistics and visualization. The frequency analysis and bar chart illustrated the number of schools offering and not offering Advanced Placement Computer Science Principles courses in the Chicago Public Schools from the 2016-2017 to the 2022-2023 school years. Beginning in 2016-2017, a few schools (i.e., 12 schools) started offering the course and this number increased steadily each year. By the 2022-2023 school year, 34 schools offered Advanced Placement Computer Science Principles while 72 did not. It should be emphasized that access to Advanced Placement Computer Science Principles courses in the Chicago Public Schools continued to grow even during the pandemic years.

Pearson chi-squared test. The Pearson chi-squared test (χ^2) results (Table 1) indicated a statistically significant association between the school year and the offering of Advanced Placement Computer Science Principles courses. The results ($\chi^2 = 24.242$, $df = 6$, $p < 0.001$, $\varphi = 0.181$) reported that the observed changes in the number of schools offering Advanced Placement Computer Science Principles over the school years were not due to random chance which also suggested a medium-to-large effect size. Thus, a positive trend appeared in offering Advanced Placement Computer Science Principles courses in the Chicago Public Schools from the 2016-2017 to the 2022-2023 school years.

3.2 Multilevel Binary Logistic Regression Results

Null model. We fit an unconditional longitudinal model (Table 2) to examine to what extent the variance in offering Advanced Placement Computer Science Principles courses in the

Chicago Public Schools exists across the school years (i.e., from 2016 to 2023) using a multilevel binary logistic regression approach. The null (i.e., unconditional) model revealed that 4.33% variance lied across the school years (*Fixed intercept* = –1.27, $p < 0.001$; *Random variance* = 0.149, *Residual variance* = 1.000, *ICC* = 0.0433; $R^2 = 0.0433$). That is, the null model indicated a considerable amount of variance at the school year as well as considerable clustering effect in the data.

Conditional models. Subsequently, we built two separate conditional models (i.e., school demographics model and school capacity model) to investigate the contributions of school demographic and capacity-related factors to offering Advanced Placement Computer Science Principles courses in the Chicago Public Schools across the school years.

School demographics model. In the school demographics model (Table 3) revealed that 3.53% variance lied across the school years (*Fixed intercept* = –1.871, $p < 0.001$; *Random variance* = 0.120, *Residual variance* = 1.000, *ICC* = 0.0353; $R^2 = 0.503$). The school demographics model showed better model fit than the null model (*AIC* = 635.440, *BIC* = 700.007) and a reduction in deviance (*Deviance* = 596.302). Among the predictors, only the percentage of Asian students at the schools significantly contributed to the higher likelihood of offering Advanced Placement Computer Science Principles courses in the Chicago Public Schools ($\beta = 0.063$, *SE* = 0.029, *exp(B)* = 1.066, $p = 0.027$). The percentage of special education students at the schools were associated with the reduced likelihood of offering Advanced Placement Computer Science Principles courses in the Chicago Public Schools where this factor was the strongest negative contributor ($\beta = –6.984$, *SE* = 1.740, *exp(B)* = 0.0010, $p < 0.001$). It was followed by the percentage of students who were eligible for free or reduced lunch plans ($\beta = –3.880$, *SE* = 1.130, *exp(B)* = 0.021, $p < 0.001$) which was considered as the school-level

socioeconomic status. The percentage of students who did not report any race or ethnicity was a negative contributor to the likelihood of offering Advanced Placement Computer Science Principles courses in the Chicago Public Schools (β = –0.261, *SE* = 0.125, *exp(B)* = 0.771, p = 0.037). The percentage of Hispanic/Latinx students was also negatively related to the likelihood of offering Advanced Placement Computer Science Principles courses in the Chicago Public Schools (β = –0.018, *SE* = 0.006, *exp(B)* = 0.982, p = 0.001). None of the other factors in the school demographics model revealed significant contributions to the likelihood of offering Advanced Placement Computer Science Principles courses in the Chicago Public Schools (ps > 0.05).

School capacity model. The school capacity model (Table 4) failed to converge and results from this model should be approached with caution. Yet, this model demonstrated better model fit compared to the null model (*AIC* = 597.110, *BIC* = 643.234) and reduction in relative deviance (*Deviance* = 563.855). Therefore, we reported the model information for any potential future use. The school capacity model showed that 5.14% variance lied across the school years (*Fixed intercept* = –2.382, p < 0.001; *Random variance* = 0.178, *Residual variance* = 1.000, *ICC* = 0.0514; R^2 = 0.514). Presence of at least partially qualified Advanced Placement Computer Science Principles teachers at the schools was the strongest positive contributor of offering Advanced Placement Computer Science Principles courses in the Chicago Public Schools (β = 1.559, *SE* = 0.332, *exp(B)* = 4.756, p < 0.001) which was similarly followed by the presence of at least partially qualified ECS teachers at the schools (β = 1.450, *SE* = 0.592, *exp(B)* = 4.264, p = 0.014). School size was also a positive contributor where higher enrollment was associated with a higher likelihood of offering Advanced Placement Computer Science Principles in the Chicago Public Schools (β = 0.001, *SE* = 0.0002, *exp(B)* = 1.001, p < 0.001). Among the 5Essentials

factors, while ambitious instruction (β = 0.053, *SE* = 0.015, *exp(B)* = 1.055, $p < 0.001$) and collaborative teachers (β = 0.031, *SE* = 0.014, *exp(B)* = 1.031, $p = 0.029$) were positive contributors of the likelihood of offering Advanced Placement Computer Science Principles in the Chicago Public Schools, family involvement appeared to be the only negative predictor in the school capacity model (β = –0.037, *SE* = 0.010, *exp(B)* = 0.964, $p < 0.001$). None of the other factors in the school capacity model revealed significant contributions to the likelihood of offering Advanced Placement Computer Science Principles courses in the Chicago Public Schools (ps > 0.05).

4 Discussion

4.1 Summary of the Findings

The present study explored trends and factors related to the likelihood of offering Advanced Placement Computer Science Principles courses in the Chicago Public Schools between the 2016-2017 and 2022-2023 school years. The number of schools offering these courses steadily increased during this time which started with a small group in 2016-2017 and increased more than double by 2022-2023.

The multilevel modeling analysis showed that certain school characteristics were related to the likelihood of offering Advanced Placement Computer Science Principles. Schools with a higher percentage of Asian students were more likely to offer these courses. However, schools with a higher percentage of special education students, students eligible for free or reduced lunch, students who did not report a race or ethnicity or Hispanic or Latinx students were less likely to offer them.

In terms of school capacity, having qualified teachers for Advanced Placement Computer Science Principles or Exploring Computer Science courses has greatly increased the likelihood

of offering these courses. Larger schools were also more likely to offer Advanced Placement Computer Science Principles. Additionally, schools with strong teaching practices and collaboration among teachers were more likely to offer Advanced Placement Computer Science Principles courses. On the other hand, higher levels of family involvement appeared to slightly reduce the likelihood of offering Advanced Placement Computer Science Principles courses.

4.2 Discussion of the findings with their relevance to the previous literature

The findings of the present study provide significant insights for the factors that contribute to the likelihood of offering Advanced Placement Computer Science Principles courses in Chicago Public Schools and their alignment with previous research. Grounded in the CAPE framework, the present research emphasizes the reciprocation between school demographics, capacity factors and the equitable offering of computer science education.

The steady increase in schools offering Advanced Placement Computer Science Principles from 2016 to 2023 reflected the positive impact of the Chicago Public Schools computer science graduation requirement introduced in 2016. This trend aligns with the literature which focuses on the policy interventions that can play a key role in expanding access to computer science education, particularly in underrepresented communities [6, 12].

The results also revealed that schools with a higher percentage of Asian students were more likely to offer Advanced Placement Computer Science Principles courses which aligned with prior studies that identified disparities in Advanced Placement participation among racial and ethnic groups [11]. Conversely, a higher percentage of special education students and students eligible for free or reduced lunch were associated with a reduced likelihood of offering Advanced Placement Computer Science Principles. These findings support earlier research

suggesting that socioeconomic challenges and resource limitations often hinder access to advanced coursework [7, 17].

The presence of qualified computer science teachers emerged as a critical factor in determining whether schools offered Advanced Placement Computer Science Principles. This finding corroborates the study by [11] which emphasized the importance of teacher qualifications in expanding Advanced Placement course offerings. Additionally, larger schools were more likely to offer Advanced Placement Computer Science Principles consistent with evidence that school size positively contributed to the capacity to provide advanced courses as a demand factor [17].

The supportive environment and ambitious instruction as measured by the 5Essentials framework also positively contributed to the likelihood of offering Advanced Placement Computer Science Principles courses. These findings resonate with studies highlighting the role of school climate in fostering academic opportunities and encouraging diverse participation in science, technology engineering and mathematics education [2].

While the findings of the present study showed progress in offering Advanced Placement Computer Science Principles courses, they also reveal persistent inequities in access. Hispanic or Latinx students remained underrepresented despite the goal of the Advanced Placement Computer Science Principles courses to diversify computer science participation [1]. This finding points out the need for equity-focus efforts to address systemic barriers and ensure equitable opportunities for all students as emphasized in the CAPE framework [5].

Finally, the findings of the present study bring the importance of computer science education as a pathway to science, technology, engineering and mathematics careers. The observed disparities in offering Advanced Placement Computer Science Principles courses can

have long-term implications as research has shown that taking Advanced Placement Computer Science Principles courses and Advanced Placement Computer Science A significantly increases the likelihood of pursuing a computer science degree [15, 16]. Ensuring equitable access to these computer science courses is therefore essential for broadening participation in the technology-driven economy of the future.

5 Implications of the Present Study

The findings of the present study call attention to several critical areas for policymakers to address in order to enhance equitable access to Advanced Placement Computer Science Principles courses in the Chicago Public Schools and similar contexts. These insights emphasize the need for specific actions in teacher recruitment, resource allocation and systemic equity to ensure all students benefit from computer science education opportunities.

The positive trend in Advanced Placement Computer Science Principles course offerings since the introduction of the Chicago Public Schools computer science graduation requirement demonstrated the effectiveness of the policy. Policymakers at all levels could consider mandating similar requirements and incentivizing schools to integrate computer science education to their curricula. Expanding such requirements could drive the adoption of Advanced Placement Computer Science Principles courses and foster broader participation particularly in underserved communities. However, it is important to place these findings in the context of the Chicago Public Schools using Exploring Computer Science as the primary course for fulfilling the graduation requirement. Given that not all students are prepared for college level work when they enter high school, it may not be productive to have all students take Advanced Placement Computer Science Principles as a means to fulfill a requirement.

Second, the availability of qualified computer science teachers emerged as a significant factor in determining whether schools offered Advanced Placement Computer Science Principles courses. Policymakers could prioritize investments in teacher recruitment, certification programs and ongoing professional development. Efforts to expand the pool of certified computer science educators particularly in underrepresented and resource-constrained schools are essential. Such investments could address the existing gaps in teacher qualifications and capacity by enabling more schools to implement these courses effectively.

Third, the findings of the present study also revealed that schools serving economically disadvantaged populations were less likely to offer Advanced Placement Computer Science Principles courses. Socioeconomic disparities as indicated by the percentage of students eligible for free or reduced lunch presented significant barriers to access. Policymakers could develop targeted funding mechanisms such as grants and subsidies to support these schools. Allocated resources could be used to purchase essential technology, to provide teacher training and to enhance curricular materials to directly address financial constraints.

Persistent inequities in course offerings were evident particularly for schools with higher percentages of special education students, Hispanic or Latinx students and those with students who did not report a race or ethnicity. These findings may call for equity-focused policies to address systemic barriers. Policymakers could enforce accountability measures and adopt frameworks like the CAPE model to ensure schools have equal access to resources and support for Advanced Placement Computer Science Principles implementation regardless of demographic composition.

School size was another factor that was associated with the likelihood of offering Advanced Placement Computer Science Principles courses with larger schools more capable of

implementing advanced coursework. To address this disparity, policymakers could provide support to smaller schools through shared resources, virtual learning platforms and partnerships with local colleges or community organizations. These strategies may help overcome capacity limitations and ensure smaller schools are not excluded from offering Advanced Placement Computer Science Principles courses.

Supportive school environments measured by ambitious instruction and collaborative teacher practices were also associated with a higher likelihood of offering Advanced Placement Computer Science Principles courses. Policymakers could invest in initiatives that promote professional learning communities, teacher mentoring programs and school leadership development. These efforts may enhance school climates and create the conditions necessary for successfully implementing and sustaining Advanced Placement Computer Science Principles courses.

6 Limitations and Future Directions

Every research has its limitations, and the present research is not different. Therefore, the present study has several limitations that should be acknowledged to contextualize the findings and guide future research.

First, the use of cross-sectional data limits the ability to infer causal relationships between the variables examined. While the present study identified key factors, it cannot establish causation. Future research could employ experimental designs to better explore the causal pathways that may have been related to the likelihood of offering Advanced Placement Computer Science Principles courses in schools.

Second, the present study is restricted to the Chicago Public Schools which may limit the generalizability of the findings to other school districts or contexts. The Chicago Public Schools

has unique demographic, policy and resource characteristics that may not apply universally. Expanding the geographical scope of research to include diverse school districts and states would provide a more comprehensive understanding of the factors related to Advanced Placement Computer Science Principles course offerings.

Third, the present study clustered data by school years. While appropriate for the present research's focus, it may not capture all the relevant hierarchical structures within schools. For example, clustering by teachers, departments or geographic regions (e.g., neighborhoods) could yield additional insights. The relatively low intraclass correlation coefficient (ICC) observed in the present study also emphasized the limitations of using school years as the sole clustering unit. Future studies could employ multilevel models with alternative or additional clustering structures such as teacher-level to better capture the nested nature of the data.

Finally, a limitation of the present study is that the school capacity model failed to converge which may have implications for the robustness and reliability of the findings. Despite this issue, the school capacity model demonstrated a better fit than the null model as indicated by the lower AIC and BIC values and a reduction in relative deviance. This could suggest that the school capacity model still provided valuable insights into the factors that are related to the likelihood of offering Advanced Placement Computer Science Principles courses in Chicago Public Schools while convergence was not achieved. Future research could aim to refine the model to ensure convergence which could be possible through adjustments to the model specifications or by exploring alternative modeling techniques. Additionally, further investigations could include additional data or explore potential interactions between predictors to improve the model's stability and explanatory power.

7 Conclusions

The present study demonstrated significant trends and factors that were related to the likelihood of offering Advanced Placement Computer Science Principles courses in Chicago Public Schools from 2016 to 2023. The number of schools offering these courses steadily increased during this period which reflected the positive impact of the policy. The analysis revealed that school demographics such as the percentage of Asian students, of Hispanic or Latinx students, of special education or of economically disadvantaged students were important predictors of Advanced Placement Computer Science Principles offerings. Additionally, school capacity factors including qualified teachers and larger school sizes were positive contributors to the likelihood of offering Advanced Placement Computer Science Principles courses. While strong teaching practices and collaboration among educators positively contributed to Advanced Placement Computer Science Principles offerings, higher family involvement appeared to have a slight negative contribution.

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Figures

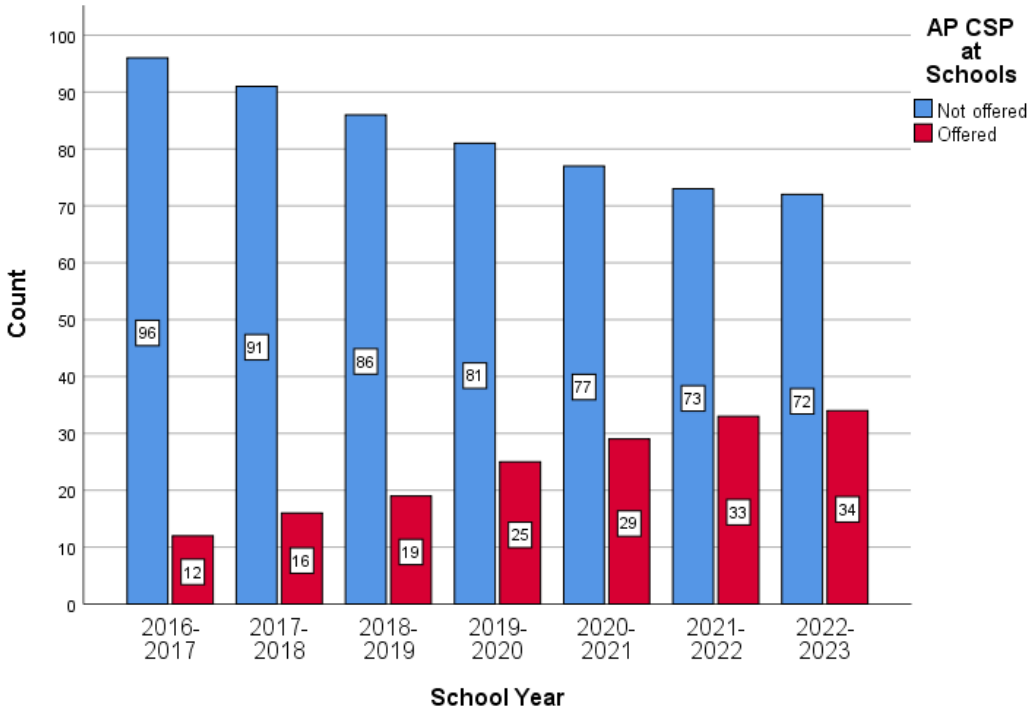

Figure 1. Frequencies and Bar Chart for Offering Advanced Placement Computer Science Principles in the Chicago Public Schools across School Years

Tables

Table 1. Pearson Chi-squared Test Results			
χ^2	*df*	*p*	φ
24.242	6	$p < 0.001$	0.181

Table 2. Model Fit Indices and Random Components of the Null (i.e., unconditional) Model					
AIC	***BIC***	***Deviance***	***SD***	***Variance***	***ICC***
789.850	799.075	771.7117	0.386	0.149	0.0433

Table 3. The School Demographics Model					
AIC	***BIC***	***Deviance***	***SD***	***Variance***	***ICC***
635.440	700.007	596.302	0.347	0.120	0.0353
Variable		***Estimate***	***SE***	***exp(B)***	***p***
White Students (%)		-0.016	0.019	0.984	0.397
Black/African American Students (%)		0.005	0.006	1.005	0.414
Native American/Alaskan Students (%)		-0.804	0.482	0.448	0.095
Asian/Pacific Islander Students (%)		2.097	2.544	8.139	0.410
Hispanic/Latinx Students (%)		-0.018	0.006	0.982	0.001
Multiracial Students (%)		-0.171	0.186	0.843	0.357
Asian Students (%)		0.063	0.029	1.066	0.027
Hawaiian/Pacific Islander Students (%)		-0.307	0.602	0.736	0.611
Race/Ethnicity Not Reported (%)		-0.261	0.125	0.771	0.037
Bilingual Students (%)		-0.143	1.260	0.867	0.909
Special Education Students (%)		-6.984	1.740	0.0009	< 0.001
Students Receiving Free/Reduced Lunch (%)		-3.880	1.130	0.021	< 0.001

Table 4. The School Capacity Model

AIC	*BIC*	*Deviance*	*SD*	*Variance*	*ICC*
597.110	643.234	563.855	0.422	0.178	0.0514
Variable		***Estimate***	***SE***	***exp(B)***	***p***
School Size		0.001	0.0002	1.001	< 0.001
Effective Leaders		-0.007	0.012	0.993	0.594
Collaborative Teachers		0.031	0.014	1.031	0.029
Involved Families		-0.037	0.010	0.964	< 0.001
Supportive Environment		0.002	0.014	1.002	0.889
Ambitious Instruction		0.053	0.015	1.055	< 0.001
ECS Teachers (Absence vs. Presence)		1.450	0.592	4.264	0.014
AP CSP Teachers (Absence vs. Presence)		1.559	0.332	4.756	< 0.001

Note. ECS = Exploring Computer Science; AP CSP = Advanced Placement Computer Science Principles