BUILDING AN OPERATING SYSTEM FOR
Computer Science Education

CS IN SCHOOLS STUDY

The CS In Schools study identifies significant supports and challenges that computer science (CS) teachers and their school administrators perceive most affect CS education in their schools. It also describes practitioners' opinions about the qualities they feel CS teachers need to have, steps that need to be taken to move CS education forward, and their visions for CS education in the future. In order to answer these questions, 19 teachers and eight administrators (see description of sample) were interviewed.

Both the CS In Schools Study and the Teacher Capacity Study examine teachers' current contexts, capacities and needs. The Teacher Capacity Study did so through the administration of a questionnaire. This study complements that questionnaire by interviewing a sample of those respondents to examine issues pertaining to CS more in-depth and provide rich qualitative descriptions.

TEACHERS

The goal of this study was to identify the most significant supports and barriers that CS teachers and principals perceive most affect CS education in their schools. We also sought to understand practitioners' opinions about the qualities they felt CS teachers needed to have; steps that needed to be taken to move CS forward' and their visions for CS in the future. In order to answer these questions, we interviewed 19 teachers and 8 principals (see description of sample).

This study complements the Teacher Capacity Study in that both examine teachers' current contexts, capacities and needs. The Teacher Capacity Study did so through the administration of a questionnaire. This study examines these issues more in-depth and provides rich descriptions, in practitioners' own words.

CHALLENGES

▼Computer science teachers feel isolated.

On the Teacher Capacity Survey, most CS teachers reported being alone in the CS teacher role at their schools. The teachers interviewed for this portion of the study confirmed that they were isolated, explaining that unlike teachers of other disciplines, they lack colleagues for formal or even simple, informal collaboration. One teacher described this feeling of isolation by saying, "I'm pretty much my own vertical team—vertical teaming is one of the big themes this year [at my school] and every time they ask, 'what have you done for vertical team?' it's like 'I had breakfast [with myself].'"

The isolation has some very practical consequences. For example, if a CS teacher needs to have a day out of school for professional development it can be difficult to find teachers to cover their classes. One teacher summed it up, saying: "It's very difficult to miss school. Because when you're a computer science teacher and you miss school, no one can teach your class. Because there's nobody else that knows how to teach computer science. So it's very difficult for us to have to miss school. And most of the professional developments, you know, take place during the day."

The sense of isolation persists even as teachers attempt to engage with the larger CS education community. More specifically, when CS teachers have other CS teachers in their schools, or have an opportunity to connect to other CS teachers in their district or region, fruitful collaborations are not a given. One teacher explained that she has met a number of CS teachers from nearby areas but that the courses those teachers teach are either too advanced or too basic compared to hers for collaborations and discussions to be useful to either party.

Isolation and its associated lack of community can put CS teachers at a disadvantage compared to other teachers. One teacher noted that although more resources are available for CS teachers than ever before, without colleagues, new CS teachers in particular may not find those resources, or even know that they exist. CS teachers face additional challenges because not only are they isolated within their schools, but also in the larger CS teacher community. As one teacher described, "When I go to work with new teachers, there's no community of practice to say this is what good, effective CS teaching looks like."

▼Computer science teachers feel that they lack sufficient instructional materials.

Other disciplines, such as mathematics and science, have a long history of comprehensive K-12 curriculum development. Developers and researchers have created programs that span years and grades, informed by emerging understandings of how students learn. Computer science education doesn't share this history, nor does it yet have the organizational and professional capacity that other fields have when it comes to instructional materials development.

This situation has left the teachers feeling that they have insufficient instructional resources. Without a variety of fully developed and coherently designed instructional resources to choose from, teachers are left on their own, which, for even the most creative and persistent teacher, can be stressful and time-consuming. One teacher described this well,

> *… it also means I have a lot that I'm trying to dig up and invent and do, because none of the classes I have—other than AP CS—none of them have standard curriculums. So when you're making up what you teach, it takes a whole lot of time. Decisions about what to put in the curriculum…and the right materials for them…and learning to use the tools. It's crazy.*

Other teachers acknowledged and referenced AP Computer Science-A (APCS-A) and Exploring Computer Science (ECS) materials, but these resources only begin to meet the wide-ranging needs of the current and emerging teacher population. Some also mentioned other instructional resources that have been created by higher education institutions (e.g. Scratch from MIT and Alice, from Carnegie Mellon University) but these are more programming environments than they are instructional resources. The end result is that there are so few instructional materials there are gaps in content and academic level. One teacher explained that she used Snap and Alice for her less experienced students but that there was a gap between these and the more advanced topics covered in the APCS-A course at her school. This lack of instructional materials, coupled with the scarcity of CS teachers can cause a perfect storm for the CS teacher:

> *If you teach Algebra 1 you've got four or five other people in the building, so if all of a sudden your kid has strep and you're out for a day, you've got somebody else to say, hey, do you have a worksheet that has to do with blah blah blah. The textbook situation is abysmal; the books that we're adopting are really written for college level even if they're "high school books," all it is is a college level book with some extra stuff slapped into it. So just material-wise, you might have four preps where most teachers have two, plus you have to develop from scratch everything you use in those classes. And then on top of that, a lot of us, because we're "the computer person" in the building, you're asked to do a lot of additional things, like I'm also my school's webmaster, I'm our technology coach so I handle all computer training for teachers. We have Blackboard, so I'm the Blackboard*

coordinator if anybody has problems; anything like that basically gets dumped on me as a duty. Time-wise, that makes it very difficult to cordon off and even get my own teaching stuff done.

Rebecca Dovi, CS Teacher
Patrick Henry High School
Hanover, Virginia

▼ Computer science teachers perceive that computer science isn't understood or valued as a rigorous discipline.

Nearly all of the teachers felt that misconceptions about what CS is are standing in the way of developing a shared vision, and common values and goals for CS education. They see that "computer science" means a range of things to people around them, from typing, to application use (e.g. Word or Excel), to web design, to procedural programming that has no focus on logic. Teachers perceive that these inconsistencies in understanding of CS have real consequences: if CS isn't understood to be a rigorous discipline, it's not valued as one and in turn, it's not prioritized as one. Considering the financial and scheduling constraints on all parts of the school day, they see that low priority courses get cut.

Inconsistent understandings about what CS is abound. As one teacher put it: "I've often likened it to people driving their car… they know they can turn it on and try the headlights and the wipers and turn on their GPS, but they don't understand what powers the car; they don't understand what's under the hood of a car." When CS is equated with basic typing or application use, this can have a trickle-down effect. One teacher explained that because CS is not understood as an important, rigorous discipline at her school, the counselors don't often suggest CS courses to students and as a result, fewer students enroll.

Teachers also felt that the low status of CS courses in schools is reinforced by the fact that they are, for the most part, counted as electives. They report that this designation affects the way they are treated in their schools. As one teacher explains, "Because I'm an elective, and I'm not a required course, and I'm not a core course, so I'm not a math, a social studies, a science, an English, or a foreign language, I'm an elective. The kids treat it differently; the other teachers that I work with treat it differently." One teacher was so interested in the students' perceptions of CS at her school that she did a study on it. She found that often, the students have a good understanding of CS, but that the adults in the community don't. She saw this as a major factor contributing to the poor perceived value CS courses had at her school.

Some of the perceptions about CS are extreme. One teacher, whose background was in the CS industry, was initially prevented from teaching CS courses at her school because the administration felt that "there was no future in CS." Another explained how misconceptions about CS resulted in the removal of a CS requirement:

I think there was a survey done amongst the top administration… someone came up with the idea that we don't really need to teach computer literacy, which is what the course was called, because [they] felt that it could be taught through the

other disciplines, and so let's get rid of that requirement and open up that spot in the ninth and tenth grade. This decision was made by administrators that don't, in my opinion, understand what CS is. They see CS as at that point Word, Excel, maybe some basic web design and web searching, rudimentary using the computer for editing video, basically what we know as computer applications, that's what they thought, oh we can do in the other classes, even though in the computer literacy class, at least half or more of the course was actually basic CS principles like algorithms, learning the really easy programming language, even if it was block structured, problem solving, that kind of stuff. They thought, well we can just keep all of that in math, science, English, history, foreign language, and art, so let's get rid of the requirement. I was the only one who really understood I think what CS was, but everybody else said 'we can do that in other classes,' so the decision was just made. It was made without consulting anyone in the entire school; there were five of us in the room, I didn't know that there was going to be a vote, there was a vote, and it was gone.

Joon Kim, CS Teacher and
Educational Technology Specialist
Brentwood School
Los Angeles, California

▼Computer science teachers perceive that because CS is low priority it receives fewer resources.

Budget cuts affect everyone, from PD providers, to districts leaders, to school administrators, to individual classroom teachers. Many teachers felt that the low priority of CS in their schools contributed even more to their struggle to get materials and professional development. One teacher, for example, vividly explained, "We haven't adopted textbooks in a decade… so I was having contractions with my ten-year-old the last time our adoption committee met."

Of course, financial constraints affect everyone at a school, and some teachers described being at schools that have significantly cut staff in recent years, putting a strain on everyone. The fact that the basic materials for computer science (computers) are relatively costly compared to the basic materials for other courses exacerbates the situation. As some teachers explained, as a non-core class, CS is often at the bottom of the priority list for improvements and changes to curricula, textbooks, computers, and other materials.

▼Computer science teachers are scarce.

All of these challenges can have a compounding effect. It is difficult to train new teachers with few opportunities for professional development and it is challenging to support them without instructional materials. In addition, it is difficult to hire new teachers if there are financial issues. These circumstances combined with the fact that CS teachers often are the sole CS teachers in the school, can have dire consequences for CS education.

One teacher described a situation in which one of their CS teachers had left, and the school was attempting to replace that teacher to keep the CS course going. "We have seven math

teachers here. Nobody wanted to touch it. They had not had... any kind of a CS course in college, and did not know what it was. I could show them a page of code, they didn't understand, and they wanted no part of it."

As for those who have experience and training in CS, the incentive to pursue CS careers is much higher than the incentive to teach CS, especially at the K-12 level. One teacher summed it up nicely: "Oh sure, I still don't make what I did in 1999 [in industry]." The teachers felt that CS majors are more likely to pursue more lucrative careers in industry and without strong CS education programs available to them; they have few reasons to consider alternatives. Some noted that they were the only individuals in their entire teacher certification cohorts with CS experience.

SUPPORTS

▼Professional networks can connect isolated teachers.

The results of the Teacher Capacity Survey revealed that overall, teachers feel supported by their school and community, and that many of them participate in professional networks such as the Computer Science Teachers Association (CSTA). Many of the teachers confirmed that their official and unofficial networks were their greatest supports for improving their CS teaching. Many professions use professional networks to communicate and share practices and ideas, but CS teachers heavily rely on these because so many lack colleagues in their immediate areas. Teachers described participating in and relying on national organizations such as the CSTA, ACM's SIGCSE (Special Interest Group for Computer Science Education), ISTE (international Society for Technology in Education), and NCWIT (National Consortium for Women & Information Technology), among others. See the Teacher Identified Resources section of this report for more information on specific professional networks.

Many teachers explained that their professional networks provided a way for them to connect with other CS teachers. As one explained, "Basically all my CS colleagues are at other schools, people I've met through the year." Another said, "We finally have our own CS teachers association, CSTA, and it's been really a blessing, because before that, every teacher was on their own, in their own school. But now we have a national level organization as well as local organization."

Although deeper collaborations can potentially grow from professional networks, one teacher explained that many CS teachers use them for more basic needs, saying, "Finding content or examples or worksheets is common. I wouldn't call that collaboration, just sharing of resources." Even though collaboration to improve instruction is sometimes viewed as a goal of professional organizations, simple resource sharing can be essential for isolated CS teachers. She continues, "The fact is for most folks, you are going to be a singleton in your school, for a lot of folks, the only person in your district, so to have organizations like the CSTA out there, trying to grow and have more chapters so you have a local community of practice where you can network and you've got some people you can call or email and say 'help, I'm about to teach this and I have no idea how to teach [it],' or 'I have a student who's struggling with this, do you have a worksheet for her? '"

In addition to official organizations, teachers create their own "informal" professional networks, comprised of CS teachers that meet locally, at conferences, and any other way they can. As

one teacher explained, the way in which teachers find each other is secondary to finding each other at all: “Finding the teachers that are passionate about it [CS] and finding the community that's willing to help is basically the way we've done it.”

▼Online resources help teachers supplement instructional materials.

While professional networks are one support for finding instructional resources, the availability of resources online helps address the lack of comprehensive instructional resources even more. While not a replacement for the kinds of comprehensive instructional resources common in other disciplines, given that CS teachers often must create their own instructional materials, the resources they find by reaching across the Internet are very helpful. Further, many explained that finding instructional resources (e.g. free programming languages, pre-created lessons, etc.) online has been easier recently than in years past.

One teacher commented:

> *It's really exciting. This is I think my 16th year doing this, and it's amazing all of a sudden that we have resources and there are books available and conferences that you can go to that are affordable; there's all this stuff happening around CS at the high school level, we have so much easier to teach it than it was when I first started. There are just so many online resources and curriculums that are out there, and it's a very exciting time to see some of the changes happening and see it be more accessible to kids…Content support, all you have to do is Google it, you can look through the ECS curriculum, you can look, now the CS Principles is developing a community of practice, there's the AP site, just with the internet, and so many teachers put their curriculum out there, their worksheets out there, there's just a lot more to pull from than there was six years ago.*

Rebecca Dovi, CS Teacher
Patrick Henry High School
Hanover, Virginia

▼Some school districts provide materials, financial support, and promote computer science education.

The Challenges section describes how some teachers feel that they have insufficient support from their districts, particularly in the areas of professional development and instructional materials. This is not universal, however. Some teachers are fortunate to have strong advocates for CS around them and in interviews credited their schools or districts with providing key supports for founding and maintaining CS courses. One such teacher noted that neither she nor her fellow CS teachers had problems securing support to teach their classes, saying,

We have the support that we need in order to do the things we need to do, whether it's add stuff to the curriculum, purchase a robot kit, attend conferences, visit other schools…the support's been there and I think as a department we've done a very good job at taking advantage of that

as often as we can…it's been very helpful in helping us keep things up to date in terms of what we do.

While some teachers face the challenge of having administrators remove CS requirements or courses (as described above), some reported being able to persuade curriculum committees and district administrators of the importance of CS, and as a result getting their courses approved. Some teachers were not only able to start new courses, but also bring in other teachers to help support them. For others, support from district administrators protected CS programs from being cut in the face of financial constraints: "Our district officials might not know too much about the nitty-gritty details, I do think they understand that it's important to offer students that program that might give them important skills and help them in their future."

Some teachers explained that convincing administrators about the importance of CS for students' success beyond high school was the determining factor in garnering their support for keeping CS courses:

> *I think our school district is onboard with us offering [CS]. We want to offer a rigorous, relevant, college and career-ready curriculum, and CS -- if you don't put that in the equation, you're missing a big part of that. So our school definitely supports it, our school district, our school board. When we brought AP CS to the CCC [Curriculum Coordinating Council], it was unanimously approved which is very rare, because there's every curriculum area in the pot for that council. There is support, because the numbers don't lie. When you present the information to these people about career outlook, job expectancy, job growth, the starting salary, the vast array of positions that are needed, they understand that that is something that could be a large value to our students as far as getting them prepared for a job that would be a great career for them. So overwhelmingly I think the support is definitely there and if we had more time in the day I think even more kids would be taking our classes. I definitely think the support's there.*

Jeff Riley, Accounting, Marketing
and Computer Applications Teacher
Joliet Central High School
Joliet, Illinois

▼Teacher professional development helps teachers stay current in computer science.

CS is a rapidly changing field requiring teachers to stay up-to-date with current technologies and practices. The Landscape Study demonstrated that universities are by far the most common source of professional development for teachers and this was confirmed in many teacher interviews. Specifically, teachers mentioned CS4HS workshops supported by Google, Tapestry Workshops focused on bringing more women to CS, and workshops supported by Georgia Tech. See the Landscape Study for more information on high school CS professional development.

▼Universities provide a range of supports.

Teachers explained that universities provide support beyond professional development. First, they can provide influence and policy support. Colleges and universities are the future destinations of many high school students, and teachers felt that they had the potential to steer high school requirements. One teacher explained,

At the high school level, I think it's going to come from the college level first, because those are the people that are going out into the workforce, and everything you read -- you turn around and all you read is that there's this huge need for people who have some CS background, … [for] people who have a strong CS background, there are just jobs, jobs, jobs, positions they can't fill.

For a specific example, see the Stories from the Field: Georgia where input from higher education had significant impact on the treatment of CS at the high school level. In Georgia, the state recognizes AP CS as a fourth science credit for high school graduation.

Teachers also believe that universities can help influence students. They felt that communication between colleges and high schools could help students enter college with the skills they need to succeed in CS-related fields, and hoped to see more collaboration between colleges and high schools for that reason. They also felt that interactions between high school students and college faculty could help students see the range of career options available to them, and the training they would need to pursue those options.

And finally, universities can help educate future CS teachers. There are few programs that focus on pre-service CS teachers, but access to such programs could go a long way in addressing the lack of CS teachers mentioned in the Challenges section of this report. See the Stories from the Field: Purdue for an example of a CS teacher-training program. According to one teacher, other universities and colleges are beginning to offer CS training to pre-service teachers:

> *It would be a good opportunity for Cornell, one of the colleges in the area, to be the first colleges to offer CS education as a major. [Pre-service teachers] don't necessarily need to focus on a career of becoming a programmer, but learn to do all the cool stuff we do in CS and be able to share that with high school or middle school students once they're done with their studies in college.*

Jason Torres, Computing and Communications
Teacher and Department Chair
Horace Mann School
Bronx, New York

▼Student and parent interest can increase computer science offerings.

Another significant support teachers reported came directly from the students. Teachers felt that they could capitalize on students' interest in technology to promote CS courses. Some teachers described a recent "significant uptick" in student interest, and as a result, their CS courses had grown. In some cases, this resulted in an additional CS teacher being hired, or in the case of

one teacher, being able to focus exclusively on CS: “This winter term, for the first time ever, I only taught CS courses.” Another teacher said,

At a time when a lot of electives are starting to shrink throughout the state of Illinois, a lot of schools are shrinking their elective departments and haven't been hiring and things like that, we're staying at the status quo, we're not losing any sections, and if anything we're gradually increasing our sections.

Parent involvement is also an important contributor to the student demand for CS courses:

> *During open house when I have the parents come in, they're so excited that their son or daughter is taking a computer class. So I think we need to work off…the parents who are working right now, they see how important technology and computers are; they see the future and how valuable that can be to their student…the whole world uses computers…Someone had to write the code that created Facebook, someone had to write the code and have the idea for Twitter, and all those things that all our students love to use.*

Jeff Riley, Accounting, Marketing
and Computer Applications Teacher
Joliet Central High School
Joliet, Illinois

WHAT SKILLS ARE ESSENTIAL FOR COMPUTER SCIENCE TEACHERS?

If the country is to fill the projected demand for computer scientists by the year 2020, the numbers of prepared CS teachers must increase. This is the goal of NSF’s CS10K project, which aims to have 10,000 well-trained CS teachers in 10,000 high schools. The question of what “well-trained” means, however, is an open one. The teachers focused on three areas: Content, Pedagogy, and Ability to Keep Current.

▼Teachers must have computer science content knowledge.

As with teaching any discipline, content knowledge is key. Situations that require unprepared mathematics teachers or business teachers to teach CS courses can result in negative experiences for both students and teachers:

> *I can just speak from my experiences here, and from listening to the students' comments and feedback, it's important to have a really solid understanding of the concepts on your own. I’m not sure about this, but looking at a lot of the workshops, it seems like the focus is on helping teachers who maybe have been thrust into teaching CS and don't have a CS background themselves, and so the workshop is about getting you up to speed on the basic concepts you need to know so you can teach this class.*

Geoffrey Schmit, CS and Physics Teacher
Naperville North High School
Naperville, Illinois

▼Teachers must have pedagogy skills.

Knowing CS content knowledge is not enough for facilitating high-quality CS instruction. Teachers must also know how to teach the content to a variety of students. Some teachers saw this as secondary to CS content knowledge, but saw it as an important skill nonetheless:

> *So not only do you have to know the skills and the technical aspect of it, you have to know the pedagogy behind teaching and how students learn and addressing multiple learning styles and different learning levels and differentiating your instruction. So I think both of those -- they're equally important and you can't do it with just one, you have to have both.*

Jeff Riley, Accounting, Marketing
and Computer Applications Teacher
Joliet Central High School
Joliet, Illinois

▼Teachers must keep up with changing field.

CS is an ever-changing field and while the basic principles of problem solving and logic may generally remain the same, the tools for teaching them constantly evolve. Teachers explained that in order to keep instruction current, they need to have “a lot of problem solving, flexibility, willingness to learn” and “self-steer.” These are very different skills for teachers who might be accustomed to getting a curriculum and being told what to teach. As one teacher explained, “Every couple years, you have to retool and learn a new language. I'm sure Java's going to be around for a while with the College Board, but eventually they'll find something else. They had Pascal, they had C++, so when that happens, you need to go out and learn something new.”

WHAT NEEDS TO HAPPEN NOW

Computer science is currently receiving unprecedented awareness; there are more instructional resources than before, and increasing numbers of students are eager to learn more. Teachers were generally positive about this change happening in the relative short-term. One explained,

I feel like we're right at the cusp of a major change in education, but I know that education doesn't change that quickly, so when I say we're at the cusp of a major change I mean a major

change that's going to take five years minimum…suddenly it's going to be like CS skills are relevant to the entire curriculum.

Teachers extrapolated the current situation to five or ten years in the future and expressed their hopes for the future of CS education.

▼Make computer science a required course with standards, curricula and assessments.

Teachers felt that making the shift from CS as an elective to a core or required course would be the first step in making it a higher priority in schools. They believe that if a requirement, CS would have more credibility and in turn, opportunities and resources for professional development, improved instructional materials, and quality assessments were more likely to grow. Teachers recognized that until then, there is little incentive to teach CS. One teacher explains:

> *There's no benefit to the teacher to teach CS. It's something you do because you enjoy it, but there's no extra money, no extra anything, no pat on the back. We had a high school that lost its CS teacher because the principal -- and there's no benefit to the principal, having a CS program, there's nothing in the rating box that checks and says gee, you have a CS program, great. People are really concerned about standardized scores, particularly math, so they're going to take this teacher, who was a math teacher and a CS teacher, drop all the CS, and have them work on remedial math to bring the kids' scores up so the school would look good. And that's certainly a worthy goal because you need that stuff…You have to figure from the principal's viewpoint, what was biting at the principal? Those math scores, he needed somebody to bring up math scores; that was much more important to the principal than having a CS program. I'm not sure there's a fix for that, unless someone starts rating principals and says 'Do you have a CS program?'*
>
> Steve Rose, Mathematics and CS Teacher
> Thomas Jefferson High School
> Alexandra, Virginia

▼Raise awareness about what computer science is and isn't, and take computer science seriously as a discipline.

Teachers felt that it was important for others, in and out of the school community, to know what CS is and isn't. From their point of view, CS is not only applications, it's not necessarily game design, it's not just programming…it's essentially critical thinking, problem solving, and logic.

The world is rapidly depending on CS: for security, communication, entertainment, commerce, and nearly every other area of life. The teachers recognize this, but feel that others in their community may not see things the same way. As one teacher explains, CS is becoming a basic skill necessary for navigating the modern world:

> *To me it's a basic literacy skill; 100 years ago, to be a literate person, you had to be able to read and write, I think now, that doesn't mean you have to be able to be a ninja-level coder who can do Enterprise Edition Java necessarily, but having some experience with coding and logical thinking and understanding what kind of problems computers can solve, what kinds of problems computers cannot solve,*

I think makes you a more informed citizen, and I think it makes you better in the workplace. You may not be the person designing the software, but you're a better user of the software if you have some concept of what that process is.

Rebecca Dovi, CS Teacher
Patrick Henry High School
Hanover, Virginia

▼Greater number of computer science courses to engage all students.

Many teachers spoke of the range of previous experience their students bring to the computer science classroom. While this is always a challenge for any teacher planning instruction, when a single course is the only opportunity for CS, the range of experience is wider than classes in other disciplines that have opportunities for introductory, intermediate and advanced work. One teacher recalled how computer science drew her in, and how she hoped to see more of that in her students. However, she felt that for this to happen, CS courses will need to meet students where they are. Another teacher noted seeing this happening already, with resources such as the Code Academy. She feels that the more opportunities available for students to learn CS at their own pace, the better.

▼Computer science education begins earlier in students' lives.

Offering courses for different levels is one solution to engaging more students in CS. Another approach is to expose students to CS much earlier in their academic careers — as early as elementary school. Some teachers saw a future in which rising high school students would have had enough experience in computer science to have a sense of the area that they might focus on in their high school careers.

I'd like to see kids exposed to programming and robots in elementary, and have that thought process and background. I'd like to see them actually dig into it some in middle school and come to high school with some idea of what they would want to do with it and pick the area…maybe it would be web design and databases, maybe it would be robotics and — but actually do that in school…

Diane O'Grady-Cunniff, CS and Engineering Teacher
Westlake High School
Waldorf, Maryland

One teacher suggested that out-of-school time might be a way to supplement what students learn about CS before high school, and to engage them in CS early. This can be done through robotics teams and other out-of-school clubs and competitions.

That there are hundreds of thousands of middle school students programming robots throughout the country is something fantastic. They'll go on to high school, maybe another robotics team, and maybe they'll stick [to] programming because that's what they've been doing, but that's a great way to expose a lot of people, and more diverse people might be in my classroom to teach these ideas in a very exciting and authentic way. I think some of these extracurricular[s] can make a big difference.

Geoffrey Schmit, CS and Physics Teacher
Naperville North High School
Naperville, Illinois

▼Require computer science both at the high school and college level.

Many teachers want CS to be a required course in high school. Some saw the college level as the driver of what is expected in high school, and expressed that a change at the college level would be needed first. This may be another way to incentivize CS to school administration, as one teacher explained,

I think it would have to be driven from the colleges…that if the colleges mandated that it was a requirement for their degree…high schools would pay more attention to it and try to meet that expectation. Or… if colleges gave some kind of bonus for students who took it, that would be great. That's the kind of thing that's going to drive the schools.

Another teacher felt that that if CS was a required high school course that could call attention to its value within the rest of the community:

The ideal is for computer science to be recognized as a requirement in high schools. If it's required, then there will be support from all the local authorities, local school superintendents and parents and everybody. So the goal is to have all students be introduced to computer programming while they are still in high school. Because it's not just coding, it's the logic behind it, it's computational thinking, and it's helpful and used in many different areas.

Maria Litvin, Mathematics and CS Teacher
Andover Phillips Academy
Andover. Massachusetts

▼Adequate computer scientists to fill increasing demand.

The US Bureau of Labor Statistics projects that there will be more than 1.4 million computing-related jobs by 2020, but that only 30% of them can be filled by US citizens if the rate of CS degrees earned remains what it is today. High school CS teachers recognize this deficiency. As one stated, “It's frustrating when you hear again that there are jobs that are not able to be filled because they can't find enough people who are good enough to, you know, to do it.” Another teacher felt that the solution to this problem was to encourage students to major in CS in college, which in turn could be encouraged by exposure in high school:

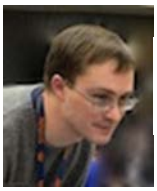
> *You know, why don't you try it out, take your high school course, hey it's going to be easier in college if you get it now. And then be able to actually get the students into a computer science major in college. So I think that's where, you know, if we don't get them into a major in college, we've lost that potential employee that everything I've seen is, we're really going to be at a deficit...*

Jeannette Anderson, Computer Teacher
Hickory High School
Hermitage, Pennsylvania

▼Culture change so that computer science is understood and valued.

Many teachers felt that a shift in the culture, both in and out of their schools, would need to pave the way for other changes. The culture change teachers described included other teachers in their school, their school and district administrators, parents in their community, and students. One teacher explained:

> *…Perhaps on the idealistic side, I would think more of the outreach and the education in terms of sharing with everyone from students to parents to administrators to people in the community about the value, the importance of this, then the natural outcome of that will be that students are interested, and more students are exposed to this, without having to make them take it or putting it on yet another standardized test that they have to sit for. In the end, if you make people take it, then give them a test, then schools might prioritize it, then yes people might take it in high school, but unless you show them why it's interesting and why it will help them, get them excited for it, they're certainly not going to continue exploring these areas in college or beyond.*



Geoffrey Schmit, CS and Physics Teacher
Naperville North High School
Naperville, Illinois

One teacher explained that in CS professionals know that their industry is not driven by socially-isolated coders, but that this knowledge needs to spread beyond professionals and into the rest of society: “There are people whose job is 75% writing code, but that is a very small minority of people that we need. We need the professional people, the thinkers, which may involve 0% writing code, just understanding it, or 20% of the time. And that is not understood by people who are not in the industry.”

ADMINISTRATORS

The administrators that we interviewed identified fewer barriers and supports than the teachers, but of those identified, many were the same that the teachers described. This overlap provided an opportunity to examine similar issues from different perspectives.

"I feel like sometimes we're educating for a future that we don't know what it looks like, and so we're just trying to push the kids to think outside the box and to think and to use those skills to basically make our community a better place."

CHALLENGES

▼ Administrators perceive that computer science isn't understood or valued as a rigorous discipline.

Like teachers, administrators cited pervasive misunderstandings about CS as a barrier to implementing quality CS instruction. While teachers sometimes included their principals among those who did not understand CS, the administrators interviewed tended to view district administrators as the problem. They confirmed what the teachers said—that there is little incentive for school administrators to prioritize CS. One administrator summed it up, "A) people don't understand what it is, and B) they don't see how it translates to the all-important standardized test."

Administrators also felt that students may not understand principles behind CS, and instead may think that CS is merely computer repair or other topics that are peripheral to the logic and problem-solving skills core to the discipline. Other administrators felt that parents in their community have serious misconceptions about what CS is today. As one explained:

> *Parents are thinking of computer science when they were in school, which is totally different now. The things that parents learned in school when they may have had computer science, our kids come to high school already knowing. So I think it's just more of a tweak, more of a PR kind of thing than a re-education.*

▼ Administrators perceive that computer science teachers are scarce.

Administrators expressed the difficulty they face finding qualified CS teachers when positions are open at their schools. They look for teachers that possess both CS and teaching

experience, but finding individuals with these skills who are also willing to sacrifice the financial benefits that come with the CS industry are difficult to find. As one administrator explained, “The single biggest challenge is getting people capable of instructing students, people with a background and interest in education that want to teach CS.” Another administrator said this of computer science teachers: “Well, you know, they're not so easy to find. They have some competing possibilities that tend to be more profitable than teaching.”

Administrators also spoke of the gap between their expectations for a CS teacher and the reality of the applicants they receive. They noted that even when they list specific skills in job descriptions, they still receive resumes from applicants with outdated skills that “don’t know what computer science is or should be.”

▼ Administrators feel that low prioritization of computer science means fewer resources.

Administrators identified the lack of funding as a significant barrier to not only bringing CS courses to their schools, but also to maintaining the quality of materials needed to teach those courses. They cited this as a challenge for many courses at their schools, but also indicated that CS requires more costly resources than other courses. One challenge is providing the necessary computer maintenance: “Whatever computer science courses you add, whether it's a one-to-one or there's a computer lab, you need that set of folks down the hall ready to assist.” Schools are receiving financial support to expand computer science infrastructure, but this might not always be enough, as one administrator explained:

> *There's a headline in the newspaper… and it talks about how the school system is going to spend a million dollars on technology. That's not going to go very far. I mean it's great, but it's going to be like a drop in the ocean, compared with how many schools they have… I could easily spend a million dollars today, and we're an individual school.*

In some cases, financial barriers impact students’ home lives in ways that pertain to CS. Students’ home contexts can sometimes limit their experience and exposure to technology in particular compared to other academic areas, due to the expense of maintaining technology in students’ homes. This may ultimately factor into the level of CS knowledge that students bring with them to school:

> *One thing that I have learned here, is that we have quite an affluent community, but when one of the parents loses their job, and they have to cut something, one of the first things they cut is technology. They cut that Internet… and so we have to try to provide those pieces for those students, which… we try to do. Well, if that happens and that child is like in the sixth grade, and the student goes through the sixth, seventh, eighth grade, and the school couldn't necessarily provide those supports, and then they get to high school, they are a little further behind. And so I think that's a component that we need to think about.*

Student interest can also influence the allocation of resources, and if students are not enrolling in CS courses, this may result in fewer CS course offerings, as one administrator explains:

> *I’m worried that we would not be able to generate a critical mass of students necessary to justify investment in the program. So I know that we have about ten students that are available at this point, and given the resource limitations we've*

had—in our school district we've cut about a hundred million dollars out of our budget, over the last four years. It seems like every year we turn around and the state legislature is asking us to cut another 20 million, 12 million, so we end up looking at how many students would potentially be interested in the course, and can we offer a staff member to teach it, and right now, I'm not confident that we'll be able to do that.

▼ Administrators recognized that computer science must compete with other courses.

In some schools, students may not enroll in CS courses at rates high enough to justify keeping the course. This may not always be due to a lack of interest in CS, however. Since CS is usually considered an elective, it must compete for space in students' schedules with all other elective courses. As one administrator said, this is "pretty scarce real estate for the high school student." Administrators that understand the value of CS try to help students fit it into their schedules, but "students are choosing from music, the arts, some of the athletic stuff, weight training, and CS Principles isn't very flashy, it isn't sexy, it's not going to sell itself. You have to market that class." In other cases, CS courses can conflict with AP courses that may have limited offerings, such as AP physics, AP math, or other advanced courses.

SUPPORTS

▼ Some administrators understand the importance of computer science.

All of the administrators expressed support for CS courses in their schools. This is not surprising, as we only spoke with administrators who already had CS courses at their schools and were willing to speak with the research team. Nonetheless, this underscores that an important support for quality CS instruction is an administrator who understands it and believes in its importance.

We just say, we think that this is a pretty fundamental skill and area for kids to be aware of, you know, that we're stepping it up from exposure to computer apps which, obviously, our kids are better at than we are. So when they enter high school, and they've got that computer app education behind them, we believe that the next step is exposure to programming language. We see it as language study as much as we see it as preparing them for any potential future work in computer science. And you know, it's like, don't you kind of want to understand the design of an airplane because you ride in them, you know? Same idea here, because, I mean, it's such an integral part of our lives, it seems like an exposure to the fundamental process of how it works is pretty important.

Erin Mayo, Assistant Head of Academics
Episcopal School of Dallas
Dallas, Texas

▼ Administrators that lack computer science knowledge rely on good teachers.

Even though most of the administrators felt they understood CS at least at a basic level, they recognized that their CS teachers are the most knowledgeable about the subject. When administrators were asked what supports they had for CS instruction, they said that they "really rely on their staff" to inform CS education at their schools. Further, they depend on their CS teachers to pursue funding both for students and to support CS extracurricular activities.

> *[The CS teacher] really does a great job of researching grants, she takes kids to competitions all the time, we had a boy who finished first place in a computer science competition at Georgia Tech, I believe two weekends ago, won a five thousand dollar scholarship. So a lot of the time when she's finding the money, it might not be for the school, it might be for the kids. But if students and parents are hearing that kids are winning scholarships like that, of course they're going to be interested.*

Megan Strange, Upper School Principal
North Cobb Christian School
Kennesaw, Georgia

▼Administrators that support professional development opportunities for computer science teachers.

The administrators we interviewed expressed that teachers must stay up-to-date in CS, a rapidly changing field, in order to deliver the most relevant content to students. They recognized that CS teachers must constantly research the industry standards, and can't "get comfortable with what's going on." They support their teachers by providing money and identifying possible CS teacher professional development opportunities.

▼Industry and other stakeholders can support and promote computer science education.

Computer science industry professionals recognize that there is a deficit of people with the skills necessary to fill job demand. As a result, the industry is involved in supporting CS education at the high school level. As one administrator explained, a lot of support is "coming from community, more technical companies, more businesses that are requiring those kinds of …so

having students leave high school prepared to enter those kinds of work areas, or go into college to pursue those kinds of careers has become really important." This administrator recognized that the role of schools and education is to improve the community, and that in a rapidly-changing world, computer science is an important part of that:

> *I feel like sometimes we're educating for a future that we don't know what it looks like, and so we're just trying to push the kids to think outside the box and to think and to use those skills to, you know, basically make our community a better place. It sounds really corny, I know, but that's really what it's about.*

Sheila Beckham, Principal
Oconee County High School
Watkinsville, Georgia

Parents and other community members also recognize the importance of CS. One administrator felt that parents in his community place value on STEM, and that they "put computer science in the bigger picture of STEM and engineering careers, so when we do put it like that, we have a lot of support for offering those classes."

Another administrator summed this point up well:

> *Basically, if you have any type of computer science knowledge, no matter what field you go in, I think it makes you more marketable, no matter if you go into the medical field or go to be an attorney, it doesn't matter if you go to be an accountant. I think it makes you more marketable.*

WHAT SKILLS ARE ESSENTIAL FOR COMPUTER SCIENCE TEACHERS?

▼ Pedagogy and content knowledge.

Nearly all administrators said that they looked for both CS content knowledge and the ability to teach well in prospective CS teachers. They recognize that this combination is difficult to come by, given the lack of monetary incentives compared to jobs in the computer science industry. The pedagogy skills are of particular importance in CS, because it is likely that students will bring vastly different background knowledge to the classroom, and it takes an experienced teacher to engage all students. As one administrator put it, "their backgrounds through math and science are so varied, so I think differentiation is huge, so that you meet that student at their level and you challenge them, but you've got to get them all to the same point at the end."

WHAT NEEDS TO HAPPEN NOW

▼ Adequate computer scientists to fill increasing demand.

Many administrators recognized the growing demand for people with CS skills in the workplace. While they acknowledge this demand, they worry that the education system will not be able to change quickly enough to equip students with the skills they will need to fill those jobs. One administrator said: "Because there isn't a whole lot of heat coming from outside schools… computer science offerings will tend more to be exposure to applications." This administrator recognized that this was not sufficient to give students the CS background that they would need to pursue a career in the field.

▼ Greater number of computer science courses to engage all students.

Administrators recognized the disparity that exists in CS, both in industry and in their schools. For example, one administrator explained that he and the CS teacher at his school actively engage underrepresented minority and female students in CS courses, noting "I would love for my daughter to have [a CS career] as an opportunity…and not necessarily have her break through doors to get there."

Another hoped to use all students' inherent interest in technology as a way to engage more students in CS courses:

> *I think all students should have some exposure to computer science before they graduate from high school, and I don't mean a computer applications class, I mean a real computer science course. Students need to see the connection between computer science and their chosen career field, as well as, other curriculum areas. I think this would go a long way in promoting computer science not only in our state, but also in our nation. I also think we need to look at computer science as a way of improving our national math and science student achievement performance. I think students see the relevance of a computer science class more than they see the relevance of a trig class. Students naturally make the connection of computer science to their lives and career aspirations. What they do not realize is that they are learning the same skills taught in their math class.*

Sheila Beckham, Principal
Oconee County High School
Watkinsville, Georgia

▼ Integrate computer science across other courses.

Administrators recognized that computer science relates to many other disciplines and expressed a vision for CS to be a subject more firmly integrated into other courses. Their suggestions included the removal of CS as a standalone course, and "a more integrated approach" that "intertwines itself with a bigger educational platform." Another administrator said that she would like to see CS instruction take place across the curriculum, and that she sees CS as similar to writing:

> *As a language arts person, I've always argued that one of our failures is to not really teach writing across the curriculum, which is a recognition of 'I don't care what area you're in.' Ultimately, you're going to have to reduce your knowledge in a meaningful fashion, which will most likely be written, not spoken, and we really haven't gotten to the point where we teach writing across the curriculum, but it seems to me that CS should be embedded in almost every course.*

However, teachers did not share this vision, and instead expressed the desire for an increase in CS course options as a way to increase student enrollment and exposure and ensure quality and resources are adequate.

SUMMARY OF FINDINGS

To summarize the findings, the teachers identified five main challenges: isolation, lack of instructional materials, misconceptions about computer science, low prioritization of computer science as a course, and limited availability of CS teachers. These findings were very consistent with the administrators who identified three of these *same* challenges (misconceptions, scarcity of CS teachers, and low prioritization of CS courses) and added one of their own: the competition CS courses face from other courses in their schools. In all tables, findings are reported with the most frequently reported finding listed first.

Major Challenges	Teachers	Administrators
Isolation	✓	
Lack of Instructional Materials	✓	
Misconceptions About CS	✓	✓
Low prioritization of CS as a course	✓	✓
Limited availability of CS teachers	✓	✓
CS must compete with other courses		✓

Regarding supports, on the other hand, teachers identified six supports most important to them: professional networks, online resources, school-provided materials, teacher professional development, support from universities, and student interest. This time, administrators identified four supports with only one overlapping with the teachers: teacher professional development. Their other three were: administrative understanding and valuing of CS, strong CS teachers in their schools, and the CS industry.

Supports	Teachers	Administrators
Professional networks	✓	
Online resources	✓	
School-provided materials	✓	
Teacher professional development	✓	✓
Support from universities	✓	
Student interest	✓	
Administrator understanding and valuing of CS		✓
Strong CS teachers in their schools		✓
CS industry		✓

CS teacher essential skills was another area of agreement for teachers and administrators. Both groups made it clear that content knowledge and pedagogical knowledge are essential. The teachers added one more essential skill: the ability to keep up with the changing field of computer science.

Essential Skills	Teachers	Administrators
Content knowledge	✓	✓
Pedagogical knowledge	✓	✓
Keep up with changing field	✓	

And finally, with regard to what needs to happen now, teachers felt that a necessary next step is to make computer science courses required in high schools, followed by efforts to develop understandings of computer as a serious discipline. These priorities are reflected in their visions for the future as they described their hopes for a culture change that embraces and values computer science. With a supportive culture in place, teachers imagined the availability of CS courses for younger students, in middle school and below. They also agreed with the administrators about their desire to have a future with high schools that have multiple computer science offerings as well as one with adequate numbers of computer scientists to fill the demand from industry.

The only point of departure between administrators and teachers came from administrators' desires to integrate computer science into other courses, rather than have it stand alone as a course. Teachers' comments, on the other hand, reflected a sentiment that integrating CS into other subjects could reduce its value as a discipline. This appears to be one of many issues ready for further careful examination.

What Needs To Happen Now	Teachers	Administrators
Make required course	✓	✓
Culture Change to Value CS	✓	✓
Early access to CS	✓	✓
Multiple CS offerings	✓	✓
Adequate outcomes to meet industry demand	✓	✓
Integrate CS into other courses		✓