PIONEER EDUCATION

Breaking the Code:
The State of Computer Science Education in America's Public Schools

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Executive Summary

We live in the Computer Age but not the Age of Computer Science

Less than half the high schools in the United States teach computer science (CS). Girls and students of color are underrepresented in computer science classes. There's a need for more certified computer science teachers and more states to create computer science learning standards.

That is the shape of K–12 computer science education in an era when the ways we learn, work, and communicate have all been revolutionized by computers. Even as computer science has accelerated research in health care, climate change and communications, it still finds itself behind the traditional disciplines of chemistry, biology, and physics within many high schools.

The situation is not limited to states that might be seen as educational laggards. Depending on the measure, Massachusetts, California, Texas, and other homes of high technology centers and top-flight technology schools do not yet elevate computer science education to a level one might expect.

In our review we expected to find a reasonably well-defined academic area with uneven implementation, and we expected to be able to showcase both successes and failures. Instead, we found several deep systemic issues plaguing "computer science in K–12."

The first deep problem area goes to the fundamental question of what is "computer science in K–12?" In college, computer science encompasses a multitude of areas and courses, from programming languages through programming constructs such as data structures and algorithms, data bases, complexity analysis, compilers, and many more. Yet, in K–12, there is general confusion about what is meant by computer science.

- Is it teaching young children how to manipulate colorful objects, real or on-screen, through some graphical interface?[1]
- Is it teaching children how to code in a general programming language with just a handful of programming elements?[2]
- Is it introducing children to programming structures and algorithms?[3]
- Is it discussing the general and philosophical ideas behind computer science but with little attention to actual programming or its structures?[4]

In general, we have found broad confusion and no common understanding when it comes to defining what K–12 computer science is. Different people pitch different ideas and what schools implement often depends on particular advocates.

We have found broad confusion and no common understanding when it comes to defining what K–12 computer science is.

The second deep problem is lack of clarity of the goal of teaching computer science in K–12.

- Is it to try and instill some kind of ill-defined "computational thinking" (CT) that is supposed to make children, even young ones, better understand the computational models underlying many modern gadgets such as cell phones, computers and video games?
- Is it to try and teach children a programming language that is both useful and offers some training in algorithmic thinking?
- Is it to promote future enrollment in college CS majors?
- Is it to promote more girls and underrepresented minority enrollment in college CS majors?

Again, we have not found any clear understanding or agreement across schools and grades. Any and all of the above may be used to justify the "need for more computer science," yet after more than half a century of effort there is an astonishing paucity of longitudinal research showing that computer science in K–12 actually promotes *any* of the goals above.

Colleges clearly indicate that they do not trust any of the K–12 programs to replace their own CS courses, and that they would rather get a high school student with solid grounding in traditional math and sciences rather than graduates of such K–12 "computer science" programs. This fact raises the question of whether adding computer science to the list of mandatory K–12 programs is worth the loss of whatever traditional academic content it would replace.

The other deep problem of the field is the lack of clarity about whether the U.S. actually needs to significantly increase its pipeline to CS majors. The argument for increased need for CS majors is often touted by business leaders, state officials, and school superintendents, as if it represented an unquestionable truth. There exist multiple advocacy organizations, such as Code.org or the Computer Science Teacher Association (CSTA), that focus on promoting good practices of CS teaching in K–12 and promote CS teaching in general. Yet, rarely do they provide evidence of the actual need to sharply increase the supply of CS majors – and STEM majors in general. In fact, there is convincing evidence from labor market research that the urgency to provide more STEM and CS graduates may be overhyped by the advocacy groups.[5]

This paper reports on our findings in terms of how CS education is implemented and promoted across the land, yet it takes no position on the actual need or usefulness of teaching computer science in K–12.

Background

In the fall of 2019, well before the appearance of COVID-19, there was heightened concern among U.S. business leaders, economists and investors about a global economic slowdown and the possibility of a recession in 2020. But a downturn in the technology sector was not prominent among their worries. In the decade from 2018 to 2028 computer and information technology (CIT) occupations were expected to grow by 12 percent, adding more than half a million new jobs, well above the average for all occupations, according to the federal Bureau of Labor Statistics.[6] In May of 2018, the median annual wage in CIT occupations was $86,320, well above the median annual wage of $38,640 for all occupations.

The spread of technology throughout society and the expanding employment opportunities changed the thinking about computer science across the board.

One reaction to the promising labor market was a leap in undergraduate enrollments in computer science courses and degree programs at U.S. colleges and universities.[7] The number of bachelor's degrees awarded nationally in computer and information science had increased by 74 percent at not-for-profit institutions between 2009 and 2015, compared to a 16 percent increase in bachelor's degrees produced overall.

The rush of students was not limited to those majoring in the field. Computer science courses grew at a similar rate among non-majors, an indication of how important computer skills were becoming to people in other fields regardless of their chosen specialization.

The spread of technology throughout society and the expanding employment opportunities changed the thinking about computer science across the board. A 2016 survey by Google/Gallup found that a majority of parents, teachers, principals and superintendents in K–12 felt that offering computer science was "more important than or just as important as required courses like math, science, history and English."[8]

But the same survey revealed a metaphorical shoulder shrug. Faced with issues such as a lack of qualified teachers and limited computer equipment, less than one-third of educators in the Google/Gallup survey said computer science was a "top priority" in their school or district.[9] Basically a "nice to have" but not a "must have." At the start of the 2019–2020 school year, only 45 percent of the nation's high schools taught computer science.[10]

The numbers are brighter in Massachusetts, where digital literacy/computer science is offered at 85 percent of high schools, although only at 44 percent of elementary and middle schools, according to a 2018 report by the Massachusetts Department of Elementary and Secondary Education (DESE).[11]

Anne DeMallie, digital literacy and computer science content specialist at DESE, said she has been taking a bottom-up approach to promoting participation among all levels.

"My focus at DESE is to get it into every elementary school, and by getting it into every elementary school I will have created a desire for it in middle school," she says. "Then from middle school an awareness of it in high school so that maybe you select a STEM major or a computer science major when… that's what you want to do in higher ed."[12]

Many states believe there is value in introducing younger students to computer science, including female and underrepresented minority students, before they are influenced by damaging cultural stereotypes. Alabama, West Virginia, and Wyoming have passed legislation requiring all K–12 schools to offer computer science instruction by 2022.

The DESE study, which covered the 2016–2017 school-year, also found a lack of access for many students. Students of color, females, low-income students, those with disabilities, and English learners were the most affected.

Elsewhere. the study found:

- More white and male students participated in computer science in schools where it was available, regardless of the overall demographics of the school.
- White and Asian students had a 97 percent pass rate in computer science courses, while the pass rate for Hispanic students was 87 percent and 85 percent for African-American students. The average, including smaller populations, was 95 percent.
- The majority of K–12 computer science courses offered in the state aligned with less than one-third of the state's Digital Literacy and Computer Science (DLCS) standards.

That mixed bag of computer science education in Massachusetts is similar to the inconsistencies found in most other states. Educators want to close participation gaps as rapidly as possible, while adequately preparing students for post-secondary schools. They're trying to offer more courses by adding computer science teachers, but the certification programs are often flawed, producing newly-minted, but inexperienced computer science teachers who are leading classes as they adjust to challenging learning standards.

But those are wrinkles that the powers that be are determined to iron out.

"They're struggling to establish the curriculum, there aren't enough teachers, and there is a lot of pressure on principals and superintendents to make sure kids pass the high stakes tests in math and science and English language arts," says W. Richards Adrion, professor *emeritus* at the University of Massachusetts Amherst and former chairman of the school's computer science department. "So it's partly due to all those factors that things are not moving quickly. But they're beginning to move much more quickly than they were a few years ago."[13]

No teachers, no courses

When the personal computer was introduced and popularized in the home, the classroom and the workplace in the 1980s and 1990s, it was new to a lot of people at the same time. Unlike other teachers in science or history or math, who graduated from college trained in their discipline, the majority of people who would become K–12 computer science teachers were already teaching. But their schools had to wait until they were trained before offering computer science classes. In many places they're still waiting. In the Google/Gallup survey, 63 percent of K–12 principals and 74 percent of superintendents who did not have computer science in their school or district said one reason was a lack of teachers with the necessary skills to teach it.[14]

In 2013 the Computer Science Teachers Association, a computer science teachers' advocacy group, produced a report that was highly critical of computer science teacher certification in the U.S. It stated "the one discipline that offers those who pursue it limitless opportunities is marginalized across the educational spectrum."[15]

The report followed two prior attempts by the CSTA, in 2004 and 2007, to better understand training for K–12 teachers. In the new review the CSTA did not mince words. The critical place that computing and computer science had found in the lives of people was not found in classrooms. The teacher certification process was "confused, disparate and sometimes absurd." Across the country, the report said, the certification process was hampered by confounding processes and illogical procedures, "bugs in the system that keep it from functioning as intended."[16]

The problem was the way federal, state, and local K–12 education policies interacted. Computer science wasn't a core academic subject or a priority at the federal level, so states discounted it as well. That perception flowed down to the district and school level.

"Because non-required courses are less likely to be offered in schools, administrators are less likely to hire teachers who are specifically prepared to teach them," the CSTA wrote. "Because schools and districts are less likely to hire these teachers, teacher education programs are less likely to provide programs to train them."

The report said only two states and the District of Columbia at that time specifically required computer science certification to teach computer science classes. Only seven states required computer science certification to teach Advanced Placement computer science. In 12 other states, a teaching certification was offered but not mandated. In sum, very few states called for any kind of computer science certification for teachers to teach a course.[17]

States without certification requirements but with schools that offer computer science courses, essentially allow students to be led by someone who most likely isn't well-grounded in the subject. Without the training or professional development courses that come with acquiring certification, those teachers who lead computer science classes are less prepared and likely less effective. They lack the knowledge and understanding to be the best computer science teachers possible.

Yet the late arrival of computer science standards, and of teacher certification in computer science, are likely not the only reason to the difficulties in staffing computer science classes in K–12. Whatever staffing issues secondary education has experienced in hiring and retaining teachers in math and science, they are bound to be even bigger with computer science teachers, given that it is a discipline in high demand in the labor market, where the salaries there are considerably higher than in typical K–12 schools. Research indicates that financial incentives—hiring and retention bonuses and salary differentials—can be effective in attracting and retaining teachers in high-demand disciplines.[18]

State and federal funding grows slowly

In recent years an increasing number of states have dedicated more money to improving teacher quality and offering more courses. In 2019, 26 states allotted money for professional development, compared to 19 in 2018 and only nine in 2017. Those seven additional states in 2019 helped increase the amount of money states have committed towards computer science professional development between fiscal years 2016 and 2021 to more than $123 million.[19]

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Florida is among the leaders. Lawmakers there allocated $10 million in fiscal 2020 to train, recruit, and retain computer science teachers. The money will also be used to prepare teachers for certification and to fund bonuses for teachers certified in computer science.

Elsewhere, legislators have taken steps to ensure that money for computer science is equitably distributed. In Maryland, grant applications are prioritized by applications that focus on specific areas that are rural or high poverty; and on different student populations that are underrepresented in computer science such as females or minorities. Arizona targeted professional development in schools that serve Native-American populations and districts that do not offer high school computer science instruction.[20] Massachusetts' fiscal 2020 budget includes $1 million for implementation of a state plan to establish and promote digital literacy and computer science education.[21]

Federal spending for computer science has not always lived up to its promise. In January of 2016 President Obama asked Congress to set aside $4 billion for computer science education. But Congress never approved the funding.[22] Instead, federal agencies have provided smaller but still substantial amounts. In 2016 the National Science Foundation announced plans to spend $120 million over five years in computer science education research.[23]

Among the NSF-approved grants was $3 million to the Massachusetts Department of Elementary and Secondary Education, for a program started in 2018 to create elementary science curriculum materials that integrate computational thinking. The money also financed professional development for elementary teachers who are unprepared to teach computational thinking to students in elementary schools.

In September 2017, President Trump issued a Presidential Memorandum directing the secretary of education to establish "high-quality STEM education, with a particular focus on computer science," as one of the U.S. Department of Education's priorities. It also established "a goal of devoting at least $200 million per year in grant funds towards this priority."[24] But illustrating how computer science funding is often imprecise, only a small portion of that $200 million went to computer science, according to Code.org, while programs in literacy skills for children, and early intervention support services and scholarships to students in low-income middle and high schools (GEAR UP grants) received the bulk of the money.

Perhaps funding frustrations were a factor in 2018 when, in a survey of 540 K–12 teachers nationwide, 75 percent thought federal and state governments were not doing enough to help schools teach computer science.[25]

Computer science?

One reason computer science has been downplayed is the confusion over a fundamental question: exactly what is computer science? Lack of clarity made it difficult to find a proper place for it in programs of study and to develop appropriate learning standards for teachers to follow.

Educational learning standards are the targets for what students should know and be able to do as they progress through grade levels. When posted for a state or a district, they provide consistency for student learning across schools.

For most of the life of K–12 computer science, educators who offered courses were often unclear about what they were offering. Sometimes the traditional uses of computers, such as searching the Internet, were considered to be computer science.

One reason computer science has been downplayed is the confusion over a fundamental question: exactly what is computer science?

In 2010 the Association for Computing Machinery and the Computer Science Teachers Association published a study that showed a broad lack of understanding of computer science and the need for higher-level standards.

"Our research has shown that most states are focused on lower-level skills instead of deeper computer science concepts and capabilities," the study stated. "However, this is not enough in the 21st Century… Where computer science education differs from basic technology literacy/IT goals is that it teaches fundamental concepts of computing, just as an academic course in physics will teach a student the fundamental laws of motion and energy.

"Computer science teaching," it added, "should sit on a continuum from basic computing concepts that can be attained at elementary and middle school levels to deeper knowledge, skills, and practices more appropriate for secondary school."[26]

In 2016 the Association for Computing Machinery, Code.org, the Computer Science Teachers Association, the Cyber Innovation Center, and the National Math and Science Initiative joined to organize states, districts and computer science educators to develop guidelines for computer science education. They produced the "K–12 Computer Science Framework,"[27] a touchstone to create standards and curriculum for elementary, middle and high schools.

The new framework said the misconceptions about computer science "pose serious challenges to offering high-quality computer science experiences for all students." It argued that computer science builds on "computer literacy, educational technology, digital citizenship, and information technology" and spelled out the differences of each.[28]

The K–12 Computer Science Framework did not lay out specific, measurable performance standards. Nor did it offer detailed lesson plans and activities. Instead, it positioned itself as a "high-level guide" that states, districts, and organizations could use to develop their own standards and curricula. It included building blocks of concepts that students should know, which could be used to create targets.

In 2017 the Computer Science Teachers Association went a step further and produced the "CSTA K–12 Computer Science Standards."[29] It *did* present a set of learning objectives that could provide a foundation for a K–12 computer science curriculum. Those standards:

- Introduced the fundamental concepts of computer science to all students, beginning at the elementary school level
- Presented computer science at the secondary school level in

a way that could fulfill a computer science, math, or science graduation credit

- Encouraged schools to offer additional secondary-level computer science courses, that would allow students to study facets of computer science in more depth and prepare them for the workforce or college
- Increased the availability of rigorous computer science for all students, especially those who were members of underrepresented groups

Massachusetts introduced an updated version of its computer science standards in 2017. The "Massachusetts Curriculum Framework for Digital Literacy and Computer Science," has four strands of core concepts: Computing and Society, Digital Tools and Collaboration, Computing Systems, and Computational Thinking. It revised a set of standards that had been in place since 2008.

The increased guidance from national groups created a domino effect. In 2016 only six states had K–12 computer science standards. By 2019 that number was 34, with five other states actively developing standards.[30] But computer science regularly still finds itself being a lower priority than other disciplines.

"So often you get people in states who are heavily focused on STEM, but not computer science because they didn't see it as a part of STEM," says Pat Yongpradit, chief academic officer at Code.org, a nonprofit that promotes computer science in schools.[31] "In 2019, that's a minority attitude, but it's out there. There are probably state STEM directors who spend 95 percent of their time on all the other STEM aspects other than computer science. Yet at their state university, computer science might be their most popular major."

Struggling to reach girls and minorities

Since first introduced in the classrooms, computer science has sometimes struggled to attract girls and students of color. Cultural stereotypes often created barriers by making computers appear to be a "boys' thing." Personal computers were routinely used as toys at first. Games such as Pong and competitions that featured fighting and shooting appealed to boys more than girls, and a techie culture emerged. At the same time, it should be noted that such explanation of the scarcity of girls in computer science may be somewhat simplistic. After all, throughout the 1980s girls routinely received about one-third of computer science bachelor's degrees. Their decline started only in 1990s and continues until today, when they receive less than 20 percent of undergraduate computer science degrees.[32]

"When we think of computer sciences, we think of geeky dudes in their basement or typing away on a computer by themselves," says Yongpradit. "That's not very attractive to people who aren't that. But even if you are interested in computer science and you go into a room and you're one of three girls out of 30 people, you don't feel comfortable."

But the lack of interest in computer science among girls was unique, even if the reasons may be more complicated.

"You don't see the same gender disparity in other sciences as you do in computer science," says Reshma Saujani, founder of Girls Who Code, a non-profit organization that runs after-school clubs across the U.S. for girls up to 12th grade. "There's much more gender parity in biology or [maths] than in computer science."[33]

According to Girls Who Code, the participation of girls in computer science ebbs over time, but the biggest drop happens between the ages of 13 to 17, when the percentage of percentage of female students interested and or enrolled falls from 66 percent to 32 percent."[34] In other words, getting girls excited about computer science before they get to high school seems important.

In high school, the most significant change has been the introduction of Advanced Placement Computer Science Principles.

Girls Who Code runs a summer program for junior and senior high school girls as well as after school clubs for middle school girls. Saujani says that after completing the summer program, 90 percent of participants intend on majoring or minoring in computer science. In another survey, 77 percent of girls first entering the clubs program said they did not intend to pursue computer science in college. But after completing that program, 70 percent of them said they wanted to major or minor in the discipline.[35]

Other programs have sprung up to introduce computer science to elementary and middle school girls in a fun way. Black Girls Code[36] and CoderDojo[37] are programming clubs for girls as young as seven years old. Through elementary programming languages like ScratchJr and Hopscotch, girls can make their own interactive games and stories. Computing workshops such as ProjectCSGIRLS[38] give girls a chance to do hands-on exploring in computer science.

In high school, the most significant change has been the introduction of Advanced Placement Computer Science Principles, a general overview course started in 2016 by the College Board that had an immediate impact on girls and underrepresented minorities. Prior to AP Computer Science Principles there was AP Computer Science AB, a course exploring foundational computer science concepts and structures that started in 1998 and ended in 2009, and AP Computer Science A, which began in 1984 and is still offered. It focuses on programming in Java.

AP Computer Science Principles was meant to be the equivalent of a college introductory course, designed to broaden participation in the study of computer science. It does not rely on any programming language and involves broader ideas behind computing such as algorithms and data and their ethical use, the Internet, programming and social implications (privacy, social impacts) of pervasive computer use.

Making it less technical also made it less intimidating for curious students. Participation among female students in AP computer science exams increased 135 percent from 2016 to 2017. Participation among underrepresented minorities leaped nearly 170 percent during the same year.[39]

Nearly 100,000 students took the AP Computer Science Principles Exam in 2019, according to the College Board, more than doubling participation since the 2016–17 school year. During that span, the number of female students and students of color taking AP Computer Science Principles also more than doubled, exceeding the overall growth.[40]

Those numbers offer encouragement that more girls and minorities will be drawn to computer science. But the gender gap in computing persists and is actually expanding. Girls Who Code reports that 37 percent of computer scientists were women in 1995, but only 24 percent in 2017.[41] Girls Who Code expects the gap to spread if more steps aren't taken.

In other words, despite the many organizations that have formed to introduce computer science to girls, motivate them to major in it in college and move into careers in engineering or similar professions, they are choosing to do otherwise. Viewed another way, perhaps the gender gap in computing would be even larger without the amount of resources and attention devoted to girls.

Stuart Schmill, dean of admissions at the Massachusetts Institute of Technology, believes it takes time for changes to take hold and is optimistic that those numbers will improve.

"More people in general are coding and as that happens you're getting more of the privileged and the wealthy and young men doing it," he says. "Even if there are more women and low-income students that are coding, the gap is widening because there are more students who come from more privileged backgrounds that are participating. I think 15 years from now that gap will be shrinking instead of widening."[42]

Still, it's a baffling trend considering that females earn a greater percentage of degrees in STEM-related fields such as medicine, pharmacy, clinical psychology and biology. The female share of veterinary medicine degrees increased from 20 percent in the early 1970s when it was a male-dominated field to an 80 percent share in recent years. The female-male ratio in veterinary medical schools is now 4-to-1.[43]

Another cause for concern is the fact that despite the increased interest in computer science exhibited by girls taking early computer science programs in K–12, there is a pronounced absence of research evidence that such enthusiasm is long-lasting and translates into more college computer science majors. Programming classes for early grades have been with us for a very long time, from the Logo turtle graphics in 1960s though the Apple McIntosh HyperCard in 1980s and the modern programming environments already mentioned before. Yet the fact that there is no extant research showing how such early engagement translates into increases in the number of females majoring computer science in college is disconcerting, and sheds some doubt on the effectiveness of early teaching of computer science.

Is high school CS needed for college?

High school girls who take AP Computer Science are 10 times more likely to major in computer science than girls who do not, according to a 2007 College Board report. African American and Hispanic students who take AP Computer Science in high school are seven-to-eight times more likely to major in computer science than those who do not.[44] Yet these are correlational studies and it's unclear whether the AP courses prepared students for, and excited them about, computer science in college, or whether the students were interested in it to begin with and hence took those AP courses in high school.

If a student wants to major in computer science in college, does it matter if they have taken those courses in high school? Not so much, it turns out.

No less important of a question is if a student wants to major in computer science in college, does it matter if they have taken those courses in high school? Not so much, it turns out.

At Worcester Polytechnic Institute in Massachusetts, students are accepted based upon their academic record, not upon their intended major. Craig Wills, head of the computer science department, says WPI does not reject applicants if they lack a deep computer science background. But prospective students need to have strong math and science foundations.

"Those who have taken computer science-related courses in high school, such as the AP courses, gain two advantages," says Wills. "One, they find out if they like to do that kind of work and two; they get an idea of whether they have an aptitude to do that kind of work."[45]

Requiring students to take courses in computer science in high school would be counter to their admission goals, he says.

"One of the issues we have in computer science is broadening of students in the discipline," says Wills. "To say you already need to have experience before you come into our program would have the effect of reducing our pool of prospective students. For many years we've had 15 percent women computer science majors. For the last couple of years we're more than 30 percent in terms of first year students indicating an interest in computer science."

The policy is similar at MIT. Students apply to the university, not a department, but once accepted they can select any major without conditions, according to Schmill.

There are advantages to having taken the AP computer science courses if you select computer science as your major. Neither MIT nor WPI allow an AP computer science course to substitute for a required course, but there may be introductory-level electives students can skip. At MIT, students can take an exam in the beginning of a semester and get credit for a class.

"It's not an automatic from the AP, but if students have the knowledge they can place out," says Schmill.

At WPI, first year students who have earned a high score on their AP computer science exam can receive a one-course credit towards an elective. But that credit cannot be counted towards the 15 computer science course credits needed to graduate.

"We don't see that the AP CS students coming out match up to our first course for majors," says Wills.

Summary

K–12 students who learn about computer science benefit in several ways:

- They go beyond just using computers and acquire a deeper, more complex understanding of the basics of computing, useful at a time when technology is so pervasive
- They receive their introduction to innovation and a field that offers economic opportunity whether they attend college or not
- They prepare themselves for further academic study and success when facing new challenges in higher education

But there is no denying that computer science's presence in K–12 education is surprisingly small, given the times we live in. Technology is ubiquitous in everyday life, from smartphones to tablets to laptops to wearable technology and more. Yet, only 45 percent of U.S. high schools offer computer science courses in the 2019–2020 school year. Only 34 states have established standards for computer science. And only 26 states offer state-level funding for professional development of teachers, a key factor in the ability to offer more courses.

Especially frustrating is the slow progress to include more females and students of color. The gender gap in computer science is expected to expand, despite the formation of groups devoted to reaching more females such as Girls Who Code.

Studies continually show rural and urban schools have lower participation rates in computer science than suburban schools.

But progress is being made. The introduction of the AP Computer Science Principles course, designed as a less technical, more exploratory college introductory course for high school students, has attracted more girls and more minority students. Time will tell what impact it will have on female majors in college.

Innovations to reach more students are appearing. At the start of 2019, Carnegie Mellon University, known for its instruction in computer science and artificial intelligence, launched a free, online curriculum for high school students to help instructors teach programming skills using graphics and animations. The curriculum is intended to fill a gap between introductory computer science educational materials available for grades K–8 and the Advanced Placement courses that advanced students might take later in high school.[46]

Amid the hand-wringing about what is lacking and the pace of change, educators and policy makers are left with a question: What do they ultimately want from computer science education?

In addition to the AP Computer Science A and the AP Computer Science Principles courses, another popular course is Exploring Computer Science (ECS). It's a year-long K–12 program that features a high school intro-level curriculum and teacher training program. Developed at UCLA in collaboration with the Los Angeles Unified School District, the curriculum provides opportunities for problem-solving, collaboration and abstract thinking. It is being used by schools in 34 states

Educators and policy makers are left with a question: What do they ultimately want from computer science education?

Code.org offers CS Fundamentals For Elementary Schools, six computer science fundamentals courses created in 2017 using the Computer Science Teachers Association standards. Many states have a rich curriculum of programming and web design taught in vocational technical schools. Georgia has three pathways in high school. One ends with the AP classes, another in hands-on vocational classes and the third is a middle pathway. The result is dozens of courses housed in three separate pathways. Other states are slowly adding courses.

"But the question is what do you want to accomplish," says Adrion the former chair of the UMass Amherst computer science department. "Do you want to accomplish literacy in computer science for everybody? Those three courses (AP Computer Science-A, AP Computer Science-P, ECS) address that. Or do you want a more specialized program that will lead directly into a programming or computer science or software engineering career. The strategy for a curriculum at the high school level would be different, depending on what your desired outcome is."

Because computer science education is still relatively new in K–12, Adrion says strategies are still being tested and data to measure progress are still accumulating.

"It's early," he says. "I think it's beginning to work but it requires people to work together at the state level because each state has its own strategy for education. We still don't have enough experience with curricula below maybe three courses at the high school level, other than vocational courses. There's just not good curriculum out there to use."

Conclusions

If policymakers accept that it is important to quickly grow CS in K–12, then they should focus on the following:

1. The lack of qualified teachers is a barrier to the availability of more K–12 computer science courses. Professional development training is critical to ensure that students receive proper instruction in computer science. Yet too few states are allocating funds to finance such training. State legislators need to recognize that the quality and quantity of computer science courses throughout K–12 will increase if they earmark training funds for teachers in state budgets.
2. The shortage of computer science teachers begins with a scarcity of schools that offer any kind of pre-service computer science teacher education. State universities that add computer science courses to their requirements for students planning to become math or science teachers will expand the number capable of teaching basic computer science in K–12.
3. Serious consideration should be given to adjusting the salary schedules for teachers in high-demand professions such as computer science. Without that, no amount of pre-service and post-service training is likely to address the scarcity of qualified computer science teachers. Few CS graduates will be attracted to teaching, and many re-trained teachers will likely leave the profession for much higher salaries.
4. In many states, there are significantly fewer computer science courses in rural and urban schools than in suburban schools. Additionally, students don't have an opportunity to engage in computer science until high school, making it more likely they will already have connected to competing activities and subjects. In an era when computational thinking is a 21st century skill, policymakers and educators would be wise to create more K–8 computer science programs.

Recommendations:

The meaning of "computer science" in K–12 is interpreted in many different ways by different stakeholders. The field should strive to better define what is meant by the term, so parents and educators can make rational decisions about where they want to go. Further, the purpose of growing CS in K–12 should be elucidated and more research is urgently needed to explore the efficacy of current programs towards such goals. Currently, we're largely flying blind on the wings of hope that teaching CS in K–12 "will do good things." It is unclear that it will, and we lack research to show what long-term outcomes of those programs are.

Finally, policymakers, educators, and parents should seriously consider whether introducing another "heavy duty" mandatory subject in K–12 is worth the loss of what it may replace. We have found that colleges tend not to assign significant weight to those courses and prefer good grounding in traditional math and science instead. Is CS the preferred topic to replace some traditional academic content in math, science, English, or civics? Parents should evaluate this question with their eyes open, while carefully reviewing the research evidence and data.

Endnotes

1 The over half-century-old "Turtle Graphics" and LOGO language (1967) is an early example of such, still going strong. SCRATCH is a more recent popular example of such.

2 AP Computer Science A does that, historically in Pascal and more recently in Java

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