K-12 Computer Science Education Across the U.S.

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Abstract. Our multi-year national research study examines knowledge and perceptions of computer science (CS), disparities in access, and barriers to offering CS in the United States. The first year of the study surveyed 1,673 students, 1,685 parents, 1,013 teachers, 9,693 principals, and 1,865 superintendents, and the second year surveyed 1,672 students, 1,677 parents, 1,008 teachers, 9,244 principals, and 2,227 superintendents. We found that while large majorities of respondents from all groups continue to hold positive perceptions of computer science work as fun, exciting, and socially impactful, perceptions of who can do CS remained narrow. Despite support from large majorities in all groups for having CS in schools, few teachers or administrators strongly agree that CS is a top priority in their school or district, and principals report mixed support for CS from key stakeholders. Few principals and superintendents describe demand for CS from students and parents as high, while few parents and teachers report having specifically expressed support for CS education to school officials. Our paper also uncovers overall opportunities to learn CS in- and out-of-school. We see an increase in the percent of schools teaching computer programming/coding. Even if opportunities exist, students and parents may not know about them; just over half of students and teachers and 43 % of parents are aware of CS learning opportunities in the community, with slightly higher percentages of students and parents aware of online opportunities. Barriers to offering CS in schools remain largely unchanged from year one of the study, with principals continuing to cite a lack of teachers with the necessary skills and a prioritization of courses related to testing requirements as reasons why CS is not offered in their schools. To overcome such barriers, we discuss a potential opportunity for teachers to incorporate CS into existing school subjects.

Keywords: K-12 · Pre-university · Girls · Gender · Underrepresented · Black · Hispanic · School · Student · Parent · Teacher · Principal · Superintendent · Technology · Computational thinking

1 Introduction

Technical advancements and the expansion of professions in which computer science (CS) is relevant make it more important than ever for all students to have opportunities to learn CS. Traditionally, CS is not part of academic required subjects nor is it available in all U.S. K-12 schools [1]. With growing efforts and support for CS

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education, including districts, cities, and even states planning to implement CS across K-12 schools as well as a federal initiative announced in early 2016 called Computer Science for All, we conducted comprehensive U.S. research on CS at the K-12 level to evaluate the progression. We sought to understand the landscape and perceptions of CS for students across the U.S. in order to inform these efforts and to advance CS education at the K-12 level.

We focus on the landscape of access because positive correlations between computer use and attitudes towards computing have been well-documented [1, 2]. In fact, from the 1980s–90s, U.S. policies widely implemented technology in schools in an attempt to equalize educational opportunity [1, 3]. However, little was done to ensure these technologies were used effectively across demographics, even within schools. Lack of emphasis on advanced computing excluded CS advancement for those without the opportunity to learn CS otherwise. Further, home computer use was much lower for Blacks and Hispanics [4], while access was lower and later for girls [5]. We analyze a national sample to provide updates on which students have access and exposure to tech and CS, decades after the policies.

One major challenge in CS education is the lack of diversity. Specifically in the U.S., the lack of diversity includes the underrepresentation of women, Blacks, and Hispanics. At the high school level, Advanced Placement (AP) CS A participation is low overall, but drastically lower for Black and Hispanic students, comprising only 3.9 % and 8.8 % of test takers in 2014, respectively. At the university level, only 11.4 % of CS degrees were awarded to Blacks and 8.5 % awarded to Hispanics in 2012 [6]. And with the release of diversity data by top technology companies, the lack of diversity is sounding the alarm for action.

Perceptions, encouragement, and exposure play important roles in the lack of participation and interest [7]. Incorrect or lack of perceptions as well as stereotypes may discourage students from studying CS [8, 9]. Similarly, self-perceptions in one's own ability has been found to be correlated with interest and participation in STEM and CS [10–12].

External influences involve encouragement from adults as well as peers and increase the likelihood of pursuing and persisting in STEM and CS [10, 13, 14]. Adults, including teachers, can powerfully influence students [1]. Teachers' low expectations have negatively affected students' short- and long-term performance [15, 16]. Traditional roles and the "geek," male, and White stereotype may exclude many from feeling a belonging in CS [17] while influencers may disproportionately encourage certain types.

The lack of CS education exposure to students is possibly a large reason for the lack of knowledge and encouragement in the field [8]. Therefore, beyond perceptions and encouragement, we wanted to dig deeply to understand the landscape of CS access for students in the United States and investigate the interrelated factors behind the low numbers pursuing CS.

This paper details the first two years of a three-year study on the landscape of CS education for K-12 students in the U.S., surveying students, parents, teachers, principals, and superintendents. The goal of the study is to understand

- knowledge and perceptions of CS
- disparities in access, and
- barriers to offering CS.

2 Methodology

This study details results from the first two years of implementation, surveying 1,673 students, 1,685 parents, 1,013 teachers, 9,693 principals, and 1,865 superintendents in 2014 and 1,672 students, 1,677 parents, 1,008 teachers, 9,244 principals, and 2,227 superintendents in 2015–16, representative across the United States. Samples from the two years are not necessarily the same, though because individuals were polled from the same panels, there may have been overlap.

Telephone surveys were conducted with students, parents, and teachers currently living in all 50 states and the District of Columbia using a combination of two sample sources: the Gallup Panel and the Gallup Daily tracking survey. The Gallup Panel is a proprietary, probability-based panel of U.S. adults selected using random-digit-dial (RDD) and address-based sampling methods. The Gallup Panel is not an opt-in panel. The Gallup Daily tracking survey sample includes national adults with a minimum quota of 50 % cellphone respondents and 50 % landline respondents, with additional minimum quotas by time zone within region. Landline and cellphone numbers are selected using RDD methods. Landline respondents are chosen at random within each household based on which member had the most recent birthday. Eligible Gallup Daily tracking respondents who previously agreed to future contact were contacted to participate in this study.

Student and parent samples included targeted, detailed data on the underrepresented (Blacks and Hispanics, including Spanish-speaking only). Students were in grades 7–12 (around age 12–18) and parents had a child in grades 7–12. Teachers taught 1st–12th grade (around age 6–18), with approximately 21 % teaching or have taught computer science. The population for principals was sampled from a list of 99 % of U.S. public schools and approximately 30 % of U.S. private schools. The population for superintendents was from a panel including more than 20 % of all U.S. K-12 school district superintendents.

Student and parent samples were weighted to correct for unequal selection probability and nonresponse. Student data were weighted to match national demographics of age, gender, race, ethnicity and region. Parent data were weighted to match national demographics of age, gender, education, race, ethnicity and region. Demographic weighting targets were based on the most recent Current Population Survey. Teacher samples were weighted to correct for unequal selection probability and nonresponse. The data were weighted to match demographics of age, gender, education, race, ethnicity and region. Demographic weighting targets were based on the Gallup daily tracking information. Principal and superintendent samples were weighted to match national demographics of school ZIP code, school enrollment size, and census region.

Surveys for all five groups covered topics on perceptions of CS, interest in and desire for CS, in- and out-of-school opportunities for CS, participation in CS, and obstacles to providing and accessing CS opportunities. Survey items were closed-ended, with agreement for yes/no questions and Likert scales for agreement with statements

(1–3 Likert for students and parents and 1–5 Likert for teachers, principals, and superintendents). Surveys were not completely the same from the first year to second year, as new questions were introduced based on findings from the first year. Many questions were kept in order to track trends over the entire research study. The appendix includes sample questions.

The surveys for students, parents, and teachers each lasted about 10 min over the phone, with 30–40 questions. Principals and superintendents were emailed online surveys. Principal surveys had approximately 30 questions. Superintendents were surveyed as part of another regular online survey, with 10 closed-ended questions for this study.

After data were collected, a rigorous quality assurance process was used to clean the data. The data were then coded and reviewed by response. Indices of related variables were created and analyzed using regression to understand trends across and within the surveyed populations.

3 Findings

3.1 Knowledge and Perceptions

From the first-year survey, we found that most respondents do not have a clear understanding of what computer science is, and responses were varied. The misunderstanding was that CS includes creating documents and presentations (78 % of students, 64 % of parents, 75 % of teachers, and 63 % of principals said this) as well as searching the Internet (57 % of students, 49 % of parents, 64 % of teachers, 54 % of principals said this). In particular, Black or Hispanic students are somewhat less knowledgeable about computer science. Female students, parents, and teachers were also less knowledgeable about computer science. This confusion with basic computer literacy is important to distinguish, particularly for educators and parents who may believe they are providing CS opportunities.

However, after this initial question gauging understanding of CS, respondents were presented with a definition of CS (see Appendix). So once they understood CS, we see that perceptions of computer science are very positive and high across all populations. Most agree that people who do CS make things that help improve people's lives (93 % of students and parents, 86 % of teachers, 82 % of principals, and 76 % of superintendents agree) and that people who do CS work on fun and exciting projects (with 91 % of students and 94 % of parents agreeing in the first year, increasing to 94 % of both students and parents in the second year; and 82 % of teachers and 78 % of principals agree). Interestingly, we see that students and parents are most likely to have positive perceptions of computer science careers and work, whereas educators are less likely to have positive perceptions, with increasing authority (and distance from students) correlating with lesser positive perceptions.

Further, we see that all populations have high utility value [18] of computer science careers. Over 96 % of parents and students agree that CS can be used in a lot of different types of jobs, and 81–89 % of teachers, principals, and superintendents agree. And, most students (68 %) and parents (79 %) agreed that computer scientists have good-paying jobs. Over 86 % of students and parents say that the student will "somewhat likely" or "very likely" have a job where they need to know CS.

In addition, the majority of all groups support CS in schools and believe it is important. In the first year 90 % of parents said that they thought offering CS is a good use of school resources, which increased to 93 % in the second year. When comparing with required courses like math, science, history, and English, over 84 % of parents, 71 % of teachers, and two-thirds of principals and superintendents thought CS was more or just as important. Roughly 9 in 10 of the adults say the CS is just as or more important than elective courses like art, music, and foreign languages. Black or Hispanic parents are more likely than White parents to say that CS is even more important than the required or elective courses. Over half of teachers, principals, and superintendents think that most students should be required to take CS. With such high support, about 7 in 10 educators agree that it is a good idea to incorporate CS into other subjects at school.

Yet, while perceptions and value are very positive across populations, images of who does CS are very narrow. Half of students and parents agreed that you need to be very smart to do CS. Teachers (38 %) were less likely to agree and principals (19 %) and superintendents (17 %) were the least likely to agree with the statement. In terms of types of students, teachers (62 %) and principals (56 %) agreed that students good at math and science would be more successful in computer science. But only 42 % of students rated themselves as "very skilled" in math and 40 % as "very skilled" in science. Further, 56 % of students said they were "very confident" they could learn CS. Specifically, we saw that Hispanic students are less likely than White or Black students to say they are "very skilled" at science. Hispanic students are also less likely to say they are very confident they could learn computer science if they wanted to. With lower confidence, Hispanic students may be less likely to be encouraged or interested in fields like CS.

In the media, not surprisingly, both students and parents perceive those who do computer science as mostly White, male, and "wearing glasses." We also saw that of the students who said they saw people doing CS in the media, only 16 % said that they often see people who are like them. By gender, we see a stark contrast: 21 % of boys said they "often" see people like them while only 11 % of girls said "often." In fact, 31 % of girls said they "never" see someone like them while only 18 % of boys said "never." Thus, students who don't identify as looking like who they perceive as computer scientists or who don't identify as nerdy or smart may not feel a sense of belonging with computer science. With lower confidence and sense of belonging, certain students may be less likely to be encouraged, less interested, and less likely to learn CS, creating a cycle of reinforcement. Interestingly, by race, 13 % of Hispanic students, 16 % of White students, and 26 % of Black students said that they see someone like them doing CS "often" in the media. This points to other complex factors that may be at play. Overall, these findings imply a need to better shape CS learning environments and social influencers (from the media to educators to parents and to industry) to be inclusive of all backgrounds in order to diversify the students learning CS.

3.2 Disparities in Access

Many schools do not offer CS, with disparities by demographic. About 40 % of teachers and principals said that their school did not have any dedicated CS classes. These numbers improved from the first year survey to the second: 43 % of principals in the first year reported having no CS classes, which decreased to 39 % in the second year. Black students are less likely to report having access to CS classes and CS taught in other classes. Only about 1 in 5 of these principals said they offer Advanced Placement CS, an advanced course that allows students to receive university credit. However, the content is trending to more likely include programming and coding. In the first year, 53 % of principals reported that these CS opportunities included programming and coding, which increased to 66 % in the second year. In terms of other programs, only about half of teachers and principals said that their school offers CS groups or clubs, with numbers roughly the same in both years.

For opportunities outside of school, only about half of students and parents are aware of opportunities in their community to learn CS. And just slightly more, about two-thirds and 54 % of parents, are aware of specific websites to learn CS. Technically, online opportunities are available to anyone anywhere, so it is surprising that not more parents are aware of these websites. Male students in particular are more likely to be aware of opportunities in the community and online than female students. Parents of boys are also more likely to be aware of these opportunities. And, Hispanic students and parents are less likely to be aware of opportunities in the community. These discrepancies in awareness of CS opportunities fall in line with images of who does CS.

Exposure to technology also has disparities. Hispanic students are less likely to know an adult working in technology (49 % versus 68 % of Whites and 65 % of Blacks) and less likely to use a computer everyday at school (31 % versus 42 % of Whites and 34 % of Blacks) or at home (26 % versus 45 % of Whites and 30 % of Blacks, with 10 % of Hispanics saying they never use a computer at home).

In terms of how many students have learned CS, 53 % of students in the first year of the study said they learned CS, increasing to 55 % of students in the second year who said they learned CS. Boys are more likely to say they have learned CS than girls (59 % boys versus 50 % girls). Among students who stated learning CS, 73 % in the first year and 80 % in the second year said they learned it in a class at school and about half learn it on their own, outside of any group or program (56 % in the first year and 48 % in the second year). About a third learn it online through a class or community and about a quarter learn it through a group or club at school or through a group or program outside school. In particular, boys are more likely to have learned CS outside of school: online through a class or group, in an afterschool group or club, or on their own. Black and Hispanic students are also more likely to have learned CS in a group or club at school, and Black students are more likely to have learned it in a group or program outside of school.

When asked about computational thinking (CT) [19], only about 37 % of students said they've done CT at school while 68 % of teachers said that they've incorporated CT into their classes. More students reported doing specific CT activities. Thus, students may be learning CT without realizing that what they are doing is considered CT.

3.3 Barriers

Despite the positive value and high support of CS among parents, as discussed earlier, we saw that few principals and superintendents thought that demand from students and parents was high. Less than 8 % of principals and superintendents reported that demand from parents was high across both years of the study. We explored this further in the second year of the study and found that of parents and teachers who have expressed support for classes or curriculum to the school or principal, only one third of them have specifically expressed support for CS.

Consequently, we also saw that few educators believed that CS was a top priority at their school or district. Only about 1 in 5 teachers and principals agreed with this, and less than 30 % of superintendents agreed. Just over 40 % of principals reported that teachers and guidance counselors thought CS was important to offer and roughly the same percentage of teachers, principals, and superintendents believed that their school board was committed to offering CS. A large portion, about 25–40 %, also stated that they did not know or were neutral about teacher, guidance counselor, and school board support.

In both years of the study, we found that the greatest barriers to offering CS were related to lack of a qualified teacher, budget to train or hire a teacher, as well as the need to devote time towards standardized testing requirements[1] rather than computer science. Over 73 % of superintendents in both years said that a barrier to offering CS is they do not have teachers at the school qualified to teach CS. In the first year of the study, 42 % of principals said this, increasing to 63 % in the second year. Around 56 % of superintendents in both years said that there was not enough money to train or hire a teacher. This same barrier also became more prevalent for principals, increasing from 44 % who said this in the first year to 55 % in the second year. And about half of principals and superintendents stated that the need to devote time to testing requirements and CS is not a testing requirement, increasing slightly from 47 % of principals and 52 % of superintendents in the first year to 50 % of principals and 55 % of superintendents in the second year. Overall, the most common single "main reason" for not offering CS were the testing requirements, cited by about 30 % of principals and 23 % of superintendents.

Despite the lack of perceived demand, the lack of prioritization, and the challenges with obtaining qualified CS teachers and testing requirements, an opportunity lies in incorporating CS into existing subjects. As noted earlier, about 7 in 10 educators agree that it is a good idea to incorporate CS into other subjects at school. In the second year, we found that 29 % of teachers say they have already incorporated some elements of CS in their classes. And, 62 % of teachers reported that they know where to learn more about incorporating CS and 58 % said they would be willing to spend their own time to learn more about CS. Because elements of CS – programming/coding and CT – are tools of critical thinking, problem solving, and creative expression, teachers can and have effectively incorporated CS into various subjects in order to teach content knowledge by means of CS.

[1] In the U.S., public school students are required to take annual standardized tests in math, reading, and in later years science to provide a measure of how students and schools are performing.

4 Conclusion

With all the momentum of CS education in K-12 schools, there is still a need to distinguish CS from basic computer literacy among all populations, including educators, so that students are engaged in opportunities to advance beyond using computers to creating technologies and tools. And more work is also needed to dispel stereotypes of who does CS, even with the high value of CS and positive image of CS careers and work across all groups – students who don't fit these stereotypes often lack access to these CS opportunities and are even unaware of existing opportunities. Further, with barriers like discrepancies in perceived demand for CS, lack of prioritization, obtaining qualified teachers, and testing requirements, the education infrastructure does not provide all students with the needed exposure, particularly Blacks and Hispanics. We also saw that girls are less likely to have learned CS. Finally, to overcome challenges in the education infrastructure, we saw an opportunity to incorporate CS into existing subjects. Our findings suggest:

- We need to increase awareness of the differences between basic computer literacy and CS;
- Computer science training resources that are inclusive of all students need to be made accessible, available, and known;
- Influencers should be aware of the images they promote and diversify images of those who do CS;
- Educators should talk to parents, and parents should speak up about their demands in CS;
- Policymakers and administrators should consider strategies to be more supportive of K-12 computer science offerings, such as
  - more flexible curriculum and class schedules,
  - modifying requirements for standardized testing,
  - allowing computer science courses to count towards graduation and college admission requirements,
  - offering a variety of paths to learn computer science in and out of school, as well as through various means using computers, mobile devices, and without technology.

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Appendix

Sample survey questions. For agreement statements, students and parents were given 1–3 Likert scale and teachers, principals, and superintendents were given a 1–5 Likert scale.

Knowledge of CS. Based on what you have seen or heard, which of the following activities do you consider part of computer science? (yes, no, don't know, refused).

- Programming and coding
- Creating new software
- Creating documents or presentations on the computer
- Searching the Internet

After this first question (only for students, parents, teachers, and principals), respondents were provided a definition of CS and reminded multiple times throughout the survey:

> *Computer science can involve MANY types of activities. Today we are only going to focus on a specific type of computer science.*
> *For the purposes of this survey, computer science is the study of how computers are designed and how to write step-by-step instructions to get them to do what you want them to do. This is sometimes referred to as computer programming or coding. Computer science includes things like creating software, applications, games, websites and electronics and managing large databases of information.*
> *For the purposes of this survey, computer science does NOT include using a computer to do everyday things, such as browsing the Internet. Please keep this definition in mind as you answer the following questions.*

Images of CS

- People who do computer science make things that help improve people's lives.
- People who do computer science have the opportunity to work on fun and exciting projects.
- Computer science can be used in a lot of different types of jobs.
- Most people who work in computer science have good-paying jobs.
- Students who are good at math and science are much more likely to succeed in learning computer science.
- People who do computer science need to be very smart.

Self-image

- How confident are you that you could learn computer science if you wanted to? Very confident, somewhat confident, or not very confident?
- How likely are you to have a job someday where you would need to know some computer science? Is it very likely, somewhat likely, or not at all likely?
- How often do you see people who do computer science in movies or TV shows who are (read and rotate Q04A–Q04F)? Do you see them most of the time, some of the time, not very often, or never?

  - Women
  - White
  - Black or African-American
  - Hispanic/Latino
  - Asian
  - Wearing glasses
- How often do you see or read about people doing computer science in each of the following places? In TV shows (Often, Sometimes, Never)
- How often do you see or read about people doing computer science in each of the following places? In movies (Often, Sometimes, Never)
- How often do you see or read about people doing computer science in each of the following places? Online through social media, articles, or videos (Often, Sometimes, Never)
- Thinking about all of the people you see or read about doing computer science in TV shows, in movies, or online, how often do you see people like you doing computer science? (Asked only of those who see people doing CS "OFTEN" or "SOMETIMES" on TV, movies, and/or online) (Often, Sometimes, Never)

Exposure to Technology

- How often do you use a computer at your school? (Every school day, Most school days, Some school days, Never)
- In a typical week, how often do you/does your child use a computer at HOME? (Every day, Most days, Some days, Not very often, Never)
- In a typical day, how many hours do you/does your child use a computer at HOME? (Asked only of students/parents who use a computer with Internet at home every day) (Less than 2 h, 2–5 h, More than 5 h)
- In a typical week, how often do you/does your child use a cell phone or tablet? (Every day, Most days, Some days, Not very often, Never)
- In a typical day, how many hours do you/does your child use a cell phone or tablet? (Asked only of students/parents who use a cell phone or tablet every day) (Less than 2 h, 2–5 h, More than 5 h)

Learning CS

- Have you ever learned computer science in any of the following ways? (yes, no, don't know)
  - In a class at school
  - In a group or club at school
  - In a formal group or program outside of school, such as a camp or summer program
  - Online through a class, program, or online community
  - On your own outside of a class or program

Value of CS

- It is a good idea to try to incorporate computer science education into other subjects at school.

- Offering opportunities to learn computer science is a good use of resources at your child's school.
- Do you think offering opportunities to learn computer science is more important, just as important, or less important to a student's future success than required courses like math, science, history and English?
- Do you think offering opportunities to learn computer science is more important, just as important, or less important to a student's future success than other elective courses like art, music, and foreign languages?
- Most students should be required to take a computer science course.

Demand

- Which of the following best describes the demand for computer science education among parents in your school/district? Is demand… (high, moderate, low)
- Which of the following best describes the demand for computer science education among students in your school/district? Is demand… (high, moderate, low)

Priority

- My school board believes computer science education is important to offer in our schools.
- Computer science education is currently a top priority for my school/district.
- The majority of teachers at my school think it is important to offer opportunities to learn computer science.
- The majority of guidance counselors at my school think it is important to offer opportunities to learn computer science.

Barriers

- As far as you know, why doesn't your school offer any ways to learn computer science? (check all that apply)
  - There are no teachers available at my school with the necessary skills to teach computer science.
  - There are no teachers available to hire with the necessary skills to teach computer science.
  - There is not enough classroom space.
  - There is not enough money to train or hire a teacher.
  - We do not have the necessary computer equipment.
  - We do not have the necessary computer software.
  - We do not have sufficient budget to purchase the necessary computer equipment.
  - We do not have sufficient budget to purchase the necessary computer software.
  - Internet connectivity is poor at my school.
  - There is not enough demand from students.
  - There is not enough demand from parents.
  - There are too many other courses that students have to take in order to prepare for college.

  - We have to devote most of our time to other courses that are related to testing requirements and computer science is not one of them.
  - Don't know
- Among the reasons just mentioned, what would you say is the MAIN reason your school doesn't offer ways to learn computer science?

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