A Public School Model of CS Education

Leigh Ann DeLyser, Michael Preston
NYC Foundation for CS Education, New York, NY, USA
leighann@csnyc.org, michael@csnyc.org

Abstract—The New York City Foundation for Computer Science Education was launched in the summer of 2013 to ensure that all children in New York City public schools have access to computer science education. Over the past year and a half the foundation has worked with eight (8) programs to expand access to computer science, reaching more than 10,000 students in the 2014-2015 school year alone. In this paper we present a brief history of computer science education in K12 schools, focused primarily on New York City. We detail the philosophy of the foundation and highlight the programs we support and the impact they are having on New York City public school students. It is our hope that the unique approach of CSNYC in supporting research proven initiatives and connecting teachers in communities of practice will inspire other advocates of computer science education to adopt our successful model. At the end of the paper we present upcoming expansions for the 2015-2016 school year and discuss the research challenges and opportunities available.

Keywords: Public School Education, Non-Profit, Computer Science Education

1. Introduction

In 2012 Code.org released their first video, highlighting computer science professionals and celebrities encouraging students to try computer science. Prompted by the increasing need for a technical workforce, and at the same time a declining number of computer science majors at 4 year institutions, the video, and subsequent media push for students to try an "hour of code" for computer science education week in December of 2012 has unleashed a nationwide movement to bring access to computer science to K-12 education[1].

Although the majority of career opportunities in STEM (Science, Technology, Engineering, and Mathematics) professions require some proficiency in computer science, an overwhelming majority of students did not have access to rigorous computer science in public schools. In an analysis of the 2013 AP Computer Science Exam, Barbara Ericson highlighted a series of statistics exposing the lack of access by many students and the inequity of course taking across the nation [2]. In New York State, which includes the numbers for New York City, only 68 black and 150 hispanic students attempted the AP CS exam, with pass rates of 33% and 35% respectively. These numbers are shocking considering almost 310,000 students are enrolled in high school in NYC alone, where 40.5% of the student population is hispanic and 27.7% of the population is black. Additionally, students also lacked access at the school level as 50% of APCS test takers in New York City came from 3 high schools, although there are over 400 high schools in the city.

Despite the challenges of lack of pathways into computer science for a majority of public school students, New York City has a large and rapidly expanding technology industry, represented not only by major technology companies such as Google and Microsoft, but also by a large financial sector that employs a significant portion of the technology workers in New York[3]. The technology industry in New York is constantly attempting to recruit and retain employees with appropriate background, and the need to increase the pool of applicants with appropriate prior preparation enjoys support from industry and policy makers alike, as demonstrated by the creation of the NYC Tech Talent Pipeline [4].

Together industry, policy makers, public education, and a force of volunteers have been working to expand access to computer science in New York City. Although there are many models of summer and after school programs, such as Girls Who Code, All Star Code, and others, the growth of computer science at the public school level in NYC has been unprecedented.

In this paper we discuss the work of the New York City Foundation for CS Education (CSNYC) that has spearheaded many of the efforts to increase access to computer science in the public schools in New York City. Since its launch in 2013, CSNYC has supported computer science programs in public schools, including a significant amount of teacher professional development. Over the past year and a half, CSNYC has expanded its programs to over 110 schools, serving more than 10,000 students in the 2014-15 school year alone. We present the work of CSNYC as a model for other states or regions who work to grow computer science offerings in their area.

2. History

Computer science education in schools has seen a resurgence after a drop off from the 1980s. There are echoes of similarity to the earlier movement in today’s implementations of computer science, but there are also a series of differences between prior attempts to infuse computing into public schools and current initiatives.
2.1 Early CS Education in Schools

In 1980 Seymour Papert published his seminal work, *Mindsstorms: Children, Computers and Powerful Ideas*. The book focused on micro worlds, and the educational benefits of young children learning to control actors in those worlds through computer programming. Especially compelling were Papert’s claims that engaging with micro worlds and computer programming produced rich transfer to other problem solving domains and increased students’ academic performance across all subjects [5]. Papert initially worked with students from a variety of academic and socioeconomic backgrounds and the documentation of his research lead to confidence that schools everywhere could implement meaningful curriculum regardless of their student populations.

At that time schools invested in bringing computing to the classroom to support constructionism, the inquiry-based and project-based approach to learning that included programming micro worlds as a key component. At the same time a number of education and psychology researchers delved into Papert’s claims of transfer from computer programming to other domains. Although many experiments were carefully designed and executed [6], few yielded results of the transfer claims made by Papert [7].

In the 1990s and 2000s with the rise of the internet, computer usage in schools refocused from programming to information seeking, research, and as vehicles for content delivery with educational software focused on more traditional disciplines such as mathematics or reading. Fewer students were given the option of taking computer programming, and many schools dropped the courses all together, resulting in the statistic from Code.org, estimating that only 1 out of every 10 high schools in the US offers a programming course in 2012[1].

2.2 History of CS Education in NYC

New York City was one of Papert’s original sites, however went through many of the changes described in the previous section. Although work addressing and categorizing the digital divide in the early 2000s focused on simple access to computers at work and school, one can extrapolate the access to computer science education mirrored, if not was exaggerated by, similar factors[8]. Additionally, as the internet became the standard of accessibility and classroom practice, New York worked through several iterations of providing internet access to schools.

The focus on hardware, software, and internet access combined with the increased experience of the general population with general computing skills lead to the decline of professional development opportunities for teachers around computing and computer science education. New York State previously required completion of technology standards, most often implemented in a computer applications course, emphasizing the usage of computers by students. Today, those technology standards are no longer required for a standard New York State diploma, and fewer schools require even basic technology classes for all students.

Although there are over 400 high schools in New York City, a select few are able to admit students in a competitive fashion. For example, Stuyvesant High School, Bronx Science, and Brooklyn Tech all require students to apply and admit students based upon their grades, attendance, and performance on a selective exam. In 2012 50% of the APCS test takers in NYC came from these 3 schools, although these schools only represent 3.7% of the overall NYC high school population. A symptom of a larger problem, computer science had been seen as an extraordinarily difficult subject, appropriate only for the most gifted students. This belief lead to the majority of computer science offerings existing at selective high schools, relegating students in non-selective schools to no technology courses, computer applications courses, or potentially hardware support and repair courses focused on certifications such as A+ and Cisco.

The current climate in New York City, however, is much changed. Many of the programs described in the following sections specifically work with some of the most disadvantaged students in public schools and are having resounding successes.

3. Programs

The NYC Foundation for CS Education is a non-profit organization launched in the summer of 2013 to ensure that all children in the NYC public schools have access to computer science education that will put them on a pathway to academic success and a 21st century career[9]. Since 2013, CSNYC has provided support to 8 programs reaching over 10,000 students in 110 different NYC public schools. CSNYC believes that NYC is not a “one-size fits all” city and by providing schools with choice among various programs we offer the opportunity for principals and teachers to select programs that fit with school culture and student populations.

Different from many other organizations and businesses focused on providing access to computer science, CSNYC does not have a single endorsed curriculum, instead the foundation has supported local efforts such as the Academies for Software Engineering, the Software Engineering Pilot Program, and ScriptEd to develop rigorous CS curriculum tailored to NYC public school students and their needs. Additionally, CSNYC has identified research-proven computer science programs that match Department of Education priorities and facilitated the expansion of those programs in the NYC public schools. Programs such as Bootstrap, Scalable Game Design, Exploring Computer Science, and TEALS have partnered with CSNYC for assistance connecting with existing schools for recruitment, space and costs of teacher professional development, and ongoing support in NYC for the teachers teaching the program content. Finally, CSNYC believes that an important client of our services are the teachers, and we provide two monthly teacher meet ups.
Students at AFSE and BASE are representative of the larger NYC student population in terms of ethnicity, socioeconomic status, and prior academic performance. Table 1 provides basic statistics for each school. AFSE is in its third year of implementation, and therefore has a 9th, 10th, and 11th grade (adding a new 9th grade class each year), while BASE is in its second year of implementation with a 9th and 10th grade. At full size, both schools will have just under 500 students each.

Both AFSE and BASE are preparing for certification as a Career and Technical Education (CTE) High School. CTE schools still require students to meet the college readiness graduation requirements of a regular high school, but include programs for Work Based Learning (WBL) and require a structured sequence of courses that culminate in a technical assessment. At AFSE and BASE, the Work Based Learning components include job shadowing and internships, field trips, mentoring, community service, and creative experiences. The addition of creative experiences to the standard WBL gives students credit for participating in activities where they design and build technical solutions to problems. Currently students have worked on projects for the Verizon App Challenge [11], hackathons [12], and after school or summer programs requiring development or prototyping of technological solutions.

The curriculum at AFSE and BASE focus on software design and development. The certifying exam being proposed by the CTE program is the Advanced Placement Computer Science A exam in Java. Although not ideal, the exam offers an external validation of the skills and knowledge students obtain during the multi-year CS sequence. In 9th grade students take an Exploring Computer Science aligned course that covers the fundamentals of programming in Scratch, simple web design in HTML and CSS, data analysis and spreadsheet functions, and a revisit of the fundamentals of programming in Python. Additional courses offered cover programming in Java (pre-AP), AP Computer Science A, Data Structures and Algorithms, Advanced Web Design/JavaScript, 3D Printing and Modeling, and a CS Principles course that is part of the official CollegeBoard pilot program.

Both AFSE and BASE are primarily funded by the NYC Department of Education as public high schools. CSNYC provides small amounts of supplementary funding to enrich student experiences. Additionally, CSNYC funds Leigh Ann DeLyser as a CS consultant for both schools. Dr. DeLyser’s role at the schools is to facilitate the CTE program creation and approval process, provide consultation on the computer science curriculum development, assist in mentoring the computer science teachers, and engaging with the school to help surface outside-of-class activities for students.

### 3.2 Software Engineering Pilot Program

The Software Engineering Pilot (SEP) Program was launched in the spring of 2013 with 20 schools, 10 high schools and 10 middle schools. After the first year the program now has 9 high schools and 9 middle schools after releasing two schools for lack of participation. Schools participating in the program identify two teachers who attend an intensive summer institute of professional development as well as once monthly sessions on the computer science concepts and pedagogy taught in SEP courses. In the 2014-2015 school year the SEP program provides ongoing professional development to 42 teachers and over 2700 students are enrolled in SEP courses.

The SEP program brings a 3 (middle school) or 4 (high school) year sequence of computer science and software engineering to existing public schools in New York City. Students in SEP classes study programming fundamentals in scratch, basic web design with HTML and CSS, mobile app development with Touch Develop, physical computing and robotics, and more advanced topics in programming with Python and Java. Currently in its second year of implementation the SEP program is working on expanding the curriculum offerings to include AP CS Principles and AP Computer Science A.

In addition to the classwork, students at SEP schools also engage in out-of-class learning experiences including field trips to companies with technical workers such as Etsy, Microsoft, and Bloomberg, and participation in hackathons. The SEP program puts on two student-focused hackathons...
per year, each hackathon centered around a theme and offered at multiple locations to provide proximity to schools in different boroughs around the city. Students in high school can participate in the SEP Pathfinders Job Shadow Program [13]. The Pathfinders Program provides stipends for students who work in companies in NYC and observe technical staff as well as use their skills to provide web design assistance, basic quality assurance, and office support. The Pathfinders Program is supported by a generous grant from the AT&T Foundation.

3.3 Bootstrap

Bootstrap is a curricular module for use in a mathematics course, or a stand alone curriculum for computer science that teaches algebraic and geometric concepts through computer programming[14]. The Bootstrap curriculum was created by Emmanuel Schanzer, building off the work of Matthias Felleisen and Program by Design. In the Bootstrap curriculum are detailed lessons, aligned to Common Core Mathematics Standards, with student handouts. During the module students design and program a 2 dimensional video game that can be played on any device and shared with friends.

The Bootstrap curriculum is closely aligned with mathematics content standards and throughout the module students solve word problems with the design recipe in order to add functionality to their game. The design recipe makes explicit the decomposition and understanding of a word problem by requiring that students write the name of the function they are writing, the domain and range of their function, and create examples (test cases) for the function. Throughout the curriculum students practice writing functions in Scheme, a functional programming language which is very similar to functional notation in mathematics, based upon their answers to the parts of the design recipe.

CSNYC supports the Bootstrap program by advertising professional development and assisting in school recruitment. Additionally, CSNYC pays participant costs for the professional development of NYC public school teachers for expansion of the program. With an initial school recruitment goal of 10 schools for 2014-15, CSNYC has helped facilitate the training of over 60 current and pre-service teachers and 23 schools have implemented the bootstrap curriculum module as of the writing of this paper.

3.4 Scalable Game Design

The Scalable Game Design program originated at the University of Colorado Boulder[15]. The Scalable Game Design project effectively leads students from creating games to programming advanced simulations. The project is the largest study of middle school computer science education in the United States with over 10,000 students from Alaska to Texas. In NYC, with the support of CSNYC for professional development and software costs, 16 teachers from 11 schools attended summer professional development and have implemented at least one Scalable Game Design module in grades 4-8.

A key component of the Scalable Game Design program is the use of Computational Thinking Patterns to define behaviors first in the game and then move on to simulations. The Computational Thinking Patterns have been shown to facilitate transfer between the game environment and simulation environment for behaviors such as collision. Additionally, the visual programming environment of AgentSheets and AgentCubes, the software used by the Scalable Game Design program, gives students a visual stage to conceptualize and debug their desired algorithms[16].

Additionally, teachers in NYC have extended the original set of modules and activities to enable students to create their own games stories and play, or to work on games related to topical themes. One school was completing a unit on westward expansion, and the teachers modified the original Frogger and Journey games in order create a game highlighting the different segments of Lois and Clark’s journey from the book the class was reading.

3.5 Exploring CS, Code.org, and iZone

An important role for CSNYC to play in NYC is to help facilitate partnerships between organizations inside and outside New York. The iZone is a community of schools and partners who are committed to meet the individual needs of students through blended learning - using technological solutions to help provide differentiated instruction and resources. In partnership with the iZone, Code.org is implementing its high school curriculum. The first course offered in the school year 2014-2015 is Exploring Computer Science[17].

The Exploring Computer Science curriculum has proven successful with inner city students in over 8 years of research with the Los Angeles Unified School District. The curriculum takes a breadth based approach to computer science including units on Human Computer Interaction, Problem Solving, Web design, Programming, Computing and Data Analysis, and Robotics. The full curriculum is available from the Exploring Computer Science website at http://exploringcs.org.

In New York City, 36 schools (72 teachers) attended the summer professional development institute for Exploring CS and are implementing the program this school year. Future expansion is planned to include training more schools in Exploring CS, and expanding to Code.org’s CS Principles curriculum for a second year in experienced schools. The Code.org and iZone partnership currently serve over 5,000 students.

3.6 ScriptEd

Scripted is unique in the CSNYC portfolio as it started with an after school program. ScriptEd has expanded to include in-school classes in addition to after school programs.
The ScriptEd model uses professional software engineer volunteers to deliver a curriculum focused on web design with HTML, CSS, and JavaScript and practical skills such as using GitHub and wire framing tools to produce products. Students are motivated to complete the ScriptEd program by the promise of internships using their newly acquired technical skills.

The ScriptEd partnership with CSNYC serves approximately 300 students in 15 schools in the 2014-15 school year. Students in the ScriptEd program are diverse both in ethnicity (30% Black, 43% Hispanic, 24% Asian, and 3% White) and gender (50% Male, 50% Female). Students completing the ScriptEd program have interned with companies such as American Express, JP Morgan, Contently, ThoughtWorks, About.com, and Getty Images among others.

3.7 TEALS

The TEALS (Technology Education and Literacy in Schools) program recruits, trains, mentors, and places technology professionals from industry in high school classrooms as volunteers. The volunteers work closely with school teachers throughout the program implementation in schools in order to not only teach the students in the class, but to instruct the classroom teachers as well. TEALS uses a fading model where over the course of several years the instruction shifts from the technology professional supported by the classroom teacher, to the classroom teacher with support from the technology professional. In New York City TEALS currently offers two classes for schools to choose from, an introductory course based upon the Beauty and Joy of Computing curriculum[18] and the Advanced Placement Computer Science A course.

In the 2014-2015 school year TEALS had programs in 131 schools serving more than 6600 students. In New York City, TEALS works with 14 schools. The TEALS program works with CSNYC to help facilitate school recruitment and ongoing teacher and volunteer professional development. TEALS also hosts a city-wide computer science opportunity fair to help students from all computer science programs in NYC understand the career options available to technical employees. The 2015 opportunities fair had over 1200 students and more than 75 companies, universities, and organizations participating.

3.8 Teacher Meetups

Although many CSNYC programs include ongoing teacher professional development, CSNYC believes bringing together teachers, professional volunteers, interested parties, and organizations is an important component for creating a community of practice around the discipline of teaching computer science. CSNYC directly organizes, supports, and provides facilitation for two teacher meet up events each month. The CSNYC Educator Meetup occurs on a weekday evening, and the CSNYC Scratch Educator Meetup happens on weekends to allow for longer engagement.

The Educator Meetup generally involves a program containing ample time for networking, combined with featured speakers around a topic of interest to the community. Past topics have included encouraging more women in technology, the "Educators Guide to Careers in Computing", the maker movement, and NYC Computer Science program offerings with representatives from over 27 organizations. Attendance at the evening meetup events varies, ranging from 49 to 221 depending upon the topic. The Scratch Educator Meetups are run un-conference style where educators propose session topics and form an agenda in real time. The Scratch Educator meet up had an average attendance of 35 participants in the 2014-15 school year showing a steady rise in attendance during that time.

4. Future Growth and Research Challenges

CSNYC is at the beginning of its mission to expand access to computer science for every student in New York City. Along the way we anticipate facing many challenges, some already defined, and asking important research questions. In this section I detail some of the challenges currently faced by our programs, and the research questions we currently seek to address. These questions are not meant to be exhaustive, merely a way to communicate our current research priorities as we continue to look for partners who would like to study our programs and the various forms of computer science education being implemented in the New York City public schools.

4.1 Current Program Challenges

Although each individual program is unique, there are shared challenges between the programs.

4.1.1 Finding Qualified Teachers

Similar to the lack of qualified applicants for technical positions in companies, schools and programs are scrambling to find qualified teachers to teach computer science. Many programs have resorted to professional development for in-service teachers to instruct them in both the content and pedagogical content knowledge of the computer science curricula specific to the program’s needs. This effort is costly and CSNYC is currently in discussions with local colleges and universities in order to help identify potential pipelines for teachers, shape the pre-service preparation programs to meet the needs of the New York City programs, and ensure that teachers graduating from those programs are appropriately credentialed to qualify to teach in public schools.


4.1.2 Providing Students With Real World Experiences

A number of our programs use internships as a culminating activity or an integral part of the growth of the student through the program. A significant challenge, despite being in a large city, is the availability of companies willing to support high school students during an internship. Many of the internships students have been placed in have been highly successful, and all of the programs enjoy an almost perfect retention rate for companies who host interns. There is a misperception, however, in companies who have not hosted an intern, of what types of problems public school students from New York City will bring to their offices. We are working to change these perceptions by highlighting individual students and success stories, however the constant need to continue recruiting as the programs grow is a challenge.

4.2 Planned Future Growth

In addition to the growth in enrollment of current programs in New York, we are committed to supporting two additional initiatives in NYC for the 2015-16 school year. CSNYC is a partner on a National Science Foundation grant to bring the Beauty and Joy of Computing CS Principles course to New York City teachers. Over the four year grant, CSNYC will work with three additional organizations (Educational Development Center, the NYC Department of Education, and the University of California at Berkeley) to develop new curricular materials and train 100 teachers in New York City. The Beauty and Joy of Computing course is designed to prepare students for the new Advanced Placement Computer Science Principles exam.

CSNYC will also continue to work with Code.org in the 2015-2016 school year. Currently CSNYC supports the partnership between Code.org and the iZone for high school computer science. In the summer of 2015 Code.org will begin training elementary school teachers in the elementary curriculum for grades K-5 in New York City.

4.3 Research Questions

CSNYC recognizes the unique opportunity presented in the collaboration of public schools, non profit organizations, content providers, and researchers. To this end we are exploring multiple avenues for collaborative work with faculty at nearby (and some far) institutions. Driving many of the research proposals being drafted is the need to (1) identify core computer science content sequences that prepare students for success in school, college, and potentially career, (2) best pedagogical practices that enable a diverse population of students to learn the fundamentals of computer science regardless of academic background, and (3) generalizable models of best practices the emphasize both the importance of ongoing teacher professional development and also the reality of limited budgets. CSNYC welcomes new collaborations with institutions of high education in the support of programs through volunteers or space for professional development activities, and also collaborations focused on addressing research questions appropriate for NYC public schools and CSNYC programs.

5. Acknowledgments

The NYC Foundation for CS Education would like to thank our donors, board of directors, and partners who have provided guidance and support in many forms during our initial growth. We recognize the many volunteers that our programs depend upon to teach the next generation of technology workers and leaders, and the companies that generously donate space for professional development events, student field trips, and partnership meetings.

References

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