NYC CS4All: An Early Look at Teacher Implementation in One Districtwide Initiative

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***Abstract*—Computer science for all initiatives have broadened the participation of students enrolled in elective computer science (CS) courses and introduced compulsory CS instruction in many areas of the United States. However, there is a shortage of K–12 teachers with the background, preparation, and experience necessary to teach CS. To build capacity to deliver this instruction, districts must provide teacher preparation that includes not only CS content, but also high-quality pedagogical approaches that will meet the needs of all students enrolled in a wide variety of school settings. In this paper, we explore teacher outcomes across multiple CS professional development opportunities, in one large urban district. The teacher outcomes were measured via a survey administered between eight months and two years after teachers received training to implement CS.**

Though our findings are from a single district, we believe these findings are relevant to other settings and provide useful information about the outcomes of teacher professional development for CS education, as well as supports and barriers to implementing CS, in a large, urban school system. The results offer insight into professional development quality, teacher confidence, the ability of teachers to implement CS in their classrooms, and supports and barriers to offering CS instruction (even in a district where CS education is a priority). They also shed light on how supports and barriers differ in schools serving students with high economic needs and lower academic performance compared with schools serving students with lower economic needs and higher academic performance. These differences underscore the importance of considering economic need and academic performance (in addition to race and gender) when developing and executing CS for all initiatives.

Keywords—CS4All, K–12 classroom implementation, Teacher survey, Evaluation, Assessment, Computational Thinking, Gender and Diversity, Teacher Development, K–12 Curriculum, K–12 Instruction, Non-traditional Students, Professional Practice

I. Literature Review

A. CS Education Landscape

The last ten years have been marked by an explosion of computing across almost every industry, as well as a dramatic increase in jobs that require computational skills, especially in Science, Technology, Engineering and Mathematics (STEM) fields. Over the next decade, the computer science industry is projected to grow by 13 percent—adding over half a million jobs—according to the U.S. Bureau of Labor Statistics [1]. That rate exceeds the average for all occupations. Furthermore, it is widely agreed that the use of computational concepts and methods—problem solving, designing systems, refining the steps in a process, and tinkering toward creative solutions—are relevant in nearly every discipline, profession, and industry [2]. Thus, there is a growing call, at district, state, and national levels, for all students to have opportunities to become proficient computational thinkers and be exposed to hands-on computer science (CS) curriculum and courses throughout their educational careers.

However, while most students, parents, and educators support and see the value in CS education, nationally only 60 percent of schools offer any CS courses to students, and even fewer schools (40%) offer classes that teach programming and coding [3]. In fact, just 15 states require secondary schools to offer CS, only 19 provide funding for teacher training in CS, and only 22 have established K–12 CS standards [4].

Compounding these challenges, some groups are systematically underrepresented in CS and CS education [5]. For example, Black, Latinx, and low-income students are much less likely than their White and more affluent counterparts to have access to CS learning opportunities in school or access to computers at home. Female students face additional social barriers: compared with male students, they report less interest in and awareness of CS opportunities, and they are less likely to report having ever learned CS in grades 7–12 [6, 7].

An increasing number of policymakers, business leaders, and educators see it as a both practical and moral imperative to confront these disparities. They seek to empower underserved students and communities to participate as creators—and not just consumers—in a digital world. Broadening participation in STEM and computer science can strengthen the workforce and arm students with skills to help solve important problems in society.

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Answering the call for computer science expansion and equity, the New York City Department of Education (NYCDOE) launched its CS4All initiative in 2015, with the goal of providing meaningful, high-quality computer science education to all public school students in each grade band (i.e., K–2, 3–5, 6–8, 9–12) by 2025. New York City's CS4All is currently the largest districtwide effort in the country attempting to implement CS education at this scale, though there are similar efforts occurring in other districts, such as Broward County, FL, Chicago, Dallas, San Francisco, and San Diego, as well as statewide initiatives in Georgia, Alabama, Utah, Maryland, and elsewhere.

In New York City, CS4All is explicitly designed to increase access to CS education among historically underrepresented groups—in particular, girls and Black and Latinx students. The initiative aims to positively influence a range of outcomes, including CS knowledge and skills, computational thinking, problem solving, academic engagement, and eventually students' pursuit of CS-related college majors and careers.

B. *Preparing Teachers to Teach CS*

Nationally, the lack of teachers with the capacity to teach CS is widely cited as a barrier to offering CS instruction to more students [8, 9]. Most states do not offer teaching licenses specific to CS, although in 2018, New York State approved the creation of a CS certificate for teachers. Further, most educators and administrators believe teachers need extensive training or coursework in CS to successfully teach the subject [10, 11, 12]. Yet, on a national scale, the state of CS teacher preparation has been described as "deeply flawed" and inadequate to address growing demand [10]. While great strides have been made in preparing teachers to implement quality CS instruction, efforts to expand CS education will require much greater teacher capacity than currently exists [13]. Equally problematic, the training that is available is generally provided by institutions of higher education with little or no involvement from schools or districts. This disconnect between professional development (PD) opportunities and local context limits the extent to which training is aligned with and relevant to the needs of the district and its schools [14].

To address these barriers, the NYC CS4All initiative is providing PD to nearly 5,000 teachers over the course of ten years. To date, the initiative has offered a diverse selection of year-long programs to teachers in foundational and advanced CS curricula. These PD experiences last a minimum of 48 hours for foundational curriculum and 100 hours for advanced curriculum. The trainings are designed to prepare teachers to lead multi-year CS sequences of semester and year-long CS courses (ranging from introductory to advanced AP CS courses) and the integration of CS units into other courses.

These professional development options are guided by a set of principles described in the NYC CS4All Blueprint, an academic and implementation guide for teaching computer science in New York City public schools. The Blueprint articulates five key CS concepts (abstraction, algorithms, programming, data, networks) and a set of CS practices (analyzing, prototyping, communicating) around which the CS4All PD options are organized.

Sequences: The multi-year sequence PD options include the Software Engineering Program (SEP) and SEP Jr.

Software Engineering Program. The SEP program is a multi-grade comprehensive CS education sequence for grades 6–12. The PD for teachers includes a two-week summer institute, five Saturday follow-ups during the school year, and participation in "hackathons."

SEP Jr. The Software Engineering Program Junior is a CS program for kindergarten through 5th grade students that includes teacher-directed lessons and creative computing activities such as Scratch, robotics, and maker education. PD includes a five-day summer institute, as well as four optional and five mandatory Saturday follow-ups during the school year.

Courses: These PD options focus on half-year and full-year courses that range from introductory to advanced AP CS offerings.

During the 2019–20 school year, introductory CS courses include Computer Science Discoveries, Exploring Computer Science, Introduction to Physical Computing, Introduction to Computational Media, and TEALS Introduction to Computer Science. Teacher PD includes a two-week summer workshop and five Saturday follow-ups during the school year.

Advanced CS courses include Advanced Placement Computer Science Principles using either the Beauty and Joy of Computing, UTeach, or code.org Computer Science Principles curricula. PD for teachers includes a two-week summer institute, and five Saturday PD sessions during the school year.

Units: These PD options focus on meaningful CS units for grades K–8. These units include 10–15 hours of CS instruction for grades K–2 and 15–25 hours for grades 3–8, designed to be integrated into existing instruction or used as stand-alone units. These units introduce foundational computer science and computational thinking ideas to students using a creative computing approach. Units curricula include Computational Media and Creative Computing, among others. PD for teachers includes a five-day summer institute, and follow-up PD sessions during the school year. Teachers implementing units are also supported by CS education managers—locally placed district staff who provide on-site coaching and additional PD as needed.

The initiative targets teachers who have not previously received CS PD and schools that do not already have CS teachers or courses. PD experiences were designed to include key features of effective CS PD suggested by past research, including: engaging in active, inquiry-based learning, fostering teacher professional learning community; providing pedagogical and content knowledge in CS instruction; and developing teacher capacity to implement culturally-responsive CS through an inquiry- and equity-oriented approach [9, 12, 15]. In addition, the initiative is guided by research that shows that creating opportunities for teachers to collaborate in planning CS instruction and integrating opportunities for reflection are both important [15, 16, 17], as well as growing recognition of the role that in-classroom support and coaching can play in improving and scaling CS instruction [18, 19].

This paper presents findings from multiple years of a survey of teachers who participated in the district's year-long CS PD programming. There is very little prior research on efforts to increase capacity to teach CS on a wide scale, as required by the NYC CS4All efforts. This research contributes important information about implementation challenges and successes, as well as the early outcomes of a large-scale district-wide effort to develop teacher capacity and implement CS for all students.

II. Methods

A. Research Questions

The teacher survey was administered online in the spring of 2017, and again in spring of 2018. All teachers received the same survey regardless of the professional development they attended. The primary research questions guiding the survey include:

- How do teachers rate the quality of the CS PD they received?
- How confident do teachers feel about their knowledge of and ability to provide instruction in CS?
- To what extent and how are teachers implementing the CS training they received?
- What challenges do teachers report as barriers to implementation? What supports for implementation do teachers find helpful?
- What variations in implementation are there for teachers with different CS backgrounds, who attended different PD types (e.g., for units, courses, or sequences)?
- What variations in implementation are there for teachers in schools that serve students with different economic status and prior achievement?

B. Study Sample and Response Rates

In 2017, we surveyed 225 teachers (representing a 50% response rate) from 159 schools; these teachers had attended CS4All PD programs in 2015–16 or 2016–17. In 2018, we surveyed 536 teachers (representing a 66% response rate) from 446 schools; these teachers had attended CS4All PD programs in 2015–16, 2016–17, or 2017–18. Teachers could have taken surveys in both 2017 and 2018. The surveys were administered online between April and July of each year.

C. Data Measures

The survey asked teachers about their experience with the PD, as well as subsequent implementation of CS in their school. Through primarily closed-ended questions, the survey addressed issues related to the quality of the PD teachers had received and teachers' attitudes and beliefs regarding CS instruction. The survey also asked teachers about supports and barriers to implementing CS in schools and in the classroom. Most items were asked in both years of the survey, though some new items were added in 2018 (e.g., about the extent to which teachers reported covering specific CS concepts and practices in their instruction), and a few of the 2017 items were dropped in an effort to shorten the survey or because they had become less of a priority for the initiative.

D. Data Analysis

We conducted descriptive analyses of the closed- and open-ended survey questions. For closed-ended items, we ran frequencies and cross-tabulations by key subgroups of interest, including grade band taught (elementary, middle, high), whether or not the teacher had implemented CS in their classroom, and school characteristics, such as students' economic need and academic performance. To analyze differences in responses across teacher groups, we ran regression analyses controlling for teacher characteristics (gender, teaching experience, CS expertise), school level, and PD program attended.

The surveys contained a few open-ended items, mostly to allow teachers to specify and describe an 'other' option. For open-ended items, we conducted a content analysis using an iterative coding process. First, the team inductively developed a set of codes for each open-ended question using the initiative's theory of action and other documents to anticipate possible answers. Then, the team refined and added codes based on respondents' actual answers. Finally, team members discussed the coding scheme and its application to ensure consistent and accurate coding, revising the codes as necessary. Themes that emerged from the open-ended questions were reviewed in conjunction with the close-ended results, providing additional context and detail.

III. Findings

Below we present core findings from the 2018 survey, noting key differences and similarities in relation to findings from the 2017 survey.

A. How Did Teachers Rate the CS4All PD?

The CS4All PD offerings are aimed at helping teachers learn new programs and pedagogies in CS education, as well as methods for integrating CS into existing courses. CS4All then expects teachers (with support from school administrators) to put this training to use—helping students learn CS concepts, practices, and perspectives, and helping students connect their CS learning across subject areas and grade bands, as well as to their personal interests in and out of school. For that learning and connection-making to occur, teachers must be adequately prepared and supported to integrate CS knowledge with their existing areas of content expertise, and to help students build CS experiences into academic and career pathways over time. Ensuring the quality and depth of the PD that teachers experience will be crucial to the success of the CS4All initiative.

Our surveys were designed to gather information about teachers' perspectives on the quality and utility of the PD they received. Well over half of teachers (60%) surveyed in 2018 reported that they did not have a CS-related degree or certification or prior experience in the CS profession, confirming that many teachers participating in CS4All PD have limited CS knowledge. Given this, and because the initiative's PD offerings require a year-long commitment, it is critical that teacher engagement and commitment are high. If teachers' experiences are positive, they will be more likely to be engaged in the PD and committed to implementing what they learned when they return to the classroom.

Overall, teachers rated the CS4All PD highly, with a majority agreeing or strongly agreeing that it increased their CS knowledge (90%), that facilitators helped them understand how to implement their learning in the classroom (88%), and that the PD was tailored to meet their needs as a learner (86%). Agreement with statements about the PD quality were high regardless of the type of PD teachers attended (i.e., units, courses, or sequences).

B. How Confident Are Teachers in Their Ability to Teach CS?

Because CS is a new content area for many teachers, we sought to assess their level of confidence in teaching CS, following their participation in the CS4All PD. Beyond learning essential content knowledge and relevant pedagogical approaches, the CS4All PD offerings aim to increase teachers' confidence in their ability to engage their students in CS concepts and practices. Teachers who are confident in their capacity to teach computer science are better positioned to implement what they have learned in PD—and to help their students see computer science as an interesting and exciting field [4, 5]. Furthermore, to meet CS4All's goals, teachers must feel confident in their abilities to teach CS well to a wide range of students, especially students who historically had limited access to CS (e.g., girls, Black and Latinx students, students with disabilities, and others).

The majority of teachers responding to our survey reported feeling somewhat confident in their abilities to teach computer science. Teachers were asked the extent to which they agreed with statements like, "I know how to teach important computer science concepts effectively," and "I know how to facilitate students' interest in computer science." Teachers were asked to report their agreement with each statement on a 5-point scale: 1=strongly disagree, 2=disagree, 3=neutral, 4=agree, 5=strongly agree.

Overall, teachers' confidence in their ability to deliver CS instruction following PD fell between the "neutral" and "agree" categories (3.45 out of a 5-point scale). There were very few differences by grade level. Teachers receiving PD for the first time in 2017–18 had slightly lower scores on the teacher confidence scale than teachers receiving PD in 2016–17 (3.48 vs. 3.84), perhaps suggesting that teachers gain confidence with experience. Teachers implementing CS and trained to deliver stand-alone sequences and courses had slightly higher average scores (3.51 and 3.58 respectively) than teachers who were implementing CS and trained to deliver CS units integrated into other classes (3.46). This may be an indication that integrating CS units into other subjects is more difficult for teachers and requires a larger pedagogical shift from their typical practice.

Despite the moderate levels of confidence reported, 48 percent of respondents agreed or strongly agreed that they wished they had a better understanding of the CS concepts they teach. High school (48%) and especially middle school teachers (54%) were more likely to strongly agree with this statement (see Figure 1 below). This suggests that even after substantive PD experiences lasting 50 hours or more, many teachers may need more and different training and support to effectively implement CS instruction.

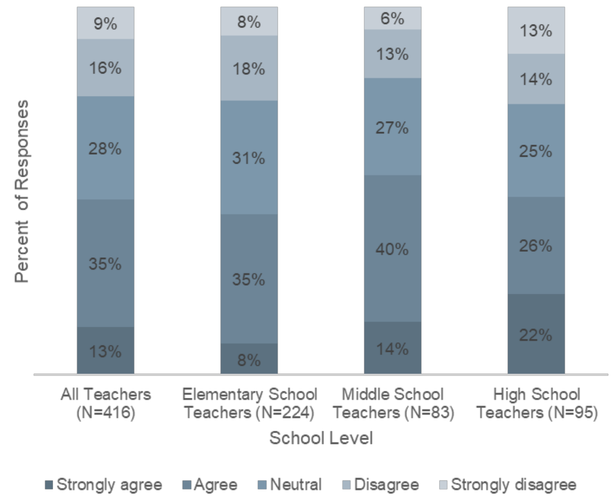

Fig. 1. Teachers' agreement with statement: "I wish I had a better understanding of CS," by school level, 2017–2018 school year

C. Are Teachers Who Received CS PD Implementing It in the Classroom?

Three fourths of the teachers surveyed (75%) in 2018 reported teaching CS in the 2017–18 school year,[1] either as a stand-alone course or integrated into other subject areas. This is slightly higher than the percentage reporting implementing CS in the prior year (70%). Teachers with prior CS experience were somewhat more likely to report implementing CS than teachers with no prior CS experience (80% versus 71%).

Elementary teachers reported implementing CS at higher rates (81%) than middle school (72%) or high school (63%) teachers. However, teachers who attended PD focused on teaching CS courses (e.g., AP CS) and CS sequences (e.g., SEP and SEP Jr.) were more likely to report implementing CS (86% and 81% respectively) than teachers who attended PD focused on CS units (70%). This suggests that stand-alone courses are more likely to be implemented in schools than units that require integration with existing courses, and may be related to the fact that teachers implementing stand-alone courses had higher confidence in their ability to do so than teachers integrating CS into other subjects.

Among the teachers who were not implementing CS, we heard several prominent themes in their responses to an open-ended question about why they were not doing so. These included a lack of ability to teach or integrate CS, competing academic priorities, lack of support to implement CS, and that they were not the designated CS teacher in the school.

[1] Teachers who did not respond to this question on the survey were counted as not implementing CS. If we take non-responders out of the denominator, the percent implementing CS in 2018 increases to 84 percent.

D. What Factors Support or Hinder Teachers' Efforts to Implement CS?

Our teacher survey examined factors that support or hinder high-quality CS implementation in schools and classrooms. Teachers were asked about the extent to which a list of individuals or resources supported their ability to implement CS in their classrooms. They were also asked about the extent to which they faced a number of specific challenges to implementation. Their responses to these questions may suggest strategies that districts can use to provide additional and more effective support to teachers, thereby increasing the initiative's odds of success.

Supports: In implementing CS in their classrooms, teachers reported drawing support from a variety of sources. The most commonly identified supports were professional development providers, administrators at their own school, and other teachers in the school. A total of 68 percent of survey respondents indicated that PD providers were a support to a "moderate" or "large" extent, while 57% said school administrators were supportive, and 41% said other teachers in their schools were. There were no notable differences in findings by grade band.

Challenges: The challenges to implementing CS cited by surveyed teachers were similar to those found in other studies (see for example [6]). In our study, the most frequently reported classroom-level challenges were lack of preparation time and lack of instructional time. The most frequently reported school-level challenges were competing priorities, the need to prepare students for high-stakes tests, and lack of time in student schedules (see Figure 2). For example, teachers' comments included.

"With focus on reading, writing and math, CS is viewed as a third-class citizen."

"Other academic classes are given priority, and CS classes are seen as less important."

It is interesting that—in a district that has articulated CS for all as clear priority—a substantial portion of teachers nonetheless reported challenges related to competing priorities (44% said it was a challenge to a large or moderate degree).

While there were few large differences by grade band, elementary and middle school teachers were more likely to report being challenged by a lack of instructional time and a lack of time in student schedules, compared with their high school counterparts. This may be related to the fact that high school students have more choice in their schedules, whereas elementary and middle school students often have set schedules. It also may be related to the additional challenge of finding time to integrate CS into existing courses and instruction, which is more prevalent in the elementary and middle grades. Teachers who participated in PD designed to implement CS units reported fewer supports and greater challenges than teachers who attended PD designed to implement multi-year CS sequences and year- or semester-long courses. Not unexpectedly, teachers who were trained in CS for the first time in 2017–18 reported more challenges and less confidence in their teaching than teachers who were trained in prior years and had more years of implementation.

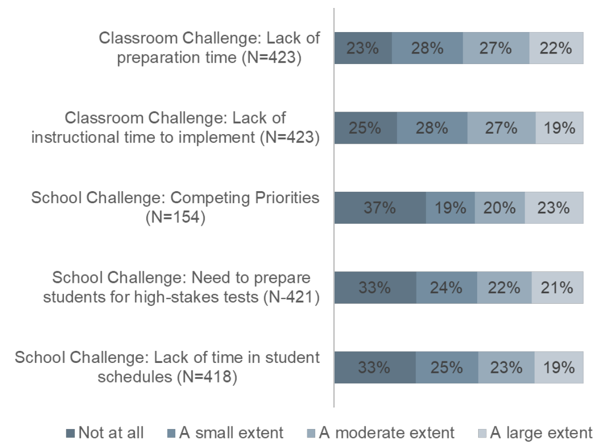

Fig. 2. Teacher-reported challenges to implementing CS, 2017–2018 school year

E. How Do Supports and Challenges Differ for Schools with High Economic Need and Low Academic Performance?

Because CS4All is committed to increasing access to CS instruction for historically underrepresented groups, we explored whether there were differences in the levels of support and challenges that teachers reported in the 2017 survey, depending on the economic need[2] and academic performance of their schools (as measured by standardized test scores and graduation rates). For each variable, we divided the schools of responding teachers into two groups: 1) high-economic-need and low-economic-need schools, and 2) high-performance and low-performance schools. About three quarters of high-economic-need schools are also low-performance schools.[3] Broadly, teachers from high-need and low-performance schools reported less support and more challenges in implementing CS instruction. Five out of the seven supports we asked about fit this pattern, as did 11 out of the 13 challenges. Figure 3 shows the supports and challenges that were statistically significantly different by school economic need. Compared to teachers from schools with low economic needs, teachers from schools with high economic needs were less likely to report receiving support from their administrators, school or network technology specialists, or other teachers in their schools. In a similar vein, teachers from schools with high economic needs were more likely to report challenges to implementing CS, including a lack

[2] Economic need is based on the NYC DOE's economic need index, a measure of students who are in poverty based on indicators such as homelessness, having a home language other than English and entered the NYC DOE for the first time within the last four years, and the percentage of families (with school-age children) in the student's census tract whose income is below the poverty level. Schools at or above the median economic need index for this sample were grouped into the "high economic need group" (N=86) and those below the median were grouped into the "low economic need group" (N=86).

[3] Schools were grouped into the "high performing schools" category if they were at or above the sample median proportion of students proficient in elementary and middle school math and ELA or at or above the sample median high school graduation rate (N=74). Schools were grouped into the "low performing schools" category if they were below the sample median on these indicators (N= 84).

of parental support, a lack of administrative support, and a lack of student interest in CS.

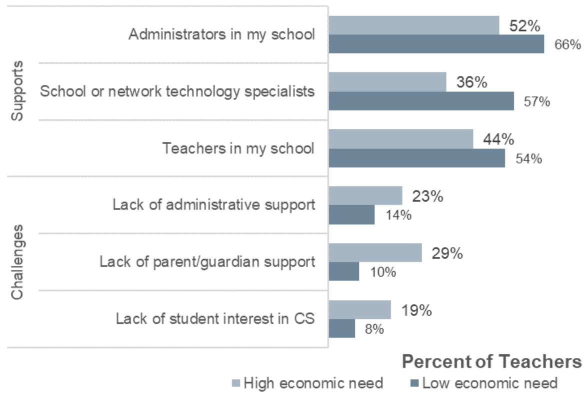

Fig. 3. Selected supports and challenges by school economic need, 2016-2017 school year. High-economic-need group N=86, low-economic-need group N=86. Differences were statistically significant at the 0.05 level.

As with schools with high economic needs, teachers from low-performance schools reported less support and more challenges, though in a few different areas (see Figure 4). In particular, teachers from low-performance schools were less likely to say that teachers from outside their school were supportive. They were also more likely to report a number of challenges, including a lack of expertise in CS education pedagogy and instructional strategies, a lack of expertise in CS content, a lack of parent/guardian support, and a lack of student interest in CS.

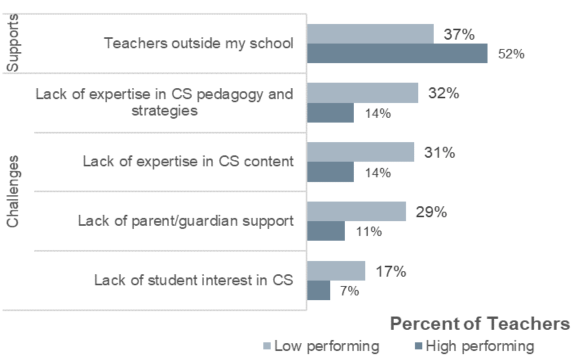

Fig. 4. Selected supports and challenges by school performance, 2016–2017 school year. High-performing schools N=74, low-performing schools N= 84. Differences were statistically significant at the 0.05 level.

IV. Summary and Implications

The survey findings presented here demonstrate that NYC's CS4All initiative has provided large numbers of teachers with CS professional development opportunities that they highly value. Most of them reported implementing CS in their classroom in the following school year. They also reported moderately high levels of confidence in their ability to deliver CS instruction, although many (especially in middle and high school) wish they had a better understanding of the CS concepts they teach. This suggests that in addition to intensive PD, teachers may need other enrichment opportunities and supports to extend their understanding of critical CS concepts and pedagogies. They may also benefit from PD opportunities and supports that are differentiated by grade level, specific content, and teachers' prior CS knowledge and experiences.

Another resource for extending learning about CS is the larger community of CS4All teachers. Among the supports teachers reported accessing were other teachers at their school. The initiative may want to expand its focus on mechanisms (e.g., interest- or need-based meetups, local affinity groups, etc.) to increase opportunities for teachers to connect with other teachers for further learning and support. Local colleges and universities may also be sources of opportunities for certification, continuing education credit, and badges. Our survey revealed that teachers in schools serving lower-performing and higher-economic-need students are less likely to find support for implementation from their peers—possibly because there are no other CS education colleagues in the building. In light of this finding, increasing opportunities for CS teachers to connect with other CS educators could be an important strategy for increasing equity.

The surveys explored both classroom- and school-level challenges to implementing CS. Teachers most frequently reported lack of preparation time and lack of instructional time as classroom-level challenges. For school-level challenges, they most frequently reported competing priorities, the need to prepare students for high-stakes tests, and a lack of time in student schedules. These time and priority challenges are not ones that teachers can necessarily manage themselves. They often require reconsidering priorities, schedule changes, and other structural changes that need the input, direction, and often approval of school administrators.

Because it is clear that administrators are a critical support and can potentially remove barriers to CS instruction, CS4All's efforts to engage school leaders are particularly important—and may be a way to address the school-based challenges teachers identified. Strengthening engagement with and professional development for school leaders will likely enhance CS implementation and help sustain CS4All over time. Further, given that teachers from more advantaged schools (serving students with higher performance and lower economic need) reported more support from their administrators, this is another strategy that can promote equity in CS.

Along similar lines, expanding efforts to coordinate with district superintendents[4] who supervise school principals may help ensure that the importance of CS is being effectively communicated throughout the district. Superintendents may be able to help school leaders balance competing priorities (e.g., by including CS-related initiatives in each school's educational plan). It is possible that priorities are somewhat different at schools with low versus high levels of economic need and performance. At high-economic-need schools, for instance, staff may be focused on meeting students' basic needs; at low-performance schools, staff may prioritize traditional academic subjects—particularly those with accountability stakes for

[4] New York City has 46 superintendents, including 32 who oversee the 32 geographic school districts, nine who oversee high schools, and five who oversee special populations, such as students with disabilities.

students, teachers, and the school as a whole—over computer science. Teacher reports on the survey that implementation of CS is challenged by competing priorities suggests this may be the case. Providing administrator training and support and working with superintendents could help increase understanding of how CS education can support school improvement efforts, rather than detract from them. For example, CS instruction may increase students' engagement in school. Sharing this perspective, along with concrete strategies to balance competing priorities, could result in greater buy-in and prioritization of CS in schools.

In sum, the significant differences that emerged in teacher-reported barriers and supports, based on students' economic need and achievement, create a picture of how school demographics and context influence CS implementation and the support that teachers need. Most commonly, CS for all efforts focus on equity in terms of race/ethnicity and gender. Findings from this study highlight the importance of considering economic need and academic performance in addition to race/ethnicity and gender as key equity factors to attend to in a CS for all initiative.

Finally, we note that as NYC's CS4All initiative moves forward, it will be important to consider how needed supports and challenges may differ for schools that adopt CS later on (and who perhaps are less likely to have a 'champion' or strong staff and parent buy-in for the efforts), or that serve students with higher needs and fewer resources (e.g., lower-performance, higher-poverty schools).

While these findings are from a single district, we believe they point to challenges and supports that are similar to those found in other districts attempting to implement CS for all students. The lessons learned and implications for policy and practice are therefore relevant to other settings.

V. LIMITATIONS

As noted earlier, we obtained a 50 percent response rate to the 2017 survey and a 66 percent response rate to the 2018 survey. Conclusions drawn from these surveys are limited by the fact that we do not know if the teachers who responded to the survey are representative of teachers overall. It is possible that teachers who did not respond were systematically different from those who did. Perhaps non-respondents were less likely to have implemented CS in their classroom, or faced additional or different types of challenges. In addition, as with all surveys and self-reported measures, teachers' answers may have been influenced by social desirability—the tendency to give answers that respondents believe are more desirable. Given that other data collected for our larger study of the NYC CS4All initiative, such as interviews with teachers and PD providers, largely corroborate these findings, we do not believe social desirability biased the findings to a significant degree.

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REFERENCES

[1] U.S. Bureau of Labor Statistics. Office of Occupational Statistics and Employment Projections. Retrieved from https://www.bls.gov/ooh/computer-and-informationtechnology/home.htm.

[2] S. Grover and R. Pea, "Computational Thinking: A competency whose time has come." Computer Science Education: Perspectives on teaching and learning in school. London: Bloomsbury Academic, 19–37, 2018.

[3] Google Inc. & Gallup Inc. Trends in the State of Computer Science in U.S. K–12 Schools. Retrieved from http://goo.gl/j291E0, 2016.

[4] Code.org Advocacy Coalition. 2018 State of Computer Science Education.

[5] Google Inc. & Gallup Inc. Diversity Gaps in Computer Science: Exploring the Underrepresentation of Girls, Blacks and Hispanics. Mountain View, CA: Google Inc. & Gallup Inc., 2016.

[6] Google Inc. & Gallup Inc. Searching for Computer Science: Access and Barriers in U.S. K–12 Education. Mountain View, CA: Google Inc. & Gallup Inc., 2015.

[7] J. Margolis, R. Estrella, J. Goode, J. Holme and K. Nao. Stuck in the Shallow End: Education, Race, and Computing, 2017.

[8] U. S. Department of Education. Office of Postsecondary Education. Teacher Shortage Areas. Retrieved from http://www2.ed.gov/about/offices/list/ope/pol/tsa.html, 2014.

[9] J. Margolis and J. Goode. "Ten Lessons for CS for All." ACM Inroads Magazine, Special Issue on Broadening Participation in Computing. Vol. 7, No. 4, 2014.

[10] Computer Science Teachers Association. Bugs In The System: Computer Science Teacher Certification In The U. S. New York, NY: The Association for Computing Machinery, 2013.

[11] J. Margolis, J. Goode, and K. R. Binning. "Expanding the Pipeline: Exploring Computer Science: Active Learning for Broadening Participation in Computing." Computing Research News, Vol. 27, No. 9, Oct. 2015.

[12] J. Ryoo, J. Goode and J. Margolis. "It takes a village: supporting inquiry- and equity-oriented computer science pedagogy through a professional learning community." Computer Science Education, DOI: 10.1080/08993408.2015.1130952, 2016.

[13] J. Margolis, J. Goode, and G. Chapman. "An Equity Lens for Scaling: A Critical Juncture for Exploring Computer Science." ACM Sept. 2015, Vol. 6, No. 3. Pp. 58-66, 2015.

[14] J. Century, M. Lach, H. King, S. Rand, C. Heppner, B. Franke and J. Westrick, J. Building an Operating System for Computer Science . Retrieved from http://outlier.uchicago.edu/computerscience/OS4CS/, 2013.

[15] J. Goode, J. Margolis, and G. Chapman. "Curriculum is not enough: The educational theory and research foundation of the exploring computer science professional development model ." In Proceedings of the 45th ACM Technical Symposium on Computer Science Education, pp. 493-498, 2014.

[16] A. Milliken, C. Cody, V. Catete, and T. Barnes. "Effective Computer Science Teacher Professional Development: Beauty and Joy of Computing 2018" ITiCSE '19 Proceedings of the 2019 ACM Conference on Innovation and Technology in Computer Science Education, pp. 271–277, 2019.

[17] T. Price, V. Catete, J. Albert, T. Barnes, and D. Garcia "Lessons Learned from "BJC" CS Principles Professional Development." SIGCSE 2016.

[18] J. Margolis, J. Goode, J. Ryoo, and D. Bernier. "Seeing Myself Through Someone Else's Eyes: The Value of In-classroom Coaching for Supporting Exploring Computer Science Teaching and Learning." Retrieved from http://www.exploringcs.org/wp-content/uploads/2014/04/SeeingMyselfArticle.pdf, 2014.

[19] R. Morelli, C. Uche, P. Lake, and L. Baldwin. "Analyzing Year One of a CS Principles PD Project." SIGCSE, 2015.