Impact of the CPS Computer Science Graduation Policy on Student Access and Outcomes

Steven McGee, The Learning Partnership
Lucia Dettori, DePaul University
Andrew Rasmussen, Chicago Public Schools
December 2022

Executive Summary

The Chicago Public Schools (CPS) leads the nation in computer science education. Each year 14,000 Chicago Public Schools students graduate with at least one year of computer science. This is the result of a graduation requirement that CPS enacted in 2016. The foundational course that most students completed to fulfill the requirement is *Exploring Computer Science* (ECS). This evaluation of the impact of the graduation requirement was framed around the CAPE framework. To ensure that a district supports equal outcomes in computer science, they need to develop **C**apacity for schools to offer computer science, increase **A**ccess to computer science, ensure equal **P**articipation, and then examine how computer science **E**xperiences lead to equal outcomes. The analysis was conducted through a CME-funded summer fellowship program, which included advanced graduate students and early career researchers. They found the following results. The ECS professional development program supported a rapid expansion of school **Capacity** after the enactment of the graduation requirement. At the time the graduation requirement was enacted, roughly half of the schools did not offer any computer science and 2/3 did not have sufficient capacity to support computer science for all students. Larger schools with fewer low-income students and a strong college going climate were more likely to offer computer science just before the enactment of the graduation requirement. **Access** to computer science expanded significantly after the computer science graduation requirement. **Participation** in computer science significantly increased across all demographic groups after the graduation requirement. By the time the 2nd cohort graduated after the requirement, the demographics of students taking computer science matched the demographics of the district. Students' **Experiences** with ECS led to equivalent course performance between students taking ECS before and after the enactment of the graduation requirement. The number of students pursuing computer science pathways in CPS doubled after the enactment of the graduation requirement.

McGee, S., Dettori, L., & Rasmussen, A.M. (2022). Impact of the CPS Computer Science Graduation Policy on Student Access and Outcomes [report]. Chicago, IL: The Learning Partnership. https://doi.org/10.51420/report.2022.4

CAFÉCS
CHICAGO ALLIANCE FOR EQUITY IN COMPUTER SCIENCE

The Learning Partnership

DePaul University

Chicago Public Schools

1. Purpose and Rationale

In June 2020, more than fourteen thousand students in the Chicago Public Schools (CPS) graduated with one year of high school computer science credit in fulfillment of CPS' recent computer science graduation requirement. This accomplishment was the culmination of over a decade of work by the Chicago Alliance For Equity in Computer Science (CAFÉCS) research-practice partnership (RPP), which include CPS teachers (Don Yanek), CPS administrators (Brenda Wilkerson, Troy Williams, Andy Rasmussen), computer science faculty from DePaul (Lucia Dettori), Loyola (Ron Greenberg), and UIC (Dale Reed), and educational researchers at The Learning Partnership (Steven McGee). In 2012, CPS was the first school district to adopt the *Exploring Computer Science* (ECS) curriculum and professional development program outside of Los Angeles where it originated (Reed et al., 2015). A recent UChicago Consortium on School Research report has documented that in the years following the adoption of ECS, there was a significant increase in the number of CPS students taking ECS (Barrow, et al., 2020). After four years of pilot implementation, CPS became the first school district to enact a high school computer science graduation requirement starting with the 2016 incoming class, with ECS serving as the foundational course for the requirement.

CAFÉCS research on the initial implementation of ECS provided preliminary evidence of the benefits of ECS as the foundational course for high school computer science pathways. Not only does ECS support equivalent outcomes regardless of students' race/ethnicity and gender (McGee, McGee-Tekula, Duck, McGee, et al., 2018), it also equivalently increases interest in pursuing additional computer science coursework (McGee, McGee-Tekula, Duck, Dettori, et al., 2018). The participation of African American and Latinx students in AP Computer Science A (AP CS A) and AP Computer Science Principles (AP CSP) jumped significantly two years after the graduation requirement was enacted—with most of these students having been inspired by their participation in ECS (Boda & McGee, 2021). ECS also serves as effective preparation for AP CS A, as the students who took ECS prior to AP CS A were 3.5 times more likely to pass the CS A exam with a score of 3 or higher than those who did not take ECS first (Boda & McGee, 2021).

With the graduation of the first two cohorts of CPS students subject to the graduation requirement, CAFECS was well positioned to complete this systematic analysis of the current state of computer science in CPS as well as the full impact of the graduation requirement. Moreover, with the recent enactment of IL legislation requiring all high schools in the state to offer computer science, the impact of this research has a potential reach beyond Chicago. This analysis of the implementation of the CPS graduation requirement reveals challenges that CPS has faced in increasing computer science opportunities for all students as well as how CPS has addressed those challenges. The results can inform school districts throughout IL as they ramp up to meet the new state policy.

1.1 The Chicago Alliance for Equity in Computer Science

In 2009, CPS computer science teacher Don Yanek, district administrator Brenda Wilkerson, and three university computer scientists, Lucia Dettori (DePaul University), Ron Greenberg (Loyola University Chicago), and Dale Reed (University of Illinois Chicago) came together to collaborate on a shared goal: to provide all CPS students access to compelling and relevant computer science experiences. At the time, the nation was experiencing a dramatic decrease in the number of college graduates majoring in computer science (McGee et al., 2013). For several years, the group explored various options for supporting computer science in CPS. In 2011, the team identified the ECS program (Goode, Margolis, &

Chapman, 2014) as a viable option to provide curriculum and teacher professional development to support all students to engage in computer science. (For a description of the ECS curriculum and professional development program, see Goode et al., 2014; Margolis et al., 2012.) A small group of teachers traveled to Los Angeles in the summer of 2011 to participate in the ECS professional development in preparation for a pilot test of the program in Chicago. The professional development actively involved the teachers in creating and explaining computer science concepts with other teachers. The groups of teachers returned to Chicago inspired and enthusiastic to share this transformative program with other CPS teachers (Reed et al., 2015).

In parallel, the group sought funding to support implementation of ECS professional development in Chicago. The first collaborative grant (Dettori et al., 2011) from the National Science Foundation (NSF)—Taste of Computing—was awarded to the group in 2011. As part of this grant, Steven McGee of The Learning Partnership joined the collaborative to support the research and evaluation activities. As the ECS program expanded to more CPS schools, the mayor's office and CPS launched the CS4All initiative in 2013 to expand computer science opportunities across all grade levels in Chicago (Zumbach, 2013). A goal of the CPS CS4All initiative was to provide computer science courses in every high school and work towards incorporating computer science in high school graduation requirements (City of Chicago, Office of the Mayor, 2013).

In 2015, CAFÉCS received a second NSF collaborative grant focused on developing and evaluating an instructional coaching program to complement the ECS professional development (Dettori et al., 2015). This coaching program supported new teachers in shifting to the inquiry-oriented, equitable instructional practices embedded in ECS, while providing additional support for computer science concepts (Wachen et al., 2022). The team received a third NSF collaborative grant (McGee et al., 2015) focused on the impact of the ECS curriculum and professional development model on student outcomes and inspiring further interest in computer science. In 2016, this hard work paid off when The Chicago Board of Education decided that students must take a computer science course to graduate from high school, a first for school districts in the United States. Beginning with the 2016-17 freshman class, students either had to complete a yearlong computer science class or apply for a waiver if they were participating in a Career and Technical Education (CTE) program, the International Baccalaureate (IB) program, or a similar career oriented or college prep program. Although only about half of the high schools in CPS offered any computer science classes in 2016, CAFÉCS research provided the Board with confidence that the ECS curriculum and professional development could spread to all schools in CPS.

When NSF launched the Computer Science for All: Researcher Practitioner Partnerships program, the Chicago team received one of the few large grants awarded, and CAFÉCS was formalized as an official RPP in 2017. At that time, Partner to Improve (Erin Henrick) joined the partnership as the external evaluator. Starting in October 2017, the goal of CAFÉCS was to understand and address variation in the implementation of ECS across CPS.

2 Methods

Through a data share agreement with CPS, The Learning Partnership has access to student demographic information, computer science enrollment and outcomes, teacher demographic data, teacher preparation data, and data about school characteristics. We used these data to examine the impact of the graduation requirement through the lens of the CAPE framework (Fletcher & Warner, 2021): Capacity, Access, Participation, and Experience. This research extends the UChicago Consortium report (Barrow, et

al., 2020) and used the CAPE framework to examine how the capacity of schools to offer computer science, the availability of computer science at high schools, the number and demographics of students participating in computer science, and student outcomes changed after the graduation requirement was enacted. The research addressed four primary research questions related to the CAPE framework:

1. How did CPS's **Capacity** to offer computer science change after the graduation requirement was enacted?
2. How did **Access** to computer science courses change after the graduation requirement was enacted?
3. How did **Participation** in computer science change after the graduation requirement was enacted?
4. How consistent were the student **Experience** in and outcomes from their computer science courses before and after the enactment of the graduation requirement?

In summer 2022, The Learning Partnership established a CME Foundation-funded summer fellowship program for advanced graduate students and early career researchers to use the CPS administrative data to analyze different aspects of the four research questions. A national search was conducted, and six fellows were invited to participate through a competitive selection process. As part of the 8-week fellowship, the fellows attended an initial 3-day orientation session in June 2022 in Chicago. The orientation included a discussion with the CAFÉCS leadership team and members of the Office of Computer Science. After the orientation, the fellows worked remotely to conduct their analyses. They had weekly remote check-ins with The Learning Partnership. They also had access to one of three quantitative mentors who met with the fellows virtually twice during the summer and provided feedback. The fellows also met remotely with staff from the Office of Computer Science at the midpoint of their analyses to get feedback. At the end of the fellowship in August, the fellows participated in a symposium event that served as a celebration of the success of the graduation requirement (Dettori et al., 2022). The six fellows are listed below along with the portion of the CAPE framework they analyzed. For more details on the fellows' experiences, see McGee (2022).

Access. *Danqing Yin* was a graduate student at the University of Kansas. She analyzed the growth in access before and after the enactment of the graduation requirement and conducted an analysis of the factors that correlated with the probability that a high school offered at least one computer science class in the year prior to the enactment of the graduation requirement.

Participation. *Aaron Park* was a graduate student at Saint Louis University. He conducted an analysis of the change in cohort participation rates before and after the graduation requirement. *Teresa Lansford* was a graduate student at Texas Tech University. She conducted a detailed analysis of cohort participation rates based on the most prevalent categories of students with disabilities.

Experience. *Dung Pham* was a graduate student at Western Michigan University. She conducted an analysis comparing ECS course grades before and after the enactment of the graduation requirement. *Regina Winters* was a recent graduate of the University of Colorado Colorado Springs. She analyzed the interaction effect of teacher qualification on course grades before and after the enactment of the computer science graduation requirement. *Sangkyoo Kang* was a recent graduate of Penn State University. He conducted an analysis comparing the rate at which students took additional computer science courses after their introductory course before and after the enactment of the graduation requirement.

3. Results

3.1 How did CPS's Capacity to offer computer science change after the graduation requirement was enacted?

We examined this question at the school level and the teacher level. One important factor that affects the capacity of schools to offer computer science is availability of qualified computer science teachers. We examined how computer science professional development fostered the growth of at least partially qualified computer science teachers, the characteristics of computer science teachers before and after the enactment of the graduation requirement, and the distribution of qualified teachers by school characteristics.

Prior to the graduation requirement (SY2013 to SY2016), CPS was adding a net average of 15 computer science teachers per year either through professional development (n=9 per year) or through teachers earning an endorsement (n=6 per year). After four years of implementing Taste of Computing through volunteerism, CPS had 86 trained (n=39) or endorsed (n=47) computer science teachers during SY2016. We examined how these teachers were distributed across three different types of schools. Neighborhood schools automatically accept all students who live within the school's attendance boundaries. Students who apply to a neighborhood school from outside the attendance boundary are accepted on a space availability basis. If more students apply than there is room, students are selected based on a lottery. Selective enrollment schools accept students based on their performance on a citywide entrance exam. There are no attendance boundaries for magnet schools, which include selective enrollment schools, STEM schools, and others. Typically, students attending selective enrollment schools are in the top 10% of CPS students based on exam scores. STEM schools provide a variety of STEM intensive pathways for interested students, with an emphasis on dual credit classes in collaboration with the City Colleges of Chicago.

We developed a metric to determine whether a school had sufficient capacity to offer computer science to all students at the school. For the purposes of this analysis, a teacher was considered qualified to teach ECS if they were endorsed in computer science or attended all the ECS professional development

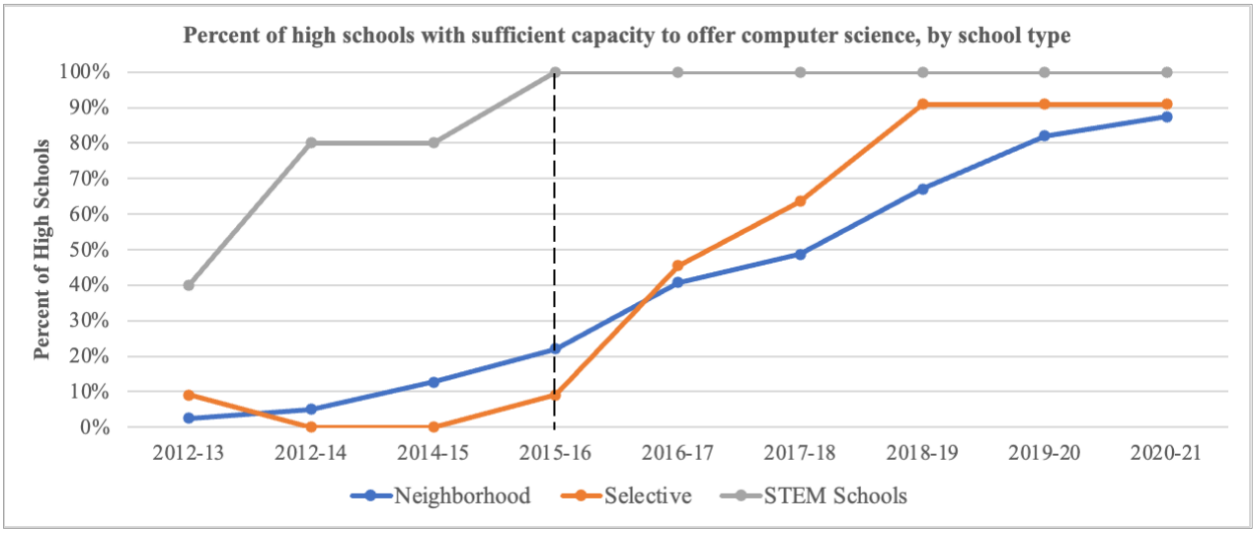

Figure 1: Capacity to offer computer science significantly increased after the enactment of the computer science graduation requirement (vertical dashed line).

sessions. A teacher was considered partially qualified if they attend most, but not all, of the ECS professional development sessions. One at least partially qualified teacher's capacity is defined as 600 students (a full load of 5 class sections with 30 students each over the course of 4 years). In SY2016, 22% of neighborhood schools had sufficient capacity, in comparison to 3% when Taste of Computing started (see Figure 1). Only one selective enrollment school had sufficient capacity to offer computer science to every student by SY2016. On the other hand, all the STEM schools had sufficient capacity to offer computer science to all their students by SY2016. In summary, the Taste of Computing project significantly increased the capacity of CPS schools to offer computer science. However, as of SY2016, after four years of schools opting, CPS was still far from the capacity needed to reach the goal of computer science for all students.

In the first four years after the graduation requirement was enacted, the rate at which CPS added computer science teachers significantly increased. CPS averaged a net increase of 38 teachers per year through professional development (n=27 per year) and endorsement (n=12 per year). The rate of net increase in computer science teachers after the enactment of the policy was more than double the rate of net increase in computer science teachers before the enactment of the graduation requirement. By the time the first cohort of students subject to the graduation requirement had graduated in 2020, CPS had almost tripled the number of teachers who were at least partially qualified in computer science (n=239) through professional development (n=145) or endorsement (n=94).

This rapid rise in the availability of computer science teachers led to a concomitant increase in the number of schools with sufficient capacity to provide computer science to every student (see Figure 1). In SY2020, 82% of neighborhood schools had sufficient capacity to offer computer science to every student (see below for some discussion of waivers for students in select programs, which might account for much of this capacity gap). All but one selective enrollment school had sufficient capacity to offer computer science to every student. All the STEM schools were able to maintain sufficient capacity to offer computer science to all students.

It is important to note that CPS would not have been able to achieve the goal of Computer Science for All students if it had relied solely on fully endorsed computer science teachers. In the first year of the Taste of Computing project when capacity to offer computer science was limited, more than two-thirds of the computer science teachers were fully endorsed. By the time the computer science graduation requirement was enacted in SY2016, just over half of the computer science teachers were fully endorsed. By the time the first cohort of students subject to the graduation requirement graduated in 2020, less than 40% of the teachers were fully endorsed.

In summary, the graduation requirement created a significant need for computer science teachers and the professional development program initially supported by the Taste of Computer project provided the means to increase capacity at a much higher rate than through fully endorsing teachers alone.

3.2 How did Access to computer science courses change after the graduation requirement was enacted?

We examined the impact of the enactment of the graduation requirement in creating equal access to computer science for students in the district. We examined the characteristics of schools that offered computer science before and after the enactment of the graduation requirement to better understand barriers that schools faced as they sought to create new computer science opportunities.

Prior to Taste of Computing, computer science was mostly available at the selective enrollment schools and through Career and Technical Education programs. In the first year of Taste of Computing

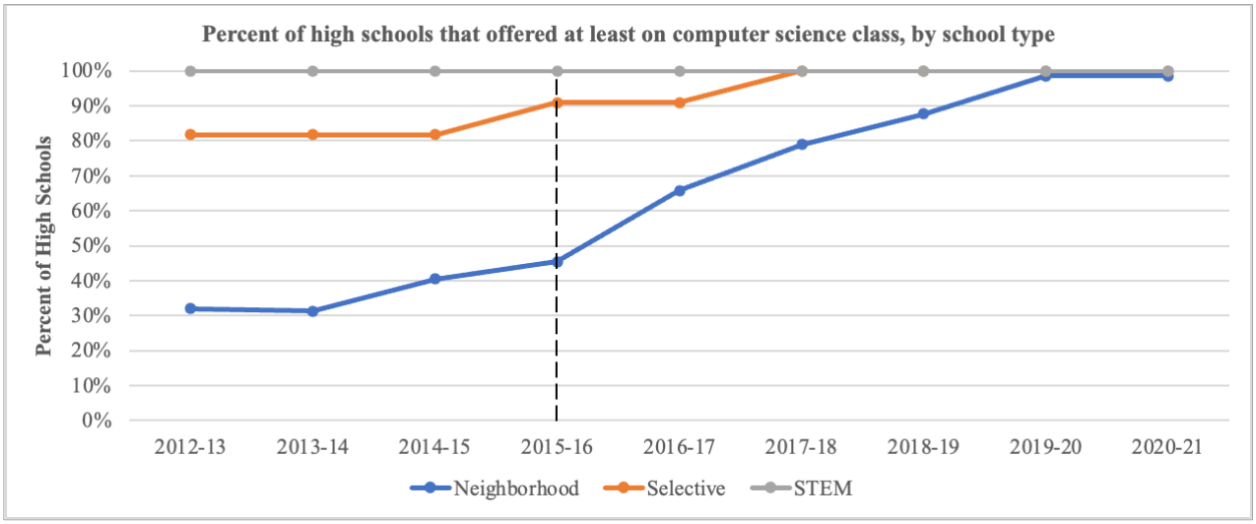

Figure 2: Access to computer science significantly increased at the neighborhood schools after the enactment of the computer science graduation requirement (vertical dashed line).

(SY2013), all the STEM schools and all but two of the selective enrollment schools offered at least one computer science class. In contrast, only about one-third of the neighborhood schools offered at least one computer science course (see Figure 2). At the time of the enactment of the graduation requirement (SY2016), all the STEM schools continued to offer at least one computer science course and all but one selective enrollment school offered at least one computer science class. Through the volunteerism of the Taste of Computing project, the number of neighborhood schools offering at least one computer science class increased to 45%. However, more than half of the neighborhood schools did not offer any computer science classes and, as indicated above, less than a quarter of schools had sufficient capacity to offer computer science to all students at the time that the Chicago Public Schools Board of Education voted to enact the high school graduation requirement.

Through an analysis of the school factors that predicted whether schools offered at least one computer science class in SY2016, Yin (in press) found that school enrollment, percent of students participating in the free or reduced lunch (FRL) program, and the percent of students earning at least one early college credit. Larger schools with higher levels of students earning early college credit and lower levels of students on FRL were more likely to offer at least one computer science class. These characteristics are very prevalent in the selective enrollment and STEM schools where there were high levels of access to computer science. Smaller high schools, with fewer students earning early college credit and higher percentages of students on free/reduced lunch were less likely to offer at least one computer science class. These characteristics are very prevalent in the neighborhood schools where less than half were offering at least computer science class.

On the strength of CPS's capacity-building efforts, the number of schools offering at least one computer science class in the year after the graduation requirement was enacted more than doubled. By SY2020, all the STEM schools, all the selective enrollment schools, and all but one of the neighborhood schools offered at least one computer science class. The one neighborhood school that did not offer a computer science class instead waived all their students due to their participation in CTE programs. In summary, the accelerated capacity building fueled by the graduation requirement enabled the rapid increase in access to computer science for all students in the district.

3.3 How did Participation in computer science change after the graduation requirement was enacted?

We examined the participation of students in computer science before and after the enactment of the graduation requirement. It was expected that by the time each of the cohorts subject to the graduation requirement completed high school, the demographics of students participating in at least one computer science course would reflect the demographics of students in the district as a whole.

For the cohort of students who entered CPS in the year that Taste of Computing started (SY13), almost one-fourth (22%) of the students completed a computer science class by the time they graduated. The overall participation rate for the last cohort before the enactment of the graduation requirement (SY16) was close to one-third (32%). The gradual increase in capacity and access to computer science supported by the Taste of Computing project resulted in a gradual increase in the number of students in each cohort who completed a computer class by the time they graduated (average of 3% growth per year).

In contrast, there was a large increase in the participation rate for the first two cohorts subject to the graduation requirement. The overall participation rates were 84% and 83% respectively. Roughly 17% of each cohort was eligible to receive a waiver from completing a computer science class. Those students were participating in a CTE program, the IB program, or a similar career oriented or college prep program. Park (in press) conducted an interrupted time series analysis and determined that the number of students taking computer science after the enactment of the graduation requirement was statistically significantly higher than the number of students taking computer science before the enactment of the graduation requirement. Therefore, all students in the first two cohorts after the enactment of the graduation requirement fulfilled the requirement by either completing a computer science class or securing a valid waiver from the requirement.

Figure 3 shows the cohort participation rate over time by race/ethnicity. There was a rapid increase in the cohort participation rate for all students after the enactment of the graduation requirement. However, there was some variation in the cohort participation rate by race/ethnicity. Students who identify as Asian had higher rates of cohort participation prior to the enactment of the graduation requirement than students who identify in other racial/ethnic groups. After the enactment of the

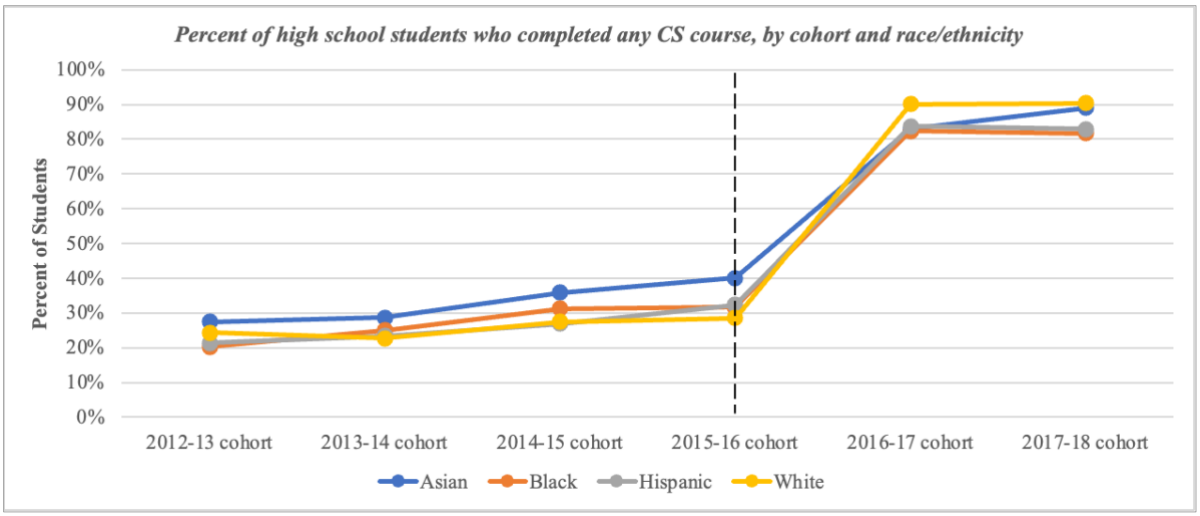

Figure 3: There was a significant increase in the participation rate of all racial/ethnic groups of students after the enactment of the graduation requirement (vertical dashed line).

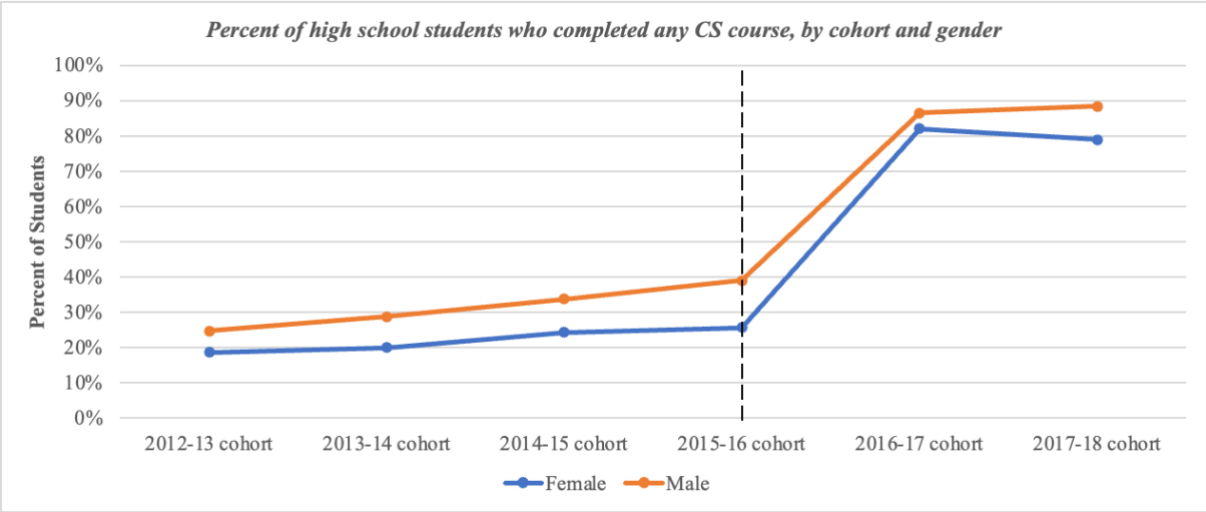

Figure 4: There was a significant increase in the participation rate of both male and female students after the enactment of the graduation requirement.

graduation requirement, students who identify as Asian and White had higher rates of cohort participation than students who identify as Black and Hispanic.

Figure 4 shows the cohort participation over time by gender. Prior to the enactment of the graduation requirement, students who identify as female had lower rates of cohort participation than students who identify as male and the gap in cohort participation rate had been growing. After the enactment of the graduation requirement, the gap in cohort participation rates had narrowed, but students who identify as female still had lower rates of cohort participation than students who identify as male.

Throughout the implementation of the CS4All initiative in Chicago, the racial/ethnic representation of students taking computer science was reflective of their respective representations in the district as a whole (see Table 1). With a few exceptions highlighted in red, the percent representation of Asian, Black, Hispanic, and White students taking computer science was within 2% of their representation in CPS overall.

Table 2 provides a comparison of the representation of computer science students by gender to the gender representation in the district as a whole. Throughout the period prior to the enactment of the graduation requirement, there was an average of 8.5% difference (highlighted in red) between the

Table 1: Comparison of the representation of computer science students and all CPS students by race/ethnicity

Race/Ethnicity	Population	2012-13 cohort	2013-14 cohort	2014-15 cohort	2015-16 cohort	2016-17 cohort	2017-18 cohort
Asian	% of CS students	6%	6%	6%	6%	5%	5%
	% of CPS	5%	5%	5%	5%	5%	5%
Black	% of CS students	34%	37%	37%	33%	32%	31%
	% of CPS	37%	36%	35%	33%	33%	32%
Hispanic	% of CS students	47%	46%	45%	49%	48%	49%
	% of CPS	47%	47%	48%	49%	49%	50%
White	% of CS students	11%	10%	10%	10%	12%	12%
	% of CPS	10%	11%	11%	11%	12%	11%

Table 2: Comparison of the representation of computer science students and all CPS students by gender

Gender	Population	2012-13 cohort	2013-14 cohort	2014-15 cohort	2015-16 cohort	2016-17 cohort	2017-18 cohort
Female	% of CS students	44%	43%	43%	41%	50%	48%
	% of CPS	51%	52%	51%	51%	51%	50%
Male	% of CS students	56%	57%	57%	59%	50%	52%
	% of CPS	49%	48%	49%	49%	49%	50%

representation of computer science students who identify as female and the representation of all CPS students who identify as female. After the enactment of the computer science graduation requirement, the gap in representation had narrowed to 2% or less.

3.3.1 Participation of Students with Disabilities

Lansford (in press) conducted an analysis of the participation of students with disabilities. She examined the cohort participation rate for students with the six most prevalent special education categories: Autism, Deaf/Hearing Impaired, Emotional Disability, Intellectual Disability, Learning Disability, and Other Health Impairment. For the cohort of students with an IEP who entered CPS in the year that Taste of Computing started (SY13), 14% completed a computer science class by the time they graduated. The overall participation rate for the last cohort before the enactment of the graduation requirement (SY16) had more than doubled and was close to one-third (32%), which is the cohort participation for CPS as a whole. The increase in capacity and access to computer science supported by the Taste of Computing project enabled a 6% average annual growth rate for students with IEPs. After the enactment of the graduation requirement, the cohort participation rate for students with IEPs more than doubled for the first two cohorts subject to the graduation requirement (71% and 76% respectively).

Figure 5 shows the cohort participation rate over time by category of IEP. Students with autism had the highest cohort participations rates in the first year of Taste of Computing and students who were dead/hearing impaired had the lowest cohort participation rates. After the enactment of the graduation

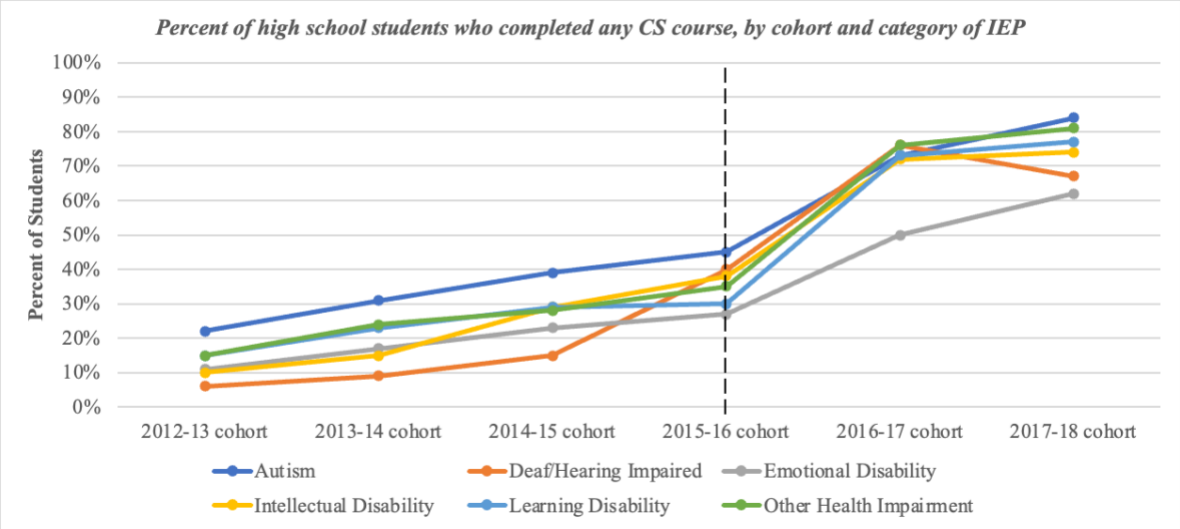

Figure 5: There was a significant increase in the participation rates for the six most prevalent categories of IEPs after the enactment of the graduation requirement (vertical dashed line).

requirement, the cohort participation rates grew significantly for all students with IEPs. Five of the six most prevalent categories of IEPs had equivalent participation rates for the first cohort subject to the graduation requirement and were close to the cohort participation rate for all CPS students. Students with emotional disabilities had lower cohort participation rates than the other five most prevalent IEP categories in the first two cohorts subject to the graduation rate.

Lansford (in press) concluded that for most of the categories of students with disabilities the graduation requirement policy is increasing neurodiversity in computer science course taking. While some subgroups, such as those with emotional disabilities, may need additional support, most other groups saw statistically significant gains in computer science course enrollment. It is worth further study to see in the future what if any impact this policy has on representation of individuals with disabilities in the computing workforce.

3.4 How consistent were the student Experience in and outcomes from their computer science courses before and after the enactment of the graduation requirement?

We compared computer science course grades before and after the enactment of the graduation requirement. Barrow, Freire, & de la Torre (2020) found that computer science course grades were higher than other subject areas during the time when computer science was an elective class. Did the rapid expansion of computer science in CPS impact the quality of outcomes that had been achieved under the Taste of Computing program? Our analysis examined whether course grades remained consistent as more students took computer science. In addition, we examined whether there were differences in the subsequent course taking patterns before and after the graduation requirement.

3.4.1 Comparison of ECS Course Grades Before and After the Enactment of the Graduation Requirement

Pham (in press) used multilevel modeling to examine ECS course grades before and after the enactment of the computer science graduation policy. In addition, Pham examined differences by race/ethnicity, gender, and teacher preparation. She controlled for a variety of factors at the student level (participation in free/reduced lunch program, English as a second language program, special education, and homelessness, at the course level (teacher experience), and the school level (size, demographic distribution, school quality, and school type).

The average ECS course grade was 2.6 on a four-point scale. Half of the students received a grade of B or higher and seventy-five percent of the students received a grade of C or higher. After controlling for the student, course, teacher, and school factors, the results indicated that there was no statistically significant difference in course grades between before and after the enactment of the graduation requirement. Pham also tested whether there were any main effects of student gender, student race/ethnicity, and level of teacher preparation on student grades. Pham found that students who identify as female achieved higher grades in ECS than students who identify as male. Students who identify as Hispanic and Black achieved lower grades than students who identify as Asian and White. At the teacher level, Pham found that there were no overall statistically significant differences in course grades between teachers who participated in the professional development and those that were fully endorsed in computer science. However, in a separate analysis of ECS course grades, Winters (in press) used a Difference in Difference analysis to examine how the interaction of ECS teacher qualification and the enactment of the graduation environment in neighborhood schools for students whose first computer science class was

ECS. Winters found that in the post-policy enactment period, whether a teacher was at least partially qualified correlated with student course grades. Since almost two-thirds of the ECS teachers are endorsed in a subject other than computer science, these results provide validation for the ECS professional development model. Teachers who participated in the workshop were able to overall support the same level of student achievement in ECS as those teachers who were fully endorsed in computer science.

3.4.2 Comparison of Additional Course Taking Before and After the Enactment of the Graduation Requirement

Kang (in press) used multi-level modeling to examine the probability of students taking an additional computer science class after completing their first computer science class before and after the enactment of the computer science graduation requirement. Kang controlled for student demographics including gender, race/ethnicity, free or reduced lunch (FRL), special education, and English as a second language. The teacher factors included the number of years of teaching ECS and level of participation in ECS professional development. School characteristics included the number of computer science course offerings, the ratio of FRL students, enrollment size, and selectivity. The dependent variable was a binary variable that identifies whether a student took an additional computer science course after their first. Kang examined whether there are differences in the probability of taking an additional course depending on whether a student took ECS as their first computer science course. To predict the log odds of a student taking more than one computer science course, Kang used logistic regression.

Overall, about 17% of students who completed a computer science class prior to the enactment of the graduation requirement took an additional computer science class. After the enactment, about 18% of students who completed a computer science class took an additional computer science class. This increase in the probability of students taking an additional computer science class after the enactment of the computer science graduation requirement was small, but statistically significant.

Prior to the enactment of the graduation requirement students who completed ECS as their first class were 29% more likely to take an additional computer science class than students who completed any other computer science class as their first class. After the enactment of the graduation requirement, the probability of ECS students taking an additional class decreased and the probability of other computer science students taking an additional computer science class increased. While there was an overall net increase in the probability of students taking additional coursework, there was no longer a difference in the probability of taking an additional course based on which computer science class students took first. Given that ECS was the most popular course that students used to fulfill the requirement, it had the greatest influx of students taking a computer science class because of the requirement and not necessarily because they were interested. There was an overall increase in the number of ECS students who took additional coursework even though the rate decreased. For other computer science classes, it is possible that students who already had interest in computer may have opted for other computer science classes in lieu of ECS. The net effect of doubling the number of students from about 6,000 to about 12,000 taking at least one computer science class had the net effect of doubling the number of students from about 1,000 to about 2,000 pursuing computer science pathways in CPS.

Kang's results also point to areas where more work needs to be done to achieve equitable outcomes. Across all cohorts, students who identify as female were 50% less likely to take additional computer science courses relative to students who identify as male. In addition, students who identify as Hispanic were 13% less likely to take additional computer science coursework relative to students who identity as students of other racial / ethnic backgrounds.

4 Conclusion and Recommendations

Survey after survey finds that parents believe that computer science is important for their children to learn in school (e.g., Gallup & Code with Google, 2020). In addition, teachers and school administrators believe that computer science is just as important as other school subjects. Despite this universal belief that computer science is important, only about half of the schools in the country offer at least one computer science class. The national status of computer science education is the exact situation CPS was in when they were on the verge of enacting a computer science graduation requirement. The results of this research provide evidence that the graduation requirement combined with a robust curriculum and professional development program served as a catalyst to increase capacity of schools to offer computer science. The resulting increased access to computer science led to significant increases in participation by all demographic groups of students in Chicago. CPS was able to maintain the same level of student course performance despite the rapid increase in participation and succeeded in doubling the number of students pursuing computer science pathways.

The enactment of the graduation requirement came about due to the policy entrepreneurship of the leaders of CAFÉCS. Johnson et al. (2020) characterize this kind of policy entrepreneurship work as a process of *building strength*. When the CS4All initiative in Chicago first began, CPS had the license to create a graduation requirement, but did not yet have the capacity to act. By securing federal funding, CAFÉCS implemented two key strategies for supporting **equitable results**: a robust computer science curriculum and professional development **program** and **research** to support the program, thus developing the capacity of CPS to enact the graduation requirement **policy**. CAFÉCS leaders were able to point to ECS as a program that was capable of building sufficient capacity to support the entire district, and research provided evidence that ECS could support the goals of providing a meaningful introduction to computer science that inspires students to pursue computer science pathways. Relying upon the ECS curriculum, ECS professional development program and the research that provided evidence of success, the Chicago Board of Education voted to enact the policy on February 24, 2016. To support the implementation of the graduation requirement policy, CPS changed its **organizational structure** to form the Office of Computer Science to manage the implementation of the policy. The Office of Computer Science was an integral member of CAFÉCS. Figure 6 provides a framework that characterizes key

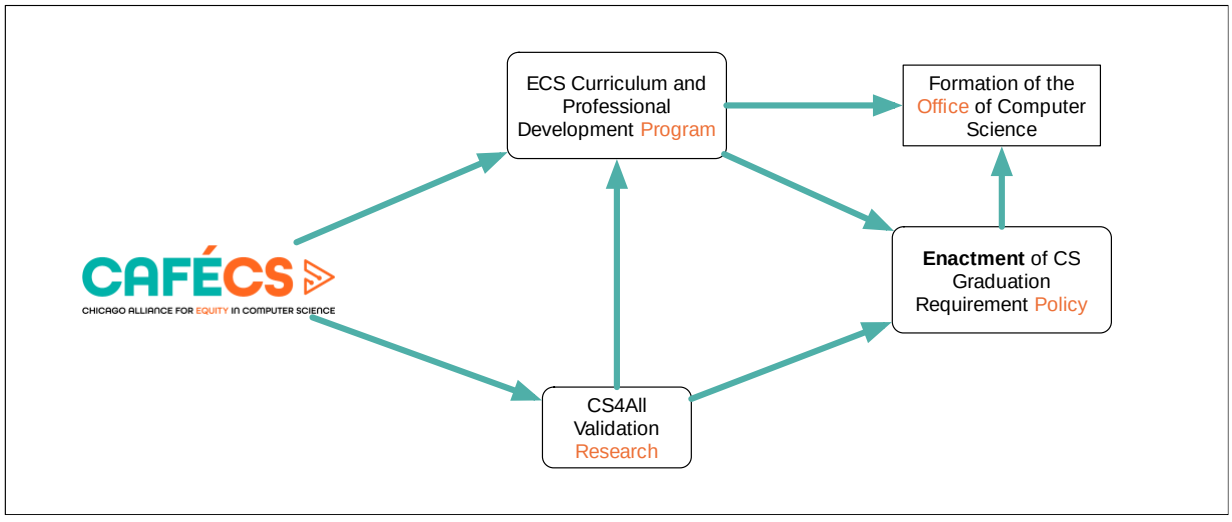

Figure 6: framework that characterizes strategies that CAFÉCS adopted to foster sustainable change that enabled the equitable growth of computer science in CPS

strategies that CAFÉCS adopted to foster sustainable change that enabled the equitable growth of computer science in CPS.

Through its work on supporting the enactment of the graduation requirement policy, CAFÉCS has identified four key strategies for enabling sustainable change in school districts. These strategies have been organized into the PROSPER framework (Programs, Research, Organizational Structure, and Policy for Equitable Results): 1) **Programs**: CAFÉCS impacted the selection and implementation of computer science programs, 2) **Research:** CAFÉCS conducted research to understand and address problems of practice facing the Office of Computer Science, 3) **Organizational Structure:** CAFÉCS funding impacted organizational structures in the CPS, and 4) **Policy**: CAFÉCS impacted the enactment and implementation of district graduation requirement policy. The successful implementation of the graduation requirement has increased **Equitable Results** in computer science education in CPS by expanding capacity, access, and participation leading to equitable experiences.

CPS provides a blueprint for other districts who are pursuing computer science access for all students. Teachers are the most important ingredient to success. Schools should focus first on capacity building before enacting significant policies. Courageous leadership is needed. Only about half of the schools offered computer science and most schools had no trained teacher. CPS administrator Brenda Wilkerson provided a vision of a pathway for getting to 100%. It took great courage on the part of CPS senior leadership and the Board to enact such a monumental policy under such conditions of uncertainty. In addition to informing school districts, the findings from this study will help other research-practice partnerships understand how to effectively leverage their working structure to help large urban districts to PROSPER in computer science education.

5 Acknowledgments

The authors were supported in part by a grant from the CME Foundation and by National Science Foundation grants CNS-1138417, CNS-1542971, CNS-1543217, CNS-1640215, CNS-1738515, CNS-1738776, CNS-1738691, CNS-1738572, CNS-1842085, CNS-2034145. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the authors and do not necessarily reflect the views of the CME Foundation or NSF.

6 References

Barrow, L., Freire, S., & de la Torre, M. (2020). *Trends in computer science education: Access, enrollment, and performance in CPS high schools.* Chicago, IL: University of Chicago Consortium on School Research.

Boda, P.A. & McGee, S. (2021). Broadening participation and success in AP CS A: Predictive modeling from three years of data. In Proc. ACM Tech. Sym. Comp. Sci. Ed. (SIG CSE'21). ACM, Virtual Event, USA, 6 pages. https://doi.org/10.1145/3408877.3432421

City of Chicago, Office of the Mayor. (2013, December 9). Mayor Emanuel and CPS CEO Barbara Byrd-Bennett announce comprehensive K–12 computer science program for CPS students [Press release]. https://www.chicago.gov/city/en/depts/mayor/press_room/press_releases/2013/december_2013/mayor-emanuel-and-cps-ceo-barbara-byrd-bennett-announce-comprehe.html

Dettori, L., Steinbach, T., Reed, D., Yanek, D., & Greeberg, R. (2011). Collaborative Research: Type I: Taste of Computing: Adding a CS Entree to the Education Choices in a Large Urban School District [Grant]. https://doi.org/10.51420/grant.2011.1

Dettori, L., Wilkerson, B., Chapman, G., McGee, S., Winters, R., Brannon, F., Yin, D., Williams, T., Park, A., Lansford, L., Easter, J., Dunketell, J., Pham, D., Kang, S., & Beck, K. (2022). Celebration of the Success of the CPS Computer Science Graduation Requirement [Webinar]. Chicago, IL: Chicago Alliance for Equity in Computer Science. https://doi.org/10.51420/report.2022.1

Fletcher, C. L., & Warner, J. R. (2021). CAPE: a framework for assessing equity throughout the computer science education ecosystem. *Communications of the ACM*, *64*(2), 23-25.

Gallup & Code with Google (2020) [report]. *Current Perspectives and Continuing Challenges in Computer Science Education in U.S. K-12 Schools* [report]. Washington, DC: Gallup. https://csedu.gallup.com/home.aspx

Goode, J., Margolis, J., & Chapman, G. (2014). Curriculum is not enough: The educational theory and research foundation of the exploring computer science professional development model. *In the Proceedings of the 45th ACM Technical Symposium on Computer Science Education*, 493-498. Retrieved from http://www.exploringcs.org/wp-content/uploads/2010/09/Curriculum-is-not-Enough.pdf

Johnson, M., Wachen, J., and McGee, S. (2020, April). Entrepreneurship, Federalism, and Chicago: Setting the Computer Science Agenda at the Local and National Levels [Paper presentation]. 2020 American Educational Research Association Annual Meeting, San Francisco, CA, United States. (conference canceled) https://doi.org/10.51420/conf.2020.1

Kang, S. (in press). Computer Science Graduation Requirement: Effect on Additional Course Taking [Report]. Chicago, IL: The Learning Partnership.

Lansford, T. (in press). ENTER CS: Enhancing Neurodiversity Through Engagement in Required Computer Sciences [Report]. Chicago, IL: The Learning Partnership.

Margolis, J., Ryoo, J. J., Sandoval, C. D. M., Lee, C., Goode, J., & Chapman, G. (2012). Beyond access: broadening participation in high school computer science. ACM Inroads, 3(4), 72-78. doi:10.1145/2381083.2381102

McGee, S. (2022). Spotlight on the 2022 CME Summer Research Fellows [blog]. Chicago, IL: The Learning Partnership. https://www.jointhepartnership.net/2022/09/spotlight-on-the-2022-cme-summer-research-fellows/

McGee, S., Greenberg, R., Mather, A., & Wilkerson, B. (2015). What Features of the Exploring Computer Science Course Equitably Inspire Students to Pursue Further Computer Science Coursework? [Grant]. https://doi.org/10.51420/grant.2015.2

McGee, S., Greenberg, R. I., Reed, D. F., & Duck, J. (2013, Summer). Evaluation of the IMPACTS computer science presentations. *Journal for Computing Teachers*.

McGee, S., McGee-Tekula, R., Duck, J., Dettori, L., Greenberg, R.I., Reed, D.F., Wilkerson, B., Yanek, D., & Rasmussen, A.M. (2018, April). Does Exploring Computer Science Increase Computer Science Enrollment? Paper presented at the American Education Research Association annual meeting, New York.

McGee, S., McGee-Tekula, R., Duck, J., McGee, C., Dettori, L., Greenberg, R.I., Snow, E., Rutstein, D., Reed, D., Wilkerson, B., Yanek, D., Rasmussen, A., & Brylow, D. (2018, February). *Equal Outcomes 4 All: A study of student learning in Exploring Computer Science. Proceedings of SIGCSE '18, Baltimore, MD, USA,* 50-55. doi:10.1145/3159450.3159529

Park, A. (in press). The Impact of Computer Science Graduation Requirements on Student Participation [Report]. Chicago, IL: The Learning Partnership.

Pham, D. (in press). Computer Science Course Grades before and after the Computer Science Graduation Requirement in Chicago Public Schools: A Multilevel Analysis [Report]. Chicago, IL: The Learning Partnership.

Reed, D., Wilkerson, B., Yanek, D., Dettori, L., and Solin, J. (2015, September) How Exploring Computer Science (ECS) came to Chicago. *ACM Inroads, 6(*3):75–77.

Wachen, J., McGee, S., Yanek, D., & Curry, V. (2022, May). Evolution and Impact of Instructional Coaching for Exploring Computer Science Teachers in a Large Urban District [Paper presentation]. RESPECT annual conference. Philadelphia, PA.

Winters, R. (in press). An Examination of Exploring Computer Science Participation on High School Computer Science Grade Outcomes Using Difference in Difference Modeling: A Working Paper [Report]. Chicago, IL: The Learning Partnership.

Yin, D. (in press). Computer Science Access in Chicago Public Schools [Report]. Chicago, IL: The Learning Partnership.

Zumbach, L. (2013, December 10). CPS making computer science core subject. *Chicago Tribune*.