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Mathematics Teachers Should Lead on the New NYS Learning Standards for Computer Science

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Introduction

Computing is an essential part of many academic fields and most occupations; therefore, it is in the best interest of school districts in New York State (NYS) to offer computer science (CS) to a larger and more diverse set of high-school students. Currently only half of the high schools in NYS offer a CS class. [1] These classes are electives taken by a small percentage of students. Meeting the educational needs of all NYS students in a meaningful and equitable way will require CS course curricula, policy changes, buy-in from stakeholders, creating and increasing capacity at schools, and leadership from the state education department.

In 2019, 34 states were actively meeting their CS learning standards. [2] At the same time, the New York State Education Department (NYSED), which took the lead on developing learning standards for CS in the state, was in the process of developing standards for CS, with the goal of full implementation by 2024 (see Table 1). The resulting NYS K-12 Computer Science and Digital Fluency (CS&DF) Learning Standards were adopted by the Board of Regents in December 2020. [3] The following five key concepts of the NYS CS&DF Learning Standards are a guide for successfully teaching CS to every student:

- Impacts of Computing
- Computational Thinking
- Networks and System Design
- Cybersecurity
- Digital Literacy

It is critical that NYS implement programs to meet these standard so that its students have the skills and knowledge needed in the 21st century. We argue that mathematics teachers will need to lead the effort if school districts are to successfully meet these new standards.

Dates	Phase	Activities
Dec. 2020 – Aug. 2021	Awareness-Building	Roll-out and building awareness of the new standards and timeline for implementation
Sept. 2021 – Aug. 2023	Capacity-Building	Focus on curriculum development, resource acquisition, professional development
Sept. 2023 – Aug. 2024	Year 1 Implementation	All credit-bearing Computer Science courses will be aligned with NYS CS&DF Standards
September 2024	Full Implementation	CS&DF Standards implemented in all grade bands K-12

Table 1: NYSED Timeline for Implementation of CS&DF Learning Standards [4]

The Need for CS Standards

There are at least five reasons every student should learn the concepts and skills that are described in the CS&DF Learning Standards.

1. **Computer Science is useful.**
   Most of us see applications of computing every day. Computer applications are important to banking, financial institutions, the arts and entertainment, businesses, communications, education, manufacturing, medicine, transportation, and all STEM fields. Computational biology, computational chemistry, and computational physics are firmly established STEM fields that rely on computing. Machine learning and artificial intelligence are being used in many fields. Of all new jobs in STEM, 67% are in computing. [5]

2. **Computer Science develops problem solving abilities.**
   Learning in CS includes recognizing patterns; using abstraction and models; organizing and analyzing data; decomposing problems; and following, developing, and testing algorithmic processes. Communicating and working collaboratively with others using digital tools is one of the Digital Literacy learning standards.

3. **Computer Science knowledge and experience makes more informed citizens in a democracy.**
   Data privacy, electronic voting, ransomware, cyber security, net neutrality, machine learning biases, the digital divide, deep fakes, and social media are some topics that must be understood to be an educated participant in our democracy.

4. **Computing is needed to understand our world and universe.**
   Astrophysics, medical research, pharmaceuticals, and climate are a few of the areas where computing is used to create sophisticated models to aid in this understanding of the world in which we live.

5. **Computer Science is beautiful.**
   Not only are computers used to create beautiful music, visuals, movies, and animations, but one can write beautiful code (and also ugly code). Some data structures, models of computing, and algorithms are aesthetically pleasing and are works of art in and of themselves.

Meeting the Staffing Requirements for Certified CS Teachers in NYS

There are approximately 2.6 million K-12 students in NYS. [6] This is an average of approximately 200,000 students at each grade level. If each student is to take one year-long CS course to meet the NYS CS&DF Learning Standards before graduating from high school, then 10,000 classes with 20+ students in a class must be offered every year. To offer 10,000 classes per year with a certified CS teacher requires 2,000 certified teachers each of whom must teach 5 CS classes per year.

The NYS Board of Regents approved the CS&DF Learning Standards in 2020. Less than two years prior, in 2018, they adopted regulations that created K-12 teaching certification in CS with a corresponding tenure area. Siena College was the first institution to have its CS certification program approved. [7] As of June 2021 there are only seven colleges or universities in New York that have an approved certification program for CS and to provide some context to this number, there are almost 90 higher education institutions that have approved programs for mathematics certification. [8]

To further illustrate the magnitude of the problem, nationally, in a two year period (2016 to 2017) less than 120 CS teachers graduated from universities with a CS degree compared to over 11,000 mathematics teachers. [9]

The trickle of certified CS teachers from the pipeline of approved college and university programs will not come close to meeting the need for approximately 2,000 certified CS teachers. Fortunately, the NYSED has created additional pathways to certification. These pathways, including one for individuals who already hold a teaching certificate, require 12 credits of course work in CS, which must include specific topics. [10]

For the foreseeable future, the only way schools in NYS will be able to offer courses with certified CS teachers is if teachers certified in other fields complete the NYSED established pathway for in-service teachers. This pathway is available to teachers in any field.

Why Math Teachers?

In this section we make a strong argument for mathematics teachers taking a leading role in teaching courses to meet the CS&DF Learning Standards. Four Reasons are discussed below.

1. **CS and Mathematics are closely aligned:**
Teachers from other areas can and should be encouraged to fill the tremendous need for CS teachers. However, no other certification area is as closely aligned to CS as is mathematics.

As part of their preparation, mathematics teachers learn about the eight mathematical practices that are outlined in the Common Core. [11] Mathematics teachers have been educated to make sense of problems and persevere in solving them. Their education emphasizes reasoning abstractly and quantitatively. As mathematicians they make use of structure, identify and express regularity in repeated reasoning, model with mathematics, and attend to precision. They use appropriate tools strategically. They construct viable arguments and critique the reasoning of others.

Similarly, CS teachers need to use abstractions and pattern recognition to solve problems. They must be able to organize and analyze data. For problem solving, they break problems down into smaller parts. They apply iterative and recursive methods, develop and follow algorithmic processes, and generalize from the specific to the more general. They not only persevere in implementing solutions but seek to achieve the most efficient and effective combination of algorithmic steps and resources.

2. **Mathematics has numerous applications to CS and vice versa:**
In mathematics courses, teachers are encouraged to include what are frequently called "real life" applications. Many applications of mathematics are in science, technology, engineering, business, and especially CS. Not only is CS an application of mathematics, but in addition, almost every area of CS applies mathematics in some way. Examples include the Boolean logic fundamental to hardware circuits and software; positional notation that is fundamental to computer architecture; a group of mathematical functions that are essential in designing, analyzing, and implementing software systems; and combinatorics that underlie computer security systems. We think students will benefit from teachers who can make strong interdisciplinary connections.

3. **Need to uphold standards for courses that may satisfy mathematics graduation requirements:**
High schools in NYS and throughout the country are allowing appropriate CS courses to meet mathematics requirements for high school graduation. Substituted courses should have a strong connection to mathematics standards and mathematics teachers should be leaders in assuring that the standards are maintained for these substitutions.

"The national snapshot shows that only nine states count computer science as a core graduation credit and most state standards are focused on 'skills' (73 percent adoption) instead of deeper computing 'concepts' (only 37 percent adoption)." [12] Mathematics teachers have the background and experience to ensure that students are offered courses that teach concepts as well as skills.

4. **Teaching CS is a great experience for mathematics teachers:**
For over 35 years, the authors have worked with experienced high-school mathematics teachers, helping to prepare them to teach CS. These teachers have faced the challenges of preparing students to pass Regents and AP exams. They have worked with many students who really don't care about finding the intersection of two lines in a plane given the equations for the two lines. They have regularly heard students ask: "When are we are ever going to use this stuff?" The opportunity to teach CS provides a different and exciting teaching experience that exemplifies the application of mathematics in a way that is tangible for students.

Most of the teachers we have worked with tell us they did not have much, if any, CS background when they began working with us. Typically, as undergraduate mathematics majors they took a required course or two. But with their mathematics background, teaching experience, some professional development, and supportive colleagues, almost every teacher we have worked with has had a fantastic experience teaching CS. Here are some things mathematics teachers have told us after teaching CS for several years.

Rachel Linehan, Bethlehem High School

"I definitely recommend that math teachers considerer teaching CS. After my first year of teaching computer science, I realized that I could substantially change and improve my math teaching. Students learn by doing and talking through problems. Students barely remember when I tell them something, but they always remember when they create or discover an idea.

Getting students to interact with their peers and work through their ideas with the confidence to try again after failing is the secret to any successful classroom environment. That is why all students should take CS and all math teachers should have the experience of seeing what can happen when students talk more than the teacher.

I have used the student led lesson style from my CS classes to create a more open environment in my Calculus class where students are expected to struggle through problems on their own and in groups and become responsible for their own learning.

Teaching CS will truly broaden your perspective of how a classroom should be run and what students are capable of when they are given independence."

Jim Flanagan, Chatham High School

"High School English instructors need an understanding of the human heart and social studies instructors need an understanding of the consequences of human behavior. Both mathematics and computer science instructors require a level of expertise in logic and pattern recognition.

Proving theorems in geometry, solving equations in algebra, and calculating measures in trigonometry requires the same type of logical thinking and algorithmic understanding that is needed to program a computer. This is why I think it's critical that mathematics teachers take the lead in meeting the new NYS learning standards in computer science."

Maureen Conway, Mohonasen High School

"I had been teaching high school math for about ten years before having the opportunity to start teaching CS. I've been teaching CS for four years. It is truly terrific. I was able to see many of my math students in the CS courses and to see them excited and engaged was just great! Some students who were less than confident in math became incredibly proud of the results of their "code". As an experienced math teacher, I was able to draw in many math concepts like: "functions" to show implementation of coding functions. In our code, "calling" the functions finally gave many students a reason to even have math functions. In addition, I saw growth in focus, stamina and the skill of reading directions. These are obviously all good traits necessary for success in math too!

This past year I was able to teach a Discovering CS course where students created and shared many different projects using block coding and then graduated to Python by the end of the year. Again, terrific course. Weaker students became confident in their work and honors students created more and more details to their work. The confidence from AIS students in their work was priceless. The CS class became their favorite course."

5. **Effective deployment of faculty as enrollments decline:**
Many school districts are experiencing a decline in student enrollment. In fact, as can be seen in Table 2, which is a graph produced by NYSED, the number of secondary students in NYS has been decreasing for the past ten years and over the last five years, the number of primary students has been decreasing at an even faster rate.

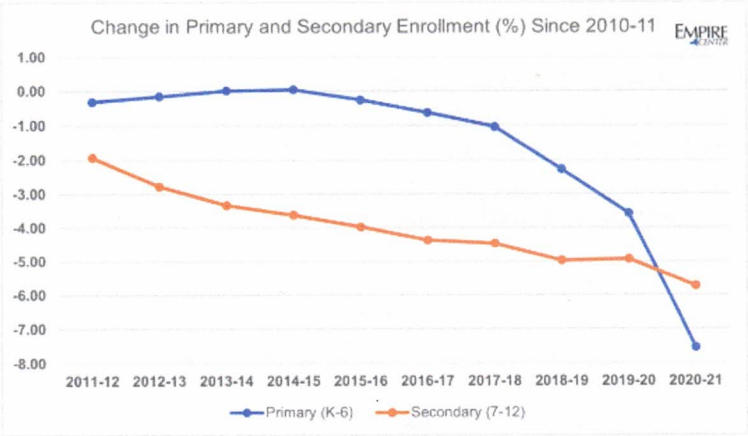


Table 2: Change in Student Enrollment [13]

Due to declining enrollments, many schools will not need to offer as many mathematics classes. We argue that this will result in an opportunity for administrators to reassign mathematics teachers from traditional mathematics teaching assignments to CS classes.

Conclusion

We need to offer students a 2020 high school program, not one from 1970. It's imperative that the new CS&DF Learning Standards are met. It will take many years and possibly decades, before traditional college and university programs meet the need for certified CS teachers. Therefore, the approved alternative program for certifying current teachers will be needed to staff CS classes with certified teachers. Mathematics teachers are uniquely positioned to successfully fill the staffing need that will be required. Mathematics teachers who have taught CS strongly recommend this experience for their colleagues.

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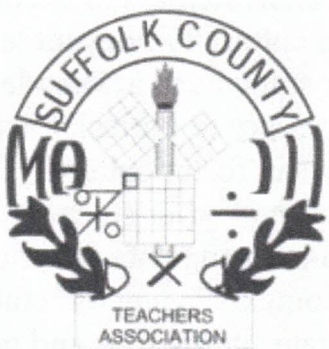
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