THE CYBERSECURITY EMPLOYMENT GAP:
WHAT IS NEW YORK STATE DOING?

by

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Abstract

Cybersecurity breaches are an ever-increasing threat to every sector of society. Bad actors are continually attacking organizations, government, industry, and individuals, but yet, they cannot fill their cybersecurity job positions. There is, currently, an extreme shortage of cybersecurity professionals to fill hundreds of thousands of job openings. New York State is in the same vulnerable position as the rest of the world. The cybersecurity education pipeline is currently not able to ease the job shortage in the near future. This paper looks at the factors in the K-12 education pipeline to find where exactly it is broken and then analyzes what is New York doing to remedy its own broken pipeline. Keywords: Christopher Riddell, Joe Giordano, cybersecurity, policy, computer science, computational thinking, career pathways.

Acknowledgements

I would not have been able to complete my cybersecurity degree without the support of my family and my supreme mentor Joe Giordano. It took a while longer than I expected due to other matters vying for my time, but it got done. Thank you! Now, on to saving the world from the hackers out there…

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According to the FBI, Americans reported over a billion dollars of loss resulting from Internet-related crimes in 2015. These crimes ranged from email scams targeting businesses or individuals, ransomware crimes, to corporate data breaches. The FBI's Internet Crime Complaint Center (IC3) receives an average of nearly 300,000 Internet-related crime complaints each year; however, the government estimates that only 15% of fraud victims ever report the crime (Federal Bureau of Investigation, 2016). This leaves millions of victims entirely excluded from these loss estimates. The losses to individuals and businesses alike are staggering and impossible to calculate precisely.

What these statistics don't impart is *why* these victims fall prey to criminals. A growing number of experts believe that no company or individual is immune from a determined and skillful hacker. It is no longer "if" one will be hacked; it is "when" they will be (or have already been) hacked. Dr. Larry Poneman, Founder and Chairman of the Information Technology (IT) Research firm Poneman Institute, remarked in one interview, “If you’re not a data breach victim, you’re not paying attention” (Pagliery, 2014, para. 13).

The Information Systems Audit and Control Association (ISACA), a well-established IT association, conducted a global survey of its 3,400+ members in 2015. It revealed that 46% of these business and IT professionals expected a cyberattack to strike their networks during the current year, but only 38% believed their organization was prepared for a sophisticated cyberattack (ISACA, 2015, p. 1). These statistics are disconcerting given the fact that the respondents overwhelmingly (83%) believed that, “cyberattacks are among the three biggest threats facing organizations today” (ISACA, 2015, p. 2).

Most cyberattacks are not particularly high-tech. Many of them exploit long-known vulnerabilities that users simply haven't patched. Multiple cybersecurity strategies exist to keep a network secure from the *majority* of attacks.

Unfortunately, there is a severe shortage of cybersecurity professionals with the skills to implement these strategies. Those hiring in the industry have a nearly universal pessimism in finding proficient cybersecurity professionals. The ISACA survey showed that a stunning 86% of respondents believed there is a shortage of skilled cybersecurity professionals, and of the organizations planning on hiring more cybersecurity professionals during the year, almost all of them, "expect it will be difficult to find skilled candidates" (ISACA, 2015, p. 1).

Given that organizations are experiencing on-the-ground shortfalls in filling their cybersecurity positions, it is unsurprising that the metrics in the cybersecurity job market support their sentiments. The job market analytic firm, Burning Glass Technologies aggregated the cybersecurity-related jobs posted on almost 40,000 job-listing sites for their annual *Job Market Intelligence, Cybersecurity Jobs, 2015* report. (Burning Glass Technologies, 2015, p. 15). They found that in 2014, employers listed 238,158 open cybersecurity jobs. The annual number of open positions grew 91% from 2010-2014 (p. 3).

The real-world consequence of this shortage is both tangible and critical. Candace Worley, Senior Vice President and General Manager of Intel Security, recently gave a speech to leaders at the Center for Strategic & International Studies. In it she laid out what Intel Security had found in their survey of IT organizations across the globe. Intel's survey concurred (82%) with the experience of having, "an extremely difficult time filling the roles in their organization" (Worley, 2016).

Worley went on to explain how critical this gap is to the security of a business or agency's network. Unfilled cybersecurity positions mean one of two things. The first scenario is that an organization is driving their staff to burnout. They are working incredibly long hours every day and are likely not as alert with the lack of sleep. The second scenario is that with too few people, they are forced to choose which functions are the most critical, and take care of these first. Potential breaches require immediate attention, whereas routine functions like updating a system may go undone (Worley, 2016).

Delaying a patch of an operating system or application is an incredible gift to the hacking community because it is one of the primary ways they actually use to get into an organization and penetrate that ecosystem or that network. And so the talent shortage is, in fact, putting organizations and companies at greater risk (Worley, 2016).

There is a direct correlation between the lack of cybersecurity personnel and the shortage of college students majoring in Science, Technology, Engineering, and Mathematics (STEM) degrees which includes cybersecurity. In fact, the entire cybersecurity pipeline is deficient; from the post-secondary level, to the interest and skills of high school students, all the way down through middle school and elementary school where skills preparation and interest already begins to wane. This deficiency is especially pervasive with non-Asian minorities and young women (National Science Foundation, 2012).

New York State (NYS) is experiencing the same shortages as the rest of the US. The purpose of this research was to examine New York State's K-12 efforts to encourage and prepare students to successfully enter post-secondary cybersecurity programs. What factors contribute to the nationwide lack of college cybersecurity graduates? What has New York's K-12 education system implemented to address these factors?

Figure 1 shows an overview of the cybersecurity pipeline and some of the factors that are draining the pool of possible STEM and cybersecurity majors in postsecondary training programs. Most of these factors will be explored further in the Literature Review section of this paper. The exception will be addressing possible solutions to poor benchmarked math and science skills, as this is beyond the scope of this paper. It is undoubtedly the most significant factor, however, it is also the most difficult to fix. The systemic low scores would be better addressed by experts in education.

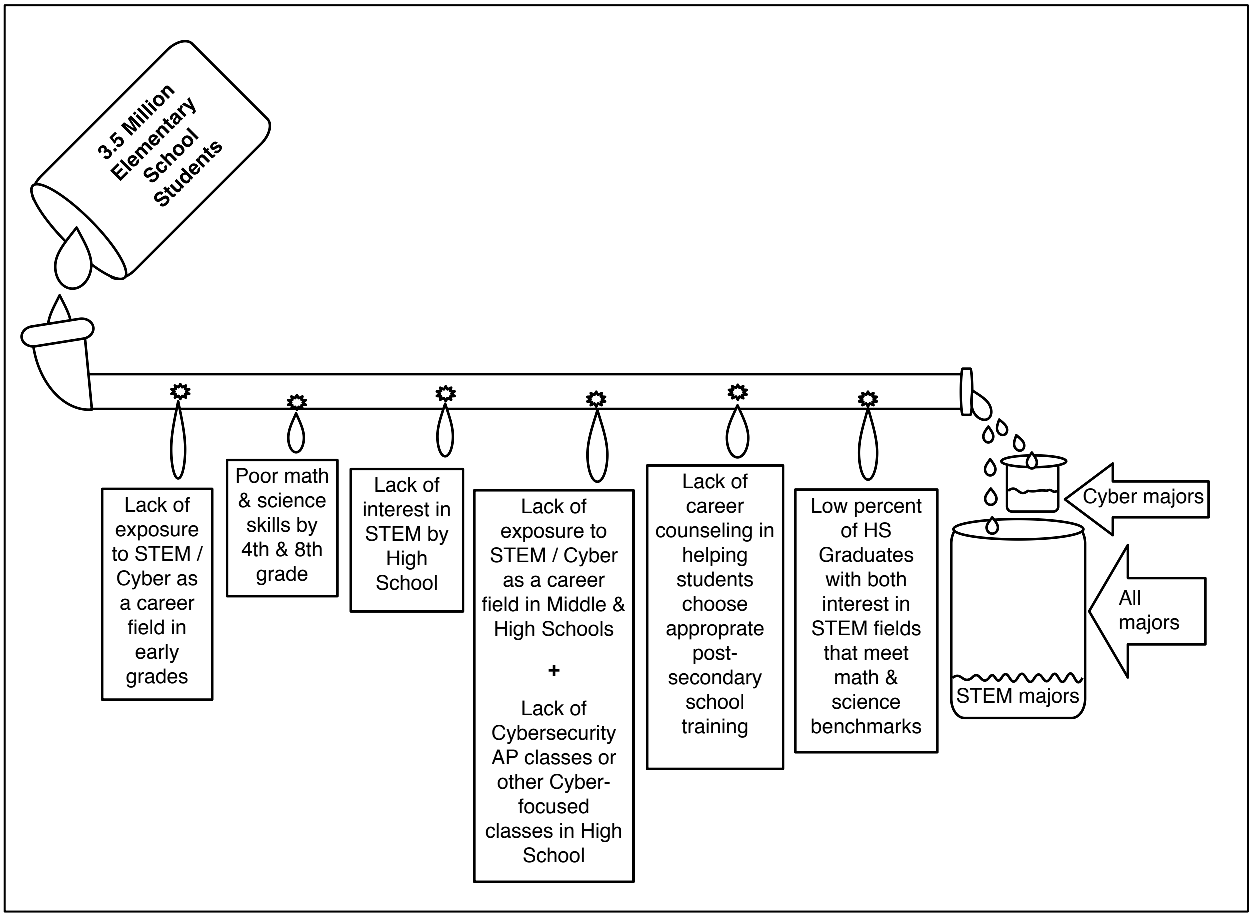

Figure 1. The cybersecurity pipeline with factors that are draining the pool of possible candidates.

According to the National Student Clearinghouse (2015), only 38% of Bachelor's of Science degrees were in science and engineering fields (p. 1). Of these, a mere 8% were in computer science (cybersecurity is generally considered a subset of computer science which decreases the pool even further). One part of this dearth of STEM graduates is that 48% of students that begin college with a STEM major do not graduate with one. For computer/information sciences, this rate is 59% (Chen and Soldner, 2013, p.15). There are multiple additional factors that may be causal to this shortage, some of which will be discussed further in this paper.

One of the most reported factors at the high school level is a deficiency in math skills. ACT reported in their *ACT Condition of College & Career Readiness 2015* report that only 42% of high school graduates were ready for college-level math, and only 38% were ready for college-level science (2015a, p. 4). High School graduates who indicated an interest in STEM only faired slightly better on their math (49%) and science (45%) scores (ACT, Inc., 2015b, p.5). Without these fundamental skills, it is impossible to begin or continue any STEM degree, including cybersecurity.

Similarly, elementary and middle school students also lack adequate math and science skills. The National Center for Education Statistics' (NCES) most recent *Nation's Report Card: 2015 Mathematics Results* (2015a, p. 1) showed that only 40% of 4th-graders and 33% of 8th-graders were at or above proficient in math. The latest available *Nation's Report Card* reports for science show that 34% of 4th-graders and 32% of 8th-graders were at or above proficient in science (NCES, 2009; NCES, 2012).

A second factor, specific to cybersecurity, is that students at the Primary to Post-secondary levels are rarely exposed to cyber as a career option. Raytheon Company (2015) polled young adults ages 18 to 26 cyber career-specific questions to gauge interest and awareness among high school students. When asked if a teacher had ever mentioned cyber as a career option, 64% said "No" (p. 2). Additionally, 64% didn't know the job tasks of a cybersecurity professional (p. 3). A third factor that Raytheon uncovered was that personal cybersecurity was not taught in the classroom for 54% of high school graduates, leaving a critical opening for discussion of the career field closed (p. 4). This doesn't even take into account the implications of a generation of students who lack basic online cybersecurity knowledge.

A fourth factor contributing to the gap is that schools rarely offer formal classes in cyber-related fields at any K-12 level. 43% of recent high school graduates said "that cybersecurity programs and activities were not available to them at all" (Raytheon, 2015, p. 3). According to The College Board, which administers the AP exams, just over 4,700 schools were authorized to teach *AP Computer Science* out of 42,000 public and private high schools nationwide. Of note, New York State had only 200 out of 1,081 public and private high schools authorized to teach *AP Computer Science A* class (College Board, 2016; NCES, 2016; New York State Education Department [NYSED], 2015). However, this does *not* mean that 4,700 schools nationwide (200 in NYS) are *currently* offering *AP Computer Science* classes. A cursory search of the individual schools shows that many, if not most, of the schools are *not* offering the course as of this writing.

Government, industry, and academia all have taken note of this employment gap and the lack of STEM degrees in high-need fields. Many have implemented programs to try to remedy the issue; however, there is no coordinated national level effort at this time. Furthermore, there seems to be a negligible amount of research on the success of these programs with only a few exceptions.

The programs implemented specifically targeting the cybersecurity career field are significantly fewer, but they do exist. This paper will highlight some of the programs that have shown promise in encouraging and preparing students for a future in cybersecurity. New York State also does not have one coordinated effort to address the cyber gap, but some individual urban hubs are coordinating internally better than others. New York City, for instance, has a significant number of STEM-oriented schools. Additionally, New York City has launched both the *Computer Science for All NYC Students* (CSNYC) and created the national *Computer Science for All* (CSforAll) Initiatives. Other hubs exist within NYS as well that tend to center around college outreach programs. One such hub is in Syracuse, where the district was forced to transform itself due to chronically failing schools. It has collaborated with academia and industry toward a career and technology-integrated model.

This research will highlight some of these hubs and evaluate their relative success or lack thereof. Lastly, it will give recommendations as to where NYS might better their efforts in helping to reduce the cybersecurity gap. The payoff of this reduction will be both economically beneficial to the individuals who will earn better wages and for the communities they live in. Even more notably, adding new cybersecurity professionals serve to make online communities safer for all.

Literature Review

The cybersecurity career field is in crisis. Companies, banks, government agencies, small businesses, hospitals, utilities, and individuals are all at risk for cyberattacks. The longer there is a shortage of skilled cybersecurity professionals the more the risk intensifies. Plugging the "leaks" in the cybersecurity pipeline is critical to fixing the skills gap. Identifying the leaks will help find solutions. Solutions must be examined and critiqued for effectiveness. An evaluation of NYS efforts to address the skills gap can then follow.

The Relationship between Cybersecurity and Computer Science

Because of a paucity of research literature on student motivations towards cybersecurity, this paper will use computer science research when necessary. There is a deep connection between the two fields. Since the 1960s, the world's largest computing society, the Association for Computing Machinery (ACM) has been the lead player in "Advancing Computing as a Science & Profession" (2016). With the collaboration of industry leaders, academia, researchers, government agencies, and experts in every computer-related field, ACM has led the charge to formulate exact computer science framework, standards, and curricula.

In October 2016, the ACM, Code.org, Computer Science Teachers Association (CSTA), Cyber Innovation Center, and the National Math and Science Initiative, computer science educators, along with 14 states (not New York) released the *K-12 Computer Science Framework*. The purpose of the *Framework*, is to serve as a "high-level guide to inform the development of computer science standards, curriculum, and professional development" (K–12 Computer Science Framework Steering Committee [K12CS], 2016b). The authors of the *Framework* describe the relationship between cybersecurity and computer science,

> Cybersecurity cuts across many domains of study, but its roots are in computer science. Expanding access to K-12 computer science in the US will help meet the specialized needs of the cybersecurity workforce by building a diverse pipeline of students interested in various aspects of technology. (K12CS, 2016a)

Even within an undergraduate computer science program that does not teach cybersecurity as a separate core class, there are nearly always modules within the curriculum that address cybersecurity. For high school students and younger, the *Framework* authors believe that cybersecurity concepts need to be taught both in computer science classes as well taught as independent topics like social networking, cyberbullying, mobile computing, password creation, and other ways that "technology impacts their lives" (K12CS, 2016b). The *Framework* authors also argue that high school introductory computer science courses should teach the "basic principles of security, such as cryptography, threats, and authentication" (K12CS, 2016a). By integrating these types of topics, students will be inspired to take more specialized coursework in cybersecurity.

Cybersecurity Pipeline Drain

Low math and science scores. As discussed earlier, low math and science scores are a prime-determining factor in the leaky cybersecurity pipeline. The literature shows that with only 42% of high school graduates ready for college-level math, and only 38% (ACT, Inc., 2015a, p.4) are ready for college-level science, the K-12 education system is not producing college and career ready graduates. Much research has been conducted as to where the "make-or-break" points in academic careers are. High School graduates are a relatively easy group to evaluate, as on the whole, they take normed knowledge tests with widely available data.

The next logical point that researchers focus on is when students enter high school. One notable education researcher, Robert Balfanz notes in his policy and practice brief, *Putting Middle Grades Students on the Graduation Path*, that, "in high-poverty environments, nonselective high schools often educate primarily students who enter with the skill levels of typical fifth or sixth graders. In short, these are students who lack a solid middle grades education" (p. 6). Other researchers, like the ACT non-profit group, points to 8th grade as a critical juncture where students must meet all of their benchmarks in to be on track for college and career. In their report, *The Forgotten Middle: Ensuring That All Students are on Target for College and Career Readiness before High School*, they make the following conclusion from their longitudinal study:

> These results show the critical importance of being on target for college and career readiness in eighth grade: regardless of race/ethnicity or income, those who are on target

are on a trajectory of success that enables them to be ready for college and career by high school graduation, while those who are not on target are much less likely to eventually be ready for college and career. (2008, p. 24)

Eighth grade may be a valuable assessment point, but current research indicates that the achievement gaps in math and science do not start in high school, but occur much earlier in students' academic careers. Balfanz (2009) stressed, "It is during the middle grades, particularly in lower-performing schools that serve high-poverty populations, that achievement gaps often become achievement chasms" (p. 6). This means that with the nation's 4th-grade math and science score benchmarks rate of 40% and 34% respectively (NCES, 2009, p.1), the prospects of higher passing rates, later on, are unlikely.

This paper does not intend to address the specific measures that might be taken to rectify the math and science achievement gap, as it is beyond the purpose scope. However, the gap is something that must be fixed before any STEM career field can be fully staffed with qualified workers. Balfanz expresses this best: "To achieve the nation's goal of graduating all its high school students ready for college and career, it will be essential for students to enter high school with at least close-to-grade-level skills and knowledge" (Balfanz, 2009, p. 6).

Lack of exposure to cyber and misperceptions. K-12 students as a whole have misperceptions of computer science and its associated fields. Research shows that "Students avoid computing because of their perceptions of it as boring, tedious, asocial, and irrelevant" (Yardi and Bruckman, 2007). These misperceptions negatively influence students from pursuing a computer science or cybersecurity degree. Student perceptions have been both formally assessed (as in the Yardi and Bruckman study), and informally assessed by educators in the field with decades of experience.

George Washington University Professor, C. Dianne Martin has for years, begun each Fall Semester's Introductory Computer Science class with a survey. The students were asked to define what they thought computer science was. The students mostly answered "programming", with few other ideas offered. The second task Martin gave was to "draw a picture of a computer scientist." *Figure 2* shows an example of what one type of depiction that college freshmen drew.

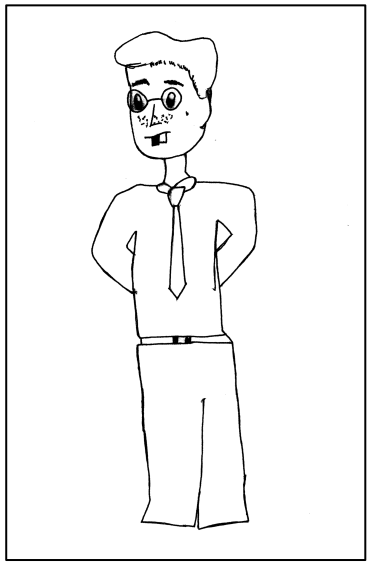

Figure 2. Example of what college students drew when asked to "Draw a Computer Scientist". Reprinted from "Draw a Computer Scientist," by C. D. Martin, 2006*, Inroads - The SIGCSE Bulletin,* 36(4), p. 11. Reprinted with permission.

Martin states in her paper, *Draw a Computer Scientist* (2006), that both women and men would draw a white man with "various degrees of 'geekiness.'" The man would usually include glasses, pocket protectors, t-shirts with obscure computer code, among other characteristics. One version included, "overweight, eating junk food, bleary-eyed and drinking coffee, messy hair, acne, sloppy dress" (p.11). The other distinct "type" drawn by the undergraduates was of professor-type with facial hair and glasses. The nature of the stereotyped drawings strongly suggests that students generally did not see *themselves* as future computer scientists. Martin draws a line in the sand, saying, "These results clearly indicate that our profession is not doing a good job communicating the diversity and complexity of our field to the general public and to high school students in particular" (2006, p.1).

Computer science professor and researcher, Lori Carter, headed a survey of over 800 secondary school students in nine different school districts to study why students with high mathematics aptitude (currently enrolled in calculus or pre-calculus) chose *not* to major in computer science after high school. Her research was both complementary and built upon previous research suggesting that if students do not know what Computer Scientists do, then their impressions of the career field will be skewed. Her team found similar results as previous research,

> An alarming number of students (80%) had no idea what computer science majors learned. Of the students who did give a response, most believed that the major focused on computer programming. Only 2% of the high school students surveyed had a reasonably good grasp of what the field of Computer Science entailed. (Carter, 2006, p.3)

Martin and Carter, among a myriad of other researchers, postulate that if first-year college students have a rigidly stereotyped view of what a computer scientist looks like, and also do not understand what the career field entails, then this could be a determining factor in whether a student chooses to pursue computer science or cybersecurity degree (Martin, 2006; Raytheon, 2015; Carter, 2006; Yardi and Bruckman, 2007).

This raises the question, *why* is there such an unfamiliarity of the computer science and cybersecurity fields?

One group of researchers, Goode, Estrella, & Margolis (2006) explain that the media, whether from Hollywood or magazines, are some of the main perpetrators of "erroneous images of computer science and computer scientists" (p. 100). However, if schools integrate computer science classes into their curriculum, these erroneous images might be offset. The stereotypes continue because there are few representatives from these technology fields that might interact with students, encourage, influence, and possibly pique their interest (p. 100). What is interesting, however, is that policymakers and educators also are contributing to these misperceptions, but in a different manner (ACM, 2010, p.10).

For decades, there has been a push by policymakers and educators to embed technology use into classrooms. A student that has fluent technology skills will be better prepared in the future, whatever career they might pursue. Despite the good intentions of this technology campaign, the unintended result has been classrooms full of technology literate students, but few that understand "deeper computer science concepts and capabilities" (ACM, 2010).

Schools today almost universally teach computer skills to their students. These skills are taught either as separate computing (often called technology) courses or integrated into other core classes. ACM defines *Information Technology (IT)* coursework as teaching the "proper use of technologies by which people manipulate and share information in its various forms—text, graphics, sound, and video" (2003, p.6). This is in contrast to their definition of *Computer Science*, which is the "study of computers and algorithmic processes, including their principles, their hardware and software designs, their applications, and their impact on society" (2003, p.6). Schools commonly misperceive that the two are the same, and as alluded to earlier, policymakers and educators confuse these as much as the students. The lines have become blurred as to what is technology *use*, what is technology *literacy*, and what is "computer science as a core academic discipline within the STEM fields." Without clear definitions, policymakers will continue to legislate educational policy based on misinformation (ACM, 2010, p. 10).

Margolis, Goode, and Bernier (2011) explain, "In too many schools, the computing curriculum is defined by basic computer literacy and rudimentary computing skills, such as typing, word processing, Internet searching, and working with spreadsheets" (p.68). These types of tasks are tedious and are not engaging to most students. Rivier College computer science professors, Sabin, Higgs, Riabov, and Moreira (2005), have studied this phenomenon in high school students and found that the discipline of computer science is not being given the opportunity to tell its "compelling story." They assert that high school students must start studying actual computer science, versus programming or Microsoft applications so that students begin to "associate their professional future with computer science" (Sabin, Higgs, Riabov, & Moreira, 2005, p.177). To that end, President Obama announced a new "Computer Science for All" initiative to offer "every student the hands-on computer science and math classes that make them job-ready on day one" (Obama, 2013). He proposed in his Fiscal Year 2017 budget with significant increases in funding to the Department of Education, the National Science Foundation (NSF), and the Corporation for National and Community Service (CNCS). States and districts would have access to grants to be able to increase access to computer science in the classroom (The White House, Office of the Press Secretary, 2016). As of this writing, the President's proposed budget has not been passed by Congress, so it remains to be seen whether the additional funding will materialize.

As previously mentioned, Raytheon Company (2015) found that of recent high school graduates, 54% had never been taught even basic personal cybersecurity, and 64% had never had a teacher mention cyber as a career option at all (pp. 2-4). Less than 9% of US high schools are registered to offer *AP Computer Science* to its students, however this does not mean they are offering the course at any given time (College Board, 2016; NCES, 2016). *AP Computer*

Science is currently relegated to the secondary school level, however, more and more academic organizations are pointing to earlier grades as a better point to introduce computer science principles.

Computer science, like other pure academic subjects, builds from basic to high-level skills. The core of computer science (and increasingly mathematics and science) is what researchers and educators call *computational thinking*. There is not yet one agreed-upon definition of computational thinking, however the International Society for Technology in Education (ISTE) and the Computer Science Teachers Association (CSTA) (2011) worked in collaboration with experts across the computer science spectrum to formulate an operational definition:

> Computational thinking (CT) is a problem-solving process that includes (but is not limited to) the following characteristics:
>
> • Formulating problems in a way that enables us to use a computer and other tools to help solve them.
>
> • Logically organizing and analyzing data
>
> • Representing data through abstractions such as models and simulations
>
> • Automating solutions through algorithmic thinking (a series of ordered steps)
>
> • Identifying, analyzing, and implementing possible solutions with the goal of achieving the most efficient and effective combination of steps and resources
>
> • Generalizing and transferring this problem solving process to a wide variety of problems

This type of problem solving is something that must be learned in a sequential way and not conducive to being introduced as a whole until secondary or post-secondary school, where computer science curriculum currently lies. The term originator, Jeanette Wing, Corporate Vice President of Microsoft Research (2008), argues that computational thinking is a way of learning that is best taught in the early years of childhood in order for all students to have a "common and solid basis of understanding" (p. 3720). Experts liken this progression of problem-solving skills to the skill-building within mathematics. In fact, by narrowing the scope of teaching computer science to the problem-solving aspect (computational thinking), it becomes a skill that can be universally applied to virtually every other academic field. Barr and Stephenson (2011), implore educators and policymakers to understand that "computational thinking is a skill that helps students in many more subjects than just computer science" (p. 49).

Barr and Stephenson (2011), echo Wing's argument that these skills need to be introduced early on in a student's academic career. "It is no longer sufficient to wait until students are in college to introduce these concepts...They must begin to work with algorithmic problem solving and computational methods and tools in K-12" (p. 49). A growing body of literature has been written to address this understood gap in the computer science/cybersecurity pipeline.

Computer science standards. Several notable organizations have spent considerable time and effort to present science/computer science standards, albeit these have not been necessarily adopted, nor implemented by states. The Computer Science Teachers Association (CSTA) developed and published the ACM Model Curriculum for K-12 Computer Science (CSTA & ACM, 2003), along with supporting curriculum implementation documents. In 2011, they published the first full set of standards, and all [Interim] CSTA K–12 computer science standards (2016).

Barr and Stephenson (2011) laud, “CSTA has provided the de facto national standards for computer science in K-12” (p. 54). In 2010, Barr and Stephenson studied the extent to which these standards had been adopted wholly, or in part, by states at the secondary school level. They concluded that there were “numerous and significant gaps between current state secondary education stands and nationally recognized standards” (ACM, 2010, p. 7). A total of 14 states have adopted enough of the standards (50%) to any significant degree, and only nine states allow computer science to count as a required graduation credit in math or science. Although New York is one of the states that allows computer science to count as a math credit, it has adopted just 30% of the CSTA standards (ACM, 2010, p. 7; Code.org, 2016).

The updated standards were revised to align with the concurrently produced *K-12 Computer Science Framework*. The *Framework* is particularly significant in that it was created with a large collaborating body including ACM, Code.org, CSTA, Cyber Innovation Center, National Math and Science Initiative, and district and state partnerships. These organizations, districts, and states served collectively as the *K–12 Computer Science Framework Steering Committee* (2016). The recently formed *Computer Science for All NYC Students* (CSNYC) and offshoot initiative, the *Computer Science For All Consortium* (CSforAll) and the have begun to campaign for all states and districts to endorse the *K-12 Computer Science Framework. Computer Science for All's* mission is:

> …to empower all US students from kindergarten through high school to learn computer science and be equipped with the computational thinking skills they need to be creators in the digital economy, not just consumers, and to be active citizens in our technology-driven world. (CSforAll, 2016a)

CSforAll has asked schools/districts to pledge support for the Initiative, which 70 districts and 288 schools (together representing 3076 schools) have done so. In New York State (excluding NYC), the number of public, private, and charter schools totals at 3877 (NYSED, 2016c). Of these, one school and one school district (four schools), plus one BOCES program have pledged support for the Initiative (CSforAll, 2016b).

As New York City was the architect of the *CSforAll* initiative, the city's schools have done significantly better in the integration of computer science. Their goal, according to NYC Mayor Bill De Blasio's 2015 announcement, was that within 10 years, all of the city's public schools (with 1.1 million students) would be required to offer computer science instruction. Additionally, NYC plans on spending $81 million (half to be raised by private sources) towards the goal, including the training of 5,000 new teachers (Taylor & Miller, 2015).

The International Society of Technology in Education (ISTE) wrote an earlier set of standards, the *National Educational Technology Standards (NETS)*. Later, they changed the name to the *ISTE Standards* which now consists of "five sets of standards and provide a framework for amplifying — or even transforming — digital age learning, teaching and leading" (International Society for Technology in Education [ISTE], 2016a). Barr and Stephenson, like others in the field, show optimism that ISTE has built a well-received technology framework. "By convening K-12 educators, teacher educators, curriculum and education associations, government, business, and private foundations, ISTE built consensus for the framework and momentum for using the standards" (2011, p. 54). Nine states have fully adopted these standards; seven states have adapted the ISTE Standards while developing their own standards. New York has not adopted any (ISTE, 2016b).

The National Academies Press published the third set of standards, entitled the *Next Generation Science Standards (NGSS)*. The NGSS was authored collaboratively by multiple organizations and states, including the National Research Council, the National Science Teachers Association, the American Association for the Advancement of Science, Achieve, Inc. The authors of the NGSS explained the purpose for their three-year project: “The standards are rich in content and practice and arranged in a coherent manner across disciplines and grades to provide all students an internationally benchmarked science education” (NGSS Lead States, 2013). The standards include some “computational thinking” elements in the lower grades, but no explicit computer science concepts. Although 26 states collaborated to develop the NGSS, only 16 have adopted the standards since they were released in 2013. New York was one of the collaborating states, but chose to adapt them, finally releasing the *New York State P-12 Science Learning Standards* in December 2016 (NGSS Lead States, 2013; Academic Benchmarks, 2015b; NYSED, 2016c). New York did not add computer science to their version of the science standards.

Finally, the Common Core State Standards (CCSS), first written in 2009, have gained traction as the national standards in English Language Arts (ELA) and Mathematics. Currently, 46 States have adopted the CCSS either in full, or adopted with modifications (Academic Benchmarks, 2015a). The ACM, acknowledges the absence of computer science in the CCSS. “Computer science does not exist in these documents despite being taught across the United States, having an Advanced Placement exam, and in some states having computer science courses count as either a mathematics or science credit in secondary education” (ACM, 2010, p.30). To remedy this, CSTA has mapped the tenets that might correspond to the CCSS (ACM, 2013, p.1). An excerpt of the beginning part of this “mapping” is shown in Figure 3. In the figure, the CSTA Computation Thinking (CT) standard **CT.L2-02 - Describe the process of parallelization as it relates to problem solving** maps to the CCSS **Writing Standards for Literacy in History/Social Studies, Science, and Technical Subjects 6-12**. In other words, to implement the CSTA standard **CT.L2-02**, the educator could have the student write (an essay, short answer, etc.) about parallelization in any of the subjects of history, social studies, science, or technical subjects.

		Common Core State Standards						
Standard	**Description**	College and Career Readiness Anchor Standards: Reading	Reading Standards for Literacy in Science/ Technical Subjects	College and Career Readiness Anchor Standards: Writing	Writing Standards for Literacy in History/Social Studies, Science, and Technical Subjects 6-12	College and Career Readiness Anchor Standards: Speaking and Listening	College and Career Readiness Anchor Standards: Language	Standards for Mathematical Practice
	CT: Computational Thinking							
CT.L2-01	Use the basic steps in algorithmic problem-solving to design solutions (e.g., problem statement and exploration, examination of sample instances, design, implementing a solution, testing, evaluation).							✓
CT.L2-02	Describe the process of parallelization as it relates to problem solving.				✓			
CT.L2-03	Define an algorithm as a sequence of instructions that can be processed by a computer.						✓	
CT.L2-04	Evaluate ways that different algorithms may be used to solve the same problem.							✓
CT.L2-05	Act out searching and sorting algorithms.		✓					

Figure 3: Example of CSTA's computer science standards mapped to Common Core State Standards. Reprinted from "CSTA K-12 Computer Science Standards: Mapped to Common Core State Standards," by Association for Computing Machinery [ACM], 2013, https://csta.acm.org/Curriculum/sub/K12Standards.html. 2013 by ACM. Reprinted with permission.

Although New York State does not mandate specific literature to be read in 3-12 ELA classes, the state-provided curriculum modules *do* mandate specific literature. As of now, there are a few science texts included in the list, but these are all in the biological sciences. No technology, computer science or cybersecurity texts are included in the reading list (NYSED, 2014b).

Inadequate career counseling for career exploration and realistic goal-setting. In the United States, career counseling almost universally falls under the purview of the guidance office. High school guidance counseling in the United States is neither a regulated nor a standardized career field. Only 30 of 51 states (including the District of Columbia) legislatively mandate guidance counseling in high school, although in some states, the department of education mandates guidance counselor services, which in effect mandates counselors. Of the states who mandate, funding sources vary. Some states allocate funds into their state budget, whereas other states require the districts use their own funds without help from the state. Other states leave the mandate unfunded and lastly some states have a combination of state and local funding sources (American School Counselor Association [ASCA], 2016).

The title of guidance counselor position does not have a precise definition; therefore counselors are often given additional tasks unrelated to career and college preparation. The pervasive administration's view of guidance counselor duties are scheduling, testing, and disciplinary actions (NACAC, 2005, p. 30). Additionally, when schools have to make budget cuts, counseling positions are often cut because of their "non-essential" status (NACAC, 2005, p. 30). The ramification of too many tasks and underfunding is that less than 79% of high schools have a guidance counselor. In the vast majority of schools that do have one or more counselors, the student-to-counselor ratio averages 491-to-1 (U.S. Department of Education, 2012; ASCA, 2014). The American School Counselor Association recommends no more than a 250-to-1 ratio for effectiveness. New York State has an even more alarming average of 624-to-1 school counselor ratio during the 2013-2014 academic year (ASCA, 2014). The result is that the bulk of career counseling often goes by the wayside.

Schools and educators have begun to recognize this lack of career and college readiness. Many have implemented transition programs, sometimes called freshman seminar for incoming ninth-graders. The courses are widely varied with little guidance given from higher education administration to help design effective programs. The National Association for Secondary School Principals (NASSP) conducted a research on the topic, reporting,

> There are few resources and no comprehensive standards in place for classes and programs that seek to meet the personal, social, educational, and career and life-skills goals of students. As a result, principals and teachers have become caught up in well-intended, but largely unsuccessful strategies as they have tried to develop curricula with little support and direction from districts and only vague notions of what is required to motivate the least motivated students. (Dedmond, Brown, & LaFauci, 2006).

NASSP describes the programs might vary from a "one-day overview of a new school to a full school year of career-focused curriculum" (Dedmond, Brown, & LaFauci, 2006).

There are a number of organizations that have created research-based standards and curriculum that show promise. One such organization is from the George Washington University (GWU) Freshman Transition Initiative. They explain that research shows that a transition program that is comprehensive and longer-term can be beneficial to students. They have created rigorous transition guidelines (standards) whose goal is to "increase school retention, academic achievement and post-secondary matriculation" (George Washington University, 2005, para. 5). Although GWU does not offer standards-approved curriculum, they offer a list of organizations and vendors who sell/provide curriculum that do.

New York's Effort

New York, like the rest of the U.S., does not graduate the needed computer science and cybersecurity students from any of its education pathways to fill the market need. The job market analytic firm, Burning Glass Technologies (2015) posted in their report that employers listed 17,982 open cybersecurity jobs in New York in 2014; the annual number of open positions grew 90% from 2010-2014 (p. 14).

New York, historically, has been an ardent of supporter of education reform. Policymakers of the past have instituted new programs, enacted a plethora of regulations, and provided a modicum of funding at times from public and private sources related to college and career readiness (Folts, 1996). These upheavals have had some successes, but regrettably failing schools (and failed reforms) continue to plague NY State. According to Governor Cuomo's *The State of New York's Failing Schools 2015 Report* there are 178 failing schools, 77 of which have failed for the last 10 consecutive years (Office of the Governor, p. 8). Fifty of the failing schools are at the secondary level. Even if these students graduate high school, they will not likely be college-ready –thereby not only will they not help the cybersecurity employment gap, but will also add to a myriad of other societal problems. Fixing New York's failing schools, although essential, will help –but not fix the breaks in the cybersecurity pipeline.

Influencing secondary students toward post-secondary STEM majors. Much research has been conducted on why students choose to go on to college in STEM majors. One established finding is that the more math and science courses a high school student takes (i.e. "exposure"), the more likely they are to pursue STEM fields of study. Exposure seems to be a much bigger predictor of STEM pursuit than even math achievement, although this does not discount the influence of adequate math achievement (Wang, 2013; Subotnik, Tai, Rickoff, & Almarode, 2010).

Earlier, it was highlighted that for the 2015-2016 school year, NYS had only 200 of 1,081 (18.5%) public and private high schools authorized to teach *AP Computer Science A*. Most of these schools are private, and of the public high schools, a significant number are not actually offering the course (College Board, 2016; NCES, 2016; New York State Education Department, 2015). An example is from the Rochester Central School District. The AP directory lists three public high schools as authorized to teach *AP Computer Science A*. One high school, *School of the Arts*, only offered the course virtually. Of the other two (*Leadership Academy for Young Men* and *Integrated Arts and Tech High School*), neither of these schools actually offered it for the 2015-2016 school year. Additionally, those two schools are currently on Governor Cuomo's lowest achieving schools list. It would be unlikely that these two schools will be offering *AP Computer Science* in the near future.

The other significant predictor of STEM pursuit is interest, specifically, interest in STEM careers by the end of eighth grade. One longitudinal study of over 3,000 eighth-graders (who later received their college degree) asked, "What kind of work do you expect to be doing when you are 30 years old?" The researchers divided the answers into two career-types: science, and non-science. They surveyed the same students twelve years later to see what baccalaureate degree they had attained. The results were definitive in that,

> …among the students who graduated with baccalaureate degrees from 4-year colleges, those who expected as eighth graders to have science- related careers at age 30 were 1.9 times more likely to earn a life science baccalaureate degree than those who did not expect a science-related career. Students with expectations for a science- related career

were 3.4 times more likely to earn physical science and engineering degrees than students without similar expectations. (Tai, Liu, Maltese, & Fan, 2006)

With so many studies that show that exposure and interest in STEM will encourage students to pursue it at the postsecondary level, it is no wonder that parents and educators look to specialized STEM high schools to encourage students toward that end.

Specialized STEM high schools in New York City. With its dense population, New York City (NYC) contains more than 400 public high schools. Of these, just over 100 schools offer STEM-specific programs and 18 are "Career and Technical Education" (CTE) schools. Three high schools have computer forensics as a program offered, but none offer a "cybersecurity" degree (NYC Department of Education, 2016a). Six of the nine prestigious "Specialized High Schools" are STEM specific (NYC School District, 2016b). Finally, NYC boasts 58 charter high schools (including schools that serve lower grades in addition to the 9-12 grades), a few of which have a technology focus. An example is the *Math, Engineering, and Science Academy (MESA) Charter High School*, located in Brooklyn (New York State Department of Education [NYSED], 2016a/b). The overwhelming majority of NYC charter schools do not have a science or technology focus.

There is a dichotomy of educational performance within the New York City (NYC) School District. Of the 630 failing NY public schools (K-12) in 2015, half were located in NYC. At the other end of the spectrum, NYC also has the nine highest performing public high schools in the state. Six of these rank in the top 50 public high schools nationally (Office of the Governor, 2015; U.S. News and World Report, 2016). Each high-performing school has stringent entrance requirements and fierce competition to be admitted, so it is unremarkable that nearly 100% of graduates go on to college.

STEM high schools – the research. There is a moderate body of research that has been conducted on the effectiveness of specialized STEM high schools. The different studies each focus on different facets, outcomes, or demographics of the schools; however, they generally come to similar conclusions. One study focused on STEM high schools solely located in NYC (Wiswall, Steiefel, Schwartz, & Boccardo, 2014), while others reviewed schools throughout the U.S. (Almarode et al., 2014; Gnagey & Lavertu, 2016).

The Wiswall et al. (2014) study used the NYC Department of Education database including over 72,000 NYC students for their study. The initial results showed that in NYC STEM schools, more students took higher-level math and science courses and also scored higher on their Regents tests. On further examination, however, the authors found that the STEM school students had stronger middle school performance, making much of the differences statistically insignificant (p. 100). In other words, students with higher scores in 8th grade were much more likely to go on to attend a STEM school. When the authors compared similarly performing (and demographically similar) 8th-graders, there was little difference in course taking or scores later on (p. 101).

Other studies found similar results. Gnagney & Lavertu (2016) studied what is termed "inclusive" public STEM schools, in which schools are not selective in their admission policies. This is in contrast to the NYC study, in which the majority of the schools were highly selective, inviting higher caliber students only. The Gnagney & Lavertu study was also a much smaller, but still rigorous study, looking at six STEM schools in Ohio. The study showed that when the students' prior science test scores were taken into account; there was actually a significant *negative* impact across the core courses. They did find that two of the schools had slight increases in science scores, but at the expense of lowered social studies scores (p. 9).

This does not mean the STEM high schools do not serve a meaningful purpose. Almarode et al., (2014) compared high school graduates within the U.S. who had attended STEM high schools, to those who were academically gifted and participated in a science-based program called Talent Search. The study focused on the "relationship between reported feelings of intellectual capacity to be a scientist, mathematician, or engineer at different points in time and earning an undergraduate degree in a science related area" (p. 310). The second focus was if STEM interest level (or a change in) affected whether they later earned a science-related undergraduate degree.

In the first focus area, the authors found a strong correlation between high school juniors and seniors who felt they had good intellectual capacity to later earing a science-related college degree (p. 324). This correlation was the strongest in the Talent Search group. Likewise, students who reported interest in STEM later in high school were more likely to continue into college as STEM majors (pp. 325-326). Almarode et al. found that students with early interest in STEM did not affect whether they continued into college STEM, but students whose interest increased during high school were significantly more likely to. Given this the authors conclude "…these findings suggest that early interest is not enough, and that these students need engaging experiences including advanced coursework and challenging peers who build their feelings of intellectual capacity (e.g., mentorships, internships, research experiences, etc.)" (p. 325). In other words, STEM high schools (and the Talent Search program) seem to serve as "incubators of talent for adolescents with a proclivity for STEM related disciplines" (p. 307).

Career pathways. In the last five years, federal education and labor policy has shifted a renewed momentum towards the "career pathways" educational reform. Although "career pathways" is not a new concept, there gradually have been adjustments to the definition, scope, and implementation of them (Stipanovic, Lewis & Stringfield, 2012, p. 141). In 2012, The U.S. Departments of Education, Health and Human Services, and Labor, in a joint letter defined career pathways as "a series of connected education and training strategies and support services that enable individuals to secure industry relevant certification and obtain employment within an occupational area and to advance to higher levels of future education and employment in that area" (p.1).

Vocational education of the past had a negative perception as the path that only the low-achieving (non-college bound) students were sent on. Today, the name and the perception has been changed to Career and Technical Education (CTE) and merges "secondary education and postsecondary education elements," including rigorous academics and relevant career and technical training that will adequately prepare students to enter college or the skilled-workforce. It is now considered a critical pathway for students to be college and career ready (Stipanovic, Lewis & Stringfield, 2012, p. 141). Career pathways are implemented in many directions, including the NY-led P-TECH schools, integrated Academic+CTE schools, and NY-specific BOCES programs. These will be expanded upon below. Each of these programs has similar developmental elements. The Department of Labor in a "Career Pathways Toolkit" (2015, p. 4) describe the elements that educational organizations must take to successfully implement a Career Pathways program:

1. Build cross-agency partnerships and clarify roles
2. Identify industry sectors and engage employers
3. Design education and training programs
4. Identify funding needs and sources
5. Align policies and programs

6. Measure system change and performance

P-TECH. One specialized high school, Pathways in Technology Early College High School (P-TECH), made and continues to make national headlines after President Obama mentioned it in his second inaugural address. He contrasted the teaching of vocations in Europe to the U.S. model and extolled P-TECH as the model school of the future.

> Let's also make sure that a high school diploma puts our kids on a path to a good job. Right now, countries like Germany focus on graduating their high school students with the equivalent of a technical degree from one of our community colleges. So those German kids, they're ready for a job when they graduate high school. They've been trained for the jobs that are there. Now at schools like P-Tech in Brooklyn, a collaboration between New York Public Schools and [the] City University of New York and IBM, students will graduate with a high school diploma and an associate's degree…We need to give every American student opportunities like this. (Obama, 2013)

Soon after, Obama visited the school to hold a press conference in which he again praised its innovation. P-TECH, located in Brooklyn, opened its doors in 2011. This ground-breaking high school is a 9-14 curriculum in which students will graduate free-of-charge with both a high school diploma and an industry-needed associate degree in applied science (AAS). The two paths at the Brooklyn P-TECH are either an AAS in computer systems technology or electromechanical engineering (Davis, 2012; P-TECH, 2016b).

The P-TECH model is unique in several ways. First, the planning committee intended to create a model, rather than just one initial high school. The goal of the planning committee was to expressly "create an innovative, replicable model for education — one that united the expertise of the public and private sectors to provide new opportunities for young people, and addressed the need to strengthen the continuum from school to college and careers" (P-TECH, 2016a). To this end, IBM Corporation with the City College of NY created the "P-TECH 9-14 School Model Playbook" website which offers freely the same resources they used when developing the model. "The site focuses partnerships on the key elements that characterize the P-TECH model and provides action-oriented guidance and tools to enable them to implement the model with quality and fidelity" (P-Tech, 2015).

A second unique aspect of the P-TECH model can be found, within that goal statement. The model is based on the collaboration of both the public education sector and the private sector. There are representatives on the steering committee from each partner, and each partner remains a part of "every element of the school" for the duration of the school (P-TECH, 2016c). In the case of the Brooklyn P-TECH, the IBM Corporation is the primary business partner to the NYC Department of Education, the City University of New York, and NYC College of Technology partners. Besides standards and curriculum guidance, IBM, along with additional corporate sponsors, offers paid summer internships to the third year students and pairs every student with a corporate mentor. Finally, once students graduate with their AAS, IBM has promised to give job interviews to all "qualified graduates of IBM-affiliated P-TECH schools" (P-TECH, 2016c; IBM Media Relations, 2011).

States and school districts soon began creating their own P-TECH schools. In 2013, NY Governor Andrew Cuomo announced that NYS was providing grants to 16 public-private partnerships to follow the P-TECH model. He continued the announcement, stating, "New York State is the first in the nation to implement a statewide P-TECH initiative that links education to regional economic development" (Office of the Governor, Pressroom, 2013). In the years since the Brooklyn P-TECH opening, other P-TECH modeled schools have opened across the country. As of September 2016, 48 P-TECH programs have opened across the U.S., 33 of these in New York State. So far, only one of the NY schools offers an applied associates in cybersecurity, 13 have programs related to computers, networks, or information management. Additional states have pledged to open P-TECH schools in the future (IBM, 2016; NYSED, 2016b; NYSED, 2016c).

As the program model takes six years to graduate, there is no preliminary data to evaluate the efficacy of the program. At the time of this writing, the Brooklyn P-TECH is in its sixth year; the first cohort will not graduate the regular program until Spring, 2017. That said, 38 students fast-tracked through the program to graduate one or two years early with both a high school diploma and an associates degree in computer systems technology or electromechanical engineering (IBM Media Relations, 2016).

P-TECH –the research. Because the P-TECH school model has only been recently implemented, it is too early to draw conclusions whether the model works at meeting its goals. Even so, multiple cohorts would need to graduate to longitudinally evaluate the school. There is extensive research, however, on other early-college programs from across the U.S. This research could be extrapolated to predict the likelihood of P-TECH's success.

One study from the National Research Center for Career and Technical Education looked at students from 52 high schools in collaboration with two large community colleges. It showed that students often perform exceptionally well taking CTE courses while completing high school. Not only do they succeed while in high school, but also dual programs "offer promising opportunities for high school students to develop academic and employability skills that then foster student success in preparing for careers in high demand occupational areas during college" (Lekes, et al., 2007, p. x).

In another decade-long multi-state study, researchers found that early college schools had significant impact on its both high school and college students' graduation rates. Early college students had an 86% high school graduation rate; the comparison group was at 81%. Additionally, the early college students had higher English Language Arts (ELA) assessment scores. By the end of high school, 64% of the early college students were enrolled in college, which rose to 81% by two years after high school. For the comparison group, the numbers were 24%, rising to 71%. Finally, 21% of early college students had earned a college degree or certificate by the end of high school, rising to 24% two years later. Only 1% (2% after two years) of the comparison group had achieved any type of degree or certificate (Berger, Turk-Bicakci, Garet, Knudson, & Hoshen, 2014. pp. 8-20).

More than a few studies agree with these findings. High school students who simultaneously take college classes tend to have better grades, graduate at higher rates, continue on the college, and finish college at higher rates. (Castellano, Sundell, Overman, & Aliaga, 2012, p. 98; Alfield & Ghattacharya, 2012, p. 119; Webb & Gerwin, 2014). One thing not previously mentioned, however, is that some studies found that when the students go on to college, they do not always major in the same field that they studied in high school.

Specialized high schools in Syracuse. By 2010, three of the five Syracuse CSD high schools were on the New York State Persistently Lowest-Achieving School list (PLA) ---with a lower than 60% graduation rate. Fowler HS (38.1%), Corcoran HS (58.3%), and Nottingham HS (48.3%) were ordered to restructure. The Syracuse CSD chose the transformational restructuring model for all three schools (NYSED, 2012, pp. 91-92; NYSED, Department of Accountability, 2011a/2011b; Syracuse City School District, 2012b). The NYSED, Department of Accountability gave additional comments during their review regarding the lack of availability of professional/career opportunities. They noted that although one school had a successful *Health and Career* program, "there is a limited array of programs that are appropriate for students across a range of abilities and interests, including students who do not plan or desire to go to college." What seems to be a central theme of the report is that prior to the restructuring of the Syracuse CSD, "…students [did] not feel that the high school program [was] relevant to their post-secondary education plans" (NYSED, Department of Accountability, 2011b, p.10).

In the summer of 2012, Syracuse CSD formed a Blue Ribbon Task Force on CTE to develop a five-year plan to transform the district into one of high school choice with multiple program pathways. The mission, according to the report,

> Build, support, and sustain a CTE program in collaboration with business, labor, and postsecondary partners to provide relevant and rigorous courses of study based on contemporary industry and academic standards that prepare students for success in education, careers, and citizenship in a global society. (Syracuse City School District [SCSD], 2012a, p. 10)

Syracuse CSD's new primary goal is to graduate students who, along with earning their Regents/Advanced Regents Diploma, can also receive a technical endorsement with it, and gain an industry-approved certification. The specific standards set by the district are:

1. All CTE programs will have a rigorous curriculum crosswalk to the Common Core School Standards (CCSS), Regents assessments and the Common Career Technical Core (CCTC) standards.

2. All students completing an approved CTE program of instruction will have access to a technical assessment leading to an industry-approved credential.
3. Upon meeting all Regents graduation requirements, students will be able to earn a Regents Diploma/Regents Diploma with Advance Designation with a Technical Endorsement
4. Students in every career cluster will leave school with an employability profile/portfolio.
5. All CTE and academic-related faculty will have the skills to deliver, reinforce, and assess the CCSS, technical, and employability standards within daily instruction.

By using the Common Career Technical Core (CCTC) standards, the district would develop multiple pathways consistent with the National Career Clusters Framework. The Blue Ribbon Task Force (BRTF) prioritized the career clusters by evaluating the highest need and fastest growing jobs in central New York. Much like the P-TECH model, they collaborated with the industry leaders, business owners and community colleges in this endeavor (SCSD, 2012a, p. 11).

The implementation of the SCSD High School Choice Program centers on a modified career academy model. Within each high school, there are now career-themed academies. Students, with their families involved, choose a high school based upon an informed choice of academics or career academies. No school or program has selective admissions criteria, although when a program is at capacity a lottery system is implemented. The lowest performing high school, Fowler, was to be phased out with a new one in its place –The Public Service Leadership Academy (PSLA). This began in 2014 with the incoming 9th graders with a unique four-academy approach: Entrepreneurial Academy, Homeland Security Academy, First Responder Academy, and Military Security Academy. See *Appendix A* for the full list of the PSLA academies and programs. Like the P-TECH model, each CTE pathway has both business partners and higher education partners involved in curriculum development, mentorship and internships. (SCSD, 2014b). One difference difference between NYC's P-TECH and the PSLA, is that the Department of Homeland Security and NSA has endorsed PSLA's higher education partners as "Academic Centers of Excellence" for the cybersecurity and computer forensics pathways (SCSD, 2014c). The innovation of the new PSLA model required many of the career pathways to be created from scratch and sent through the NYSED CTE approval process. Cybersecurity and Computer Forensics were two of the eleven programs seeking certification (SCSD, 2016a).

The SCSD choices are not limited to CTE programs that culminate in a technical/industry certification. Some of the other pathways allow for dual-credit college programs (SCSD, 2014a, pp. 13-15; R. Leslie, personal communication, November 4, 2016; SCSD, 2016a/b):

- The Cybersecurity and Natural Resources career pathways offer college credit upon successful completion of the programs.
- Four P-TECH programs are offered at two Syracuse locations
- Project Lead the Way (PLTW)
- International Baccalaureate Program
- AP courses

Syracuse Central School District –the research. PSLA first opened their doors for the 2014-2015 school year. At this time they are in their third school year, with little data to analyze their performance. Research shows that effectual school transformations are difficult to achieve. Education strategist, Andy Smarick (2010) explains, "Once persistently low performing, the majority of schools will remain low performing despite being acted upon in innumerable ways" (para 4). This does not mean transformations are never successful, but, “Fix-it efforts at the worst schools have consistently failed to generate significant improvement… [a]nd exceptional urban schools are nearly always start-ups or consistently excellent schools, not drastically improved once-failing schools” (Smarick, 2010, para. 2). Lamentably, this may foretell difficulty for the two high schools that the district transformed rather than replaced. It may be different for PSLA because it is a new school replacing Fowler High School with new curriculum and staff. On the positive side, CTE students generally do well in their academic studies.

According to the U.S. Department of Education, Office of CTE (2016), in 2013, CTE participants in New York graduated at a rate of 85.5%. Comparatively, the overall NY graduation rate was 76.4% and the U.S. rate was 81.4% (NCES, 2015b). Participation in CTE seems to have a positive correlation to reading/language arts and mathematics proficiency with both at 95%. Finally, although 73.7% of the students were considered to have attained their technical skills, only 47% received a credential, certificate or degree when continuing to postsecondary school (U.S. Department of Education, Office of CTE, 2016).

These statistics include all CTE students, regardless of the academic rigor or integration of the CTE coursework. To ensure that the PSLA does have academic rigor, Syracuse CSD aligned each of their pathway courses to both the CCTC and CCLS standards. Increasing graduation rates and core class proficiency will not increase the STEM pipeline, however. Much of the research supporting the potential effectiveness of P-TECH schools also applies to schools that have an integrated CTE curriculum. The Almarode et al. study shows the potential of an integrated CTE high school to influence students to go on to college and major in STEM fields.

Another study, recently published, sought to establish if there was a link between students who took applied STEM classes (i.e. CTE) and whether they were likely to choose

STEM college majors later. Gottfried & Bozick (2016) looked at nationally representative student samples from 752 public and private high schools. They interviewed or surveyed the students at three points in their schooling: At the end of 10th grade, at the end of 12th grade, and then two years after high school. The authors utilized the students' transcripts to evaluate which STEM or applied STEM courses they had taken in high school, and what majors they went into in 2- and 4-yr. colleges (p. 181).

The study showed that students going on to a 2-yr. college, taking courses in applied science only slightly affected their choice to major in STEM. But, for students who continued on to a 4-yr. college program, studying high school applied science showed a "consistent, significant, positive relationship between applied STEM course-taking and declaring a STEM major across all three applied STEM coursework strands" (p. 192). Most importantly, for educators trying to encourage more students to pursue computer science and cybersecurity, this study shows that when students take an IT course in high school, they have 2-to-1 odds of declaring a STEM major in college, compared with others who have not taken any IT coursework. An even greater relationship (2.7-to-1) existed between students who took both an applied IT course and an applied science or engineering course in high school, compared to their counterparts (p. 194).

Boards of Cooperative Educational Services (BOCES). BOCES has existed in New York State since 1948 as a means to consolidate resources so that schools would have access to a wider range of services. For instance, districts might not be able to offer the broad range of CTE programs offered to their students that a BOCES offers to the schools within their membership. Some BOCES programs now have P-TECH, as well. There are 37 BOCES in NYS, which, by law, do not include the five largest school districts (New York City, Buffalo, Rochester, Yonkers, and Syracuse) (BOCES, 2014; BOCES, 2015).

According to the state BOCES website, BOCES students have a 94% graduation rate (BOCES, 2015), however it should be noted that high schoolers do not normally enter into a CTE program until their junior or senior year. Any potential CTE student that dropped out earlier would not be included in these numbers. Using the available report cards from the NYSED website (12 of 37 were not available), in 2013, the ELA Regents passing rate was 90% and the Math Regents was almost 89%. This is lower than the earlier reported statistics of all CTE students in NYS. Of these reporters, 70% received their technical designation on their diplomas. No data was available about how many students received a CTE credential or certificate (NYSED, 2015).

Cybersecurity (CTE classification as Computer and Information Systems Security) is a NYS approved CTE program, although only two BOCES sites offer it. A handful of other sites offer courses that feasibly could offer some cybersecurity principles within the curriculum. Examples are "Information Technology, " "Computer Systems Networking," and "Management Information Systems". The sites that offer cybersecurity are the Erie 1 BOCES, located in West Seneca and the Oneida-Herkimer-Madison BOCES, located in New Hartford, NY. After finishing the programs, students at both sites have the opportunity to sit for three industry-credential tests: CompTIA A+, Network+, and Security+. They both have articulation agreements with local colleges (NYSED, 2016b; Oneida-Herkimer-Madison BOCES, 2016, p. 14; Erie 1 BOCES, 2016, p. 29). This BOCES is also the only BOCES in NYS to pledge support for the CSforAll initiative.

Cyber competitions, overview, and research. One of the channels that government, academia, and industry has actively pursued in addressing the cybersecurity employment shortage is by sponsoring cyber competitions. Although empirical research is scant on assessing the effectiveness of competitions to fix the cybersecurity pipeline, several studies link participation in cyber competitions with an increased interest in a cybersecurity career. Tobey, Pusey, and Burley (2014) conducted a qualitative review of the literature, and with their own survey data, found that "competitions attracted an engaged population who have the potential to remain in the profession for the long-term" (p. 56). The caveat to this finding, however, was if competitors did not feel comfortable in their skills, they did not continue with further competitions, and often did not have positive feelings toward the idea of becoming a professional in cybersecurity. The authors concluded, therefore, "Rather than increasing engagement in cybersecurity careers for larger numbers of students, competitions may only assist in enhancing the interest of those select few who have already developed reasonably high levels of skill" (Tobey, Pusey, & Burley, 2014, p. 53).

Another group of researchers, Bashir, Lambert, Guo, Mermon, and Halevi (2015), surveyed competitors at the world's largest student-run cyber competition for high school and undergraduate students. Cybersecurity Awareness Week (CSAW) includes an annual competition sponsored by New York University (NYU) Polytechnic School of Engineering. The post-competition survey explored the participants' perceived cybersecurity career interests. They found that an overwhelming majority of competition attendees said they were more likely to pursue a career in cybersecurity post-competition compared to before. Also, the authors found that high school students competing were less sure than the older students that they were going to continue onto a cybersecurity career. The older the participant, the surer they became. They concluded that "…to attract those not yet committed to pursuing cybersecurity careers, competitions should target high schoolers and also communicate to undecided undergraduate and graduate students that cybersecurity isn't just about competitions but also a viable career option" (p. 77).

Several government and non-profit organizations, like the *National Initiative for Cyber Education* (NICE), advocate for treating "Cyber as a sport," where focus in the earlier years is learning the fundamentals rather than the competition aspect. Likening these competitions to other team sports, they explained that league sports like baseball, soccer and football have a leveled competition structure. As athletes progress in skill, they move to more advanced leagues (Katzcy Consulting, 2016, p. 12).

CyberPatriot, overview, and research. To this end, another organization, the Air Force Association (AFA) founded an integrated youth education and competition "league" called CyberPatriot in 2009. It is also known as the National Youth Cyber Education Program. According to the official website, "CyberPatriot was conceived by the Air Force Association (AFA) to inspire students toward careers in cybersecurity or other science, technology, engineering, and mathematics (STEM) disciplines critical to our nation's future" (CyberPatriot, 2016d). CyberPatriot has three main programs: The National Youth Cyber Defense Competition, AFA CyberCamps, and the Elementary School Cyber Education Initiative. A growing number of corporations and government agencies sponsor CyberPatriot, including Northrop Grumman Foundation as the presenting sponsor. The other sponsors at the "Diamond" ($100K+) level are AT&T, Cisco, Microsoft, the U.S. Department of Homeland Security, and the Office of the Secretary of Defense. There are many others in the lower tiers of sponsorship ($25K+ and 50K+) (CyberPatriot, 2016c).

Each year, high schools, middle schools, JROTC units, Civil Air Patrol (CAP) units, and youth organizations across the United States, U.S. Territories, and Department of Defense schools overseas form teams to compete in the National Youth Cyber Defense Competition. As of this writing, CyberPatriot is in its 9th season of competition. It has grown at a tremendous rate each year with 185 teams registered for the year two competition (year one was a closed pilot competition) to 4,404 teams registered for 2016's CyberPatriot IX competition (CyberPatriot, 2016b; Air Force Association [AFA], 2016).

In preparation for this, teams work together with mentors to learn and practice principles of cybersecurity with provided CyberPatriot training materials. The teams learn, practice, and compete online at their home facilities; however, should they progress to the final round, they receive an all-expenses-paid trip to the National Finals competition in Baltimore, MD. There, they have the opportunity to compete for national recognition and scholarships (CyberPatriot, 2016d).

In 2013, CyberPatriot added a Middle School division for competition. Structured the same as the high school division, and given the same training materials, middle school teams would be trained and evaluated with others at their same developmental stage. For the 2015-16 season, there were 598 Middle School teams registered (AFA, 2013; CyberPatriot, 2016b).

In 2014, the AFA added CyberCamps to the CyberPatriot program. These "emphasize fun, hands-on learning of cybersecurity principles that are relevant and applicable to everyday life. At CyberCamp, students learn the importance of cyber safety and how to protect their personal devices and information from outside threats" (CyberPatriot, 2016d). The camps target students from 7th-12th grades with little or no cybersecurity experience. The number of camps in the U.S. grew from 24 in 2015, to 85 in the summer of 2016. None of the 2016 camps were located in New York State (AFA, 2016a; CyberPatriot, 2016d).

In 2015, CyberPatriot introduced the Elementary School Cyber Education Initiative. This primary school was "designed for K-6 students to educate them on the importance of online safety and to equip them with skills to protect themselves on the Internet" (AFA, 2015). The program was grant-funded so is offered free-of-charge to any school or organization who requests the kit. The elementary program was designed to:

- "Engage students in learning about careers in cybersecurity and other STEM disciplines"
- "Help students understand the importance of cybersecurity"
- "Introduce students to cybersecurity principles"
- "Equip students to better protect themselves on the Internet" (CyberPatriot, 2016d).

There is little published research validating how effective the CyberPatriot programs are in accomplishing its mission to inspire students toward cybersecurity or STEM careers. However, the AFA released the findings of two internal surveys showing positive results. One survey polled participants prior to and after the 2013-14 season about their knowledge and perceptions of cybersecurity. Post-season, 70% believed they had "a lot of knowledge" or "an advanced understanding" of basic cybersecurity principles. The pre-season poll set this at 14 percent. Before the season, 85% of students said they had very little or no knowledge of cybersecurity careers. Post-season, a full 94% believed they had "some," "a lot," or "strong" understanding of career options. At the end of the season, 60% (up from 41% pre-season) of students felt "very likely" to pursue a STEM degree or career (AFA, 2014).

In 2016, the AFA released the findings of a second survey to ascertain the college and career goals of CyberPatriot participants. Ninety-six percent of respondents indicated they were planning on attending a 2- or 4-year higher education program after high school. Seventy-eight percent of respondents intended to major in cybersecurity, computer science, or another STEM field at a 2- or 4-year college. Finally, 92% of respondents "…indicated that their participation in CyberPatriot somewhat (50%) or significantly (42%) impacted their career and educational goals (AFA, 2016).

CyberPatriot in New York. New Yorkers registered 96 CyberPatriot teams for the 2016-17 school year, at 57 sites (generally located in schools). Five of these were middle school teams. To evaluate New York's relative utilization of the CyberPatriot program as a means to educate and encourage students, a state with commensurate population needs to be weighed against it. *Table 1* shows a comparison of Florida, the state with the closest population to New York. It can be seen that even though Florida has 9,000 fewer public high school students than New York, Florida had 239 registered CyberPatriot teams. Compared to New York, Florida had 2.5 times as many teams, twice as many hosting sites, and twice as many middle school teams. Lastly, Florida teams have advanced to the national finals on multiple occasions. New York has yet to advance a team to the national final rounds (U.S. Census Bureau, 2015; NYSED, 2014a; Florida Department of Education, 2014; CyberPatriot, 2016b).

Table 1

Comparison of Registered CyberPatriot Teams in New York and Florida

State	2015 State Pop.[a]	2014 Public High School Student Pop.	2016-17 Total CP Teams[d]	2016-17 Total CP Sites hosting Teams[d]	2016-17 Total hosting Middle School Teams[d]
New York	19,795,791	~816K[b]	96	57	5
Florida	20,271,272	~807K[c]	239	107	10

Note. [a]U.S. Census (2016). [b]NYSED (2014a). [c]Florida Department of Education (2014). [d]CyberPatriot (2016b). CP = CyberPatriots.

Discussion of the Findings

The United States is under unwavering attack by criminals behind computers that might be located next-door, or might be located across an ocean in a developing country. Every person, regardless of generation or socio-economic status, is vulnerable to hackers. Because our society is so inter-connected digitally, the reach of cyber attacks even affects people who never use a computer or mobile device. The losses that are reported to the FBI reaches into the billions of dollars, but the unreported losses are even more staggering (FBI, 2016).

At a time when cyberattacks are among the biggest threats that businesses face today, hundreds of thousands of cybersecurity jobs continue to go unfilled (ISACA, 2015; Burning Glass Technologies, 2015). This shortage of skilled professionals is directly responsible for much of the risk that companies, government agencies, and organizations face today (Worley, 2016). This talent shortage is a culmination of adverse factors throughout the cybersecurity education pipeline. The literature shows that students' interest and ability in STEM begin to decline before they even leave elementary school. Unfortunately, this is not where it ends, as there are "leaks" throughout middle school and high school, as well. Many of the factors drawing students away from careers in cybersecurity are well-studied, but are difficult to change due to lack of resources. Because of the limitation of resources, it is vital to carefully evaluate the most effective strategies to try to plug some of the bigger "leaks" in the pipeline.

The purpose of this research was to examine New York State's K-12 efforts to encourage and prepare students to successfully enter post-secondary cybersecurity programs. What factors contribute to the nationwide lack of college cybersecurity graduates? What has New York's K-12 education system implemented to address these factors?

The biggest reason that students do not continue in STEM fields is that they lack the skill to do so. Math and science benchmark scores at every level are woefully low. *Table 2* shows the percent of students at or above proficiency in math and science at target benchmark grades. Policymakers and educators must address this educational gap so that more students can be prepared to go on to college majors in STEM. Beyond raising test scores, it is crucial that other measures be considered to stem the exodus from the cybersecurity pipeline.

Table 2

Proficiency in Science and Math for 4th, 8th, and 12th Grade Students in the United States

Grade	Math	Science
4th	40%[a]	34%[b]
8th	33%[a]	32%[c]
12th	42%[d]	38%[d]

Note. [a]NCES (2015a). [b]NCES (2009). [c]NCES (2012). [d]ACT Inc. (2015b).

Inarguably, the foundation of any academic pipeline is in teaching students at the earliest grades not only the basics of their subjects (*what* to think), but also, more importantly, *how* to think. Educators use the term *critical thinking* to describe the pedagogy of teaching students how to think using logic and reason. Another adaptation of critical thinking is the concept of *computational thinking*, which was coined by Jeanette Wing from Microsoft Research. She defines computational thinking as, "…taking an approach to solving problems, designing systems and understanding human behaviour that draws on concepts fundamental to computing" (Wing, 2008).

It is important to note that the term *computational thinking* seems to suggest that it is a skill that would only be useful in the progression of a computer science/cybersecurity academic career. This is far from true, however. This type of problem solving can be applied to most academic subjects, and in fact, would give an extra advantage to students in math and science classes (Barr & Stephenson, 2011; Wing, 2008). As one of the biggest leaks in the cybersecurity pipeline is low math and science scores, this one measure might be a small piece towards a solution.

Computational thinking is a type of problem solving that must be learned in a sequential way and is not conducive to being introduced as a whole until high school or even later. If a computer science course is offered at all, the earliest is generally at the high school level. Wing (2008), argues that computational thinking is a way of learning that is best taught in the early years of childhood in order for all students to have a "common and solid basis of understanding." Experts liken this progression of problem-solving skills to the skill-building within the mathematics field. Students must master basic arithmetic before they learn algebraic concepts. Once mastery has been attained, they can then move to learning abstract mathematical concepts.

Considering computational thinking, Barr and Stephenson (2011) stress, “It is no longer sufficient to wait until students are in college to introduce these concepts...They must begin to work with algorithmic problem solving and computational methods and tools in K-12.”

Similarly, students who are not introduced to legitimate information about computer science and cybersecurity careers early on will form their impressions of the field from inaccurate sources. Good, Estrella, & Margolis (2006) point to the media –from Hollywood to magazines, as the main perpetrators of these erroneous images. The well-researched effect is that students have negative perceptions about what computer scientists do because they believe it is “boring, tedious, asocial, and irrelevant” (Yardi & Bruckman, 2007).

One troubling stereotype students have are that computer scientists are almost universally white and male, and although females and non-Asian minorities are, in fact, underrepresented, they are not wholly absent in the field. This view can dissuade girls and minorities from considering computer science or cybersecurity as a place they would fit into. The misunderstanding of the career field continues even to college students enrolled in computer science courses. When college students were asked to draw a picture of what they thought a computer scientist looked like, the drawings were generally of a man with “varying degrees of ‘geekiness’” (Martin, 2006). *Figure 2* shows an example of how students depicted a computer scientist. The most important takeaway, is that students don’t see themselves as future computer scientists because the profession is not exposing “the diversity and complexity” of the field before the students narrow their career choices (Martin, 2006).

Carter’s (2006) work agreed that high school students with high mathematics aptitude still chose not to go into computer science because of this absence of information. Only a small number of students knew what a computer science major learned (20%) or what a computer scientist did in the field (2%). Few representatives from computer industry fields come into the schools to engage and encourage students to look closer at computer career fields. Without mentorship from industry, students are left with the Hollywood images of the anti-social male geek (Goode, Estrella, & Margolis, 2006). However, media and industry are not the only source of misinformation.

Academia and government, while having the favorable intention of creating technology-fluent students, has also done a disservice to them. They have funded and legislated to embed technology into every classroom to the point of ubiquity, but have failed to teach students the "deeper computer science concepts and capabilities" (ACM, 2010). Students who take "technology" classes are consigned to learning rudimentary computing skills like keyboarding, Internet searches, and the use of applications like word processing, or using spreadsheets. These tasks are tedious and rarely engaging to most students, which again, fuels the negative stereotypes discussed earlier (Margolis, Goode, & Bernier, 2011; Sabin, Higgs, Riabov, & Moreira, 2005).

Within the current K-12 paradigm, computer science and cybersecurity courses are relegated to the academic "electives" category. Even when taught, it is undoubtedly in the later years of high school. This is deeply counterintuitive to the recent and widely publicized initiative of "Computer Science for All" that President Obama announced with his Fiscal Year 2017 Budget (The White House, Office of the Press Secretary, 2016). As the budget has yet to be passed, it is uncertain if the federal money tagged for computer science education will be funded.

Many in the field of cybersecurity, along with many in higher education and government are in agreement that computer science should be integrated into the K-12 academic curriculum, but making this change is a challenge not yet overcome. States have given lip service to promulgating cyber into their school systems. However, their actions have shown otherwise. Several organizations have put forward their own computer science state standards, but currently, the majority of states have only adopted the 2009 Common Core State Standards (CCSS) for mathematics and English language arts (ELA).

Forty-six states, including New York, have adopted (wholly or in-part) the CCSS (Academic Benchmarks, 2015a). As the CCSS are explicitly math and ELA standards, it is not expected that computer science would be included within them. That said, there is the opportunity to incorporate some computer science concepts because CCSS uses an "interdisciplinary" approach. Interdisciplinary means that states may choose non-literary material from other subjects, which theoretically includes science and technology texts, as reading material in ELA classes. It also means that science classes are to require more in-depth analysis of the meaning of course readings.

The CCSS does not specify curriculum, so these text choices are up to the states. New York State has provided free online curriculum modules aligned to CCSS to any school district, including schools outside of New York. Curriculum development is costly; so many districts have taken advantage of the free modules. Even though CCSS does not mandate specific literature to be read in 3-12 ELA classes, the curriculum modules explicitly require specific literature. As of now, there are a few science texts included in the list, but these are all in the biological sciences. No technology, computer science or cybersecurity texts are included in the reading list (NYSED, 2014b). This has led the Computer Science Teachers Association (CSTA) to publish a "mapping" of their own well-reviewed computer science standards in an attempt to help states to incorporate computer science into their K-12 curriculum (ACM, 2013). It is unknown how many states have or are willing to do this, however and New York State definitely has not.

Another state-led initiative to set science standards culminated in the *Next Generation Science Standards* (NGSS). New York was one of 26 states that collaborated along with the National Research Council, the National Science Teachers Association, and the American Association for the Advancement of Science, Achieve, Inc. to create them. The purpose was similar to the CCSS, but for the science disciplines, to include some "computational thinking", but not explicit computer science concepts. New York helped to create these standards, and although they did not adopt them as a whole, have now published the *New York State P-12 Science Learning Standards* that are closely aligned to them (NGSS Lead States, 2013; NYSED, 2016c). New York's version also does not explicitly include computer science.

Of the two groups that have created specific standards for computer science, the Computer Science Teachers Association's (CSTA) *ACM Model Curriculum for K-12 Computer Science Standards* (CSTA & ACM, 2003), have become the "…de facto national standards for computer science in K-12" (Barr & Stephenson, 2011). Many organizations have endorsed these rigorous standards and call educators and policymakers to adopt them at a state level, as well as take additional measures to bring computer science fundamentals to students everywhere. Unfortunately most states, including New York have failed to respond to this call to adopt these computer science standards. Barr and Stephenson's research showed that with only 14 states adopting more than 50% of the standards, policymakers fail to understand the critical need for them.

Most recently the *K–12 Computer Science Framework Steering Committee* (a collaboration of ACM, Code.org, CSTA, Cyber Innovation Center, National Math and Science

Initiative, and district and state partnerships) released the *Computer Science Framework* (2016). Dozens of organizations, school districts, states, industry leaders, and technology companies have called for all states to pledge support to the *Computer Science for All* initiative (CSforAll).

NYC, with the impetus of the mayor's office, was the lead for the CSforAll initiative, first in NYC and then nationally. The NYC school district has already taken on the mandate that by 2025, each of NYC's 1.1 million students will be taught computer science concepts at the level they are at (Taylor & Miller, 2015). The amount of money that Mayor De Blasio expects the NYC Education Department to raise/spend for the initiative is $81 million, which will include the training of an estimated 5,000 teachers.

Outside of NYC, there is a stark difference in priorities. A paltry number of schools of the 3877 schools in New York have signed the pledge to support the CSforAll initiative. This is not to say that districts are not making efforts to expand computer science or cybersecurity coursework to their students, but it does mean that they have not committed to a state- or national-coordinated effort.

In response to the CSforAll impetus, and even before, NYC has taken a proactive approach to giving its secondary students (and some primary) access to computer science. STEM high schools have been a part of the NYC school system for decades, expanding courses as technology has changed. The literature shows that there is evidence that dedicated STEM high schools are beneficial incubators for high-achieving students to hone their interests and academics towards specific career fields. However, NYC imposes extremely stringent admission criteria to these schools due to limited resources. The research also shows that school quality is less of a factor than the quality of the students for high graduation and college-bound rates. These students were already on track to graduate and attend college before entering high school

(Wiswall, Steiefel, Schwartz, & Boccardo, 2014; Almarode et al., 2014; Gnagey & Lavertu, 2016).

The recent 2011 creation of P-TECH in NYC marked a paradigm shift for the expected outcomes of high schools. The replicable P-TECH model exemplifies what the labor department identifies as a "career pathway." The high school has a strict focus of graduating all of its students within six years with both a high school diploma and an applied associates degree (Davis, 2012). The programs, which are offered free-of-charge, are laid out in collaboration with a business partner and a higher education partner. The business partner, IBM in the case of the Brooklyn P-TECH, provides curriculum and standards guidance, mentors, paid internships, and a guaranteed job interview upon graduation. P-TECH had two higher education sponsors, the City University of New York (CUNY) and the NYC College of Technology, both of which provides curriculum guidance and the instructors to teach the college classes on the high school campus (P-TECH, 2015; P-TECH, 2016a/b).

The success of the school remains to be seen as the first full 6-year cohort is not scheduled to graduate until June 2017. However, 38 students graduated one or two years early with their AAS degrees. This means that even without the preliminary results, the research strongly suggests that dual high school/college course-takers show high graduation rates and higher-than-average follow-on college attendance (Lekes, et al., 2007; Berger, Turk-Bicakci, Garet, Knudson, & Hoshen, 2014; Castellano, Sundell, Overman, & Aliaga, 2012; Alfield & Ghattacharya, 2012; Webb & Gerwin, 2014). Given the positive outcomes of other early college programs, New York among others has moved quickly to expand P-TECH into their other schools (IBM, 2016).

The six-year P-TECH model, in theory, is an effective pathway for students that are both college-bound and career-bound. An associate's degree would be immediately transferrable to the higher-ed partner colleges and perhaps to other colleges as well. Students that do not plan on going further in college would have an associate's degree that should suffice to give them job opportunities in the field they have studied. Because local industry has partnered with the school, in-demand jobs should feasibly be available upon graduation.

Currently, New York State is providing grants to school districts to expand P-TECH (Office of the Governor, Pressroom, 2013). However, should the grants be discontinued, districts may not have the resources to extend their educational system to 14 years. In contrast, New York City is the largest school district in the U.S., has a large tax base, has numerous industries, and is under mayoral control. These variables significantly affect whether upstate districts might see the same results that NYC has. Also, it must be noted that each P-TECH program has a limited number of slots available and most only have one or two fields of interest available. With only one of the 33 P-TECH schools currently offering cybersecurity (13 offer some type of computer-related field), P-TECH is not yet a viable pathway to cybersecurity in college or career (NYSED, 2016c). As a general pathway to career and college, P-TECH is a viable option, however it is not a solution for all students. Other career pathways should be considered as well.

The Syracuse CSD, for instance, has taken a novel approach to educating its students toward "college and career readiness." The district was forced to restructure after a decade of its schools failing the increasingly poor and minority students in the city (SCSD, 2012a). In the two high schools restructured according to the "transformation model," the district continues to offer college-oriented programs like P-TECH, Project Lead the Way (PLTW), the International Baccalaureate Program, and AP classes. But, in the lowest performing high school (Fowler High

School), the Public Service Leadership Academy (PSLA) began replacing/phasing in starting with 9th graders for the 2014-15 school year. The district collaborated with numerous businesses, higher education partners, and public sector partners to develop career academy that would give students a "structurally integrated" rigorous high school education, CTE training, 12 + college credits and culminating with an high-demand industry certification (SCSD, 2014b). The four academies, Entrepreneurial, Homeland Security, First Responder, and Military Security each contain from one to four career pathways within it. Some of the career paths include transferable college credits.

There are stark differences between the PSLA and the Academic+CTE high schools in NYC. Similar to the NYC P-TECH, Syracuse built their programs from scratch with outside collaboration. But, P-TECH only offers a few college major choices with no certification and the NYC Academic+CTE high schools focus mostly on industry certifications. PSLA and the other CTE programs in the Syracuse CSD identified multiple critical sectors in the community needing skilled employees (SCSD, 2014b). Syracuse CTE schools have combined both of these models by expecting students to graduate in four years with a Regents Diploma with technical designation, a minimum of 12 college credits (for all PSLA pathways), and an industry certification. The careers are all cutting edge and wide-ranging (SCSD, 2014b). There is less of a risk that a pathway will oversaturate an industry with too many skilled employees in one or two fields. The other distinct difference between NYC's programs and the PSLA, is that the Department of Homeland Security and NSA has endorsed PSLA's higher education partners as "Academic Centers of Excellence" for the cybersecurity and computer forensics pathways (SCSD, 2014c).

Like P-TECH, PSLA is in its earliest years and thus no data is available to warrant critique of its effectiveness towards college and career readiness. But, like P-TECH, the research generally shows favorable outcomes for CTE students. Researchers must conduct longitudinal cohort studies to evaluate whether the PSLA and P-TECH are meeting their goals.

New York State has much data on the effectiveness of their legacy BOCES CTE programs. BOCES published results show a high graduation rate (94%) and extremely high Regents Math (89%) and ELA (90%) scores (BOCES, 2015; NYSED, 2015). However, caution must be taken when finding causation in the data. Students taking BOCES classes do not begin until at least their junior year; therefore potential CTE students that have dropped out in their first two years of high school are unaccounted for.

The fact that BOCES students do not start until their 3rd year of high school also means that they spend the last two years bussed to another location for half of every day. This lack of academic/CTE integration precludes a BOCES student from partaking in much of the curriculum available to the traditional students, often including the arts, electives, and higher-level coursework. Even so, BOCES is a legitimate pathway for students to gain needed training in a career field they can enter immediately upon graduation.

Unfortunately, only two BOCES in the state of New York currently offer the Cybersecurity CTE program. Some other BOCES that are offering IT coursework that may include some cybersecurity principles, but that is speculative. The two BOCES that do offer cybersecurity give its students the opportunity for three industry credentials: CompTIA A+, Network+, and Security+ (NYSED, 2016b; Oneida-Herkimer-Madison BOCES, 2016; Erie 1 BOCES, 2016). These certifications are industry gold standard for entry-level cybersecurity jobs.

Finally, STEM high schools, P-TECH, Academic+CTE high schools (like PSLA), and BOCES all present viable pathways towards computer-related careers like cybersecurity. Certainly, the cybersecurity job shortage cannot be fixed without programs that give students the necessary training. All of these pathways give students a head start toward their journey to a cybersecurity career.

Notwithstanding, though, simple access to coursework in high schools will fail to fix the cybersecurity employment gap. Currently, primary school students are taught that technology fluency equals computer science. Additionally, students get their misperception of cyber careers from the media and therefore believe that a computer scientist must be a white male misfit (Good, Estrella, & Margolis, 2006). Together these lead to students early on believing that cyber is “boring, tedious, asocial, and irrelevant” (Yardi & Bruckman, 2007). Barr and Stephenson (2011) pose that the early introduction to computational thinking and computer science is vital to create students able to accomplish higher-level computer science principles later. This would certainly lay the groundwork for students of all races and genders to have unbiased exposure to the subject. The *CSTA K-12 Computer Science Standards* (CSTA & ACM, 2016) are devised to do this, and additionally integrate cross-curricular concepts like ethics, collaboration, and inclusivity into the curriculum. They neatly lay out five concepts that integrate age-appropriate practices of computer science. The concepts are: 1. Computing Systems 2. Networks & the Internet 3. Algorithms & Programming, 4. Data & Analysis 5. Impacts of Computing.

If schools utilized these standards, students would gain familiarity with foundational computer science concepts. Familiarity might not necessarily translate to interest and excitement towards the career field, however. The literature suggests that one highly-effective way of increasing interest in cybersecurity is through cyber competitions (Tobey, Pusey, & Burley, 2014; Bashir, Lambert, Guo, Mermon, & Halevi , 2015). The literature is also clear that this positive effect applies only to competitors who felt confident in their hacking skills prior to the competition.

One organization, AFA taking note of the need for youth to gain hacking skills prior to competing, founded the National Youth Cyber Education Program in 2009. The more common name is known as CyberPatriot and is one of the few groups designed to educate and inspire younger students towards cybersecurity and STEM disciplines. Most cybersecurity competitions target college students or older high school students who already have gained the knowledge to compete on their own. CyberPatriot does this through its three programs: The National Youth Cyber Defense Competition, AFA CyberCamps, and the more recent Elementary School Cyber Education Initiative.

CyberPatriot competition treats what the NICE calls “Cyber as a sport” (Katzcy Consulting, 2016). Teams from middle schools, high schools, JROTC, and Civil Air Patrol units work with mentors to learn and practice cybersecurity principles in preparation for competition. For the actual competition, they teams compete the first rounds online and then travel to the National Finals should they progress to the final rounds (CyberPatriot, 2016d).

2013-14 post-season survey results showed that the majority of participants in CyberPatriot felt that they had learned a significant amount of cybersecurity principles. Prior to the season, only 14% of participants believed they had “a lot of knowledge” or “an advanced understanding” of cybersecurity. Post-season, this jumped to 70%. The same survey showed that 94% of the participants had at least some understanding of cyber careers, and that the numbers that were planning on pursuing a STEM degree or career grew from 41% to 60% post-season

(AFA, 2014). A subsequent survey also showed that CyberPatriot had positively impacted participants' educational goals towards STEM or Cybersecurity (AFA, 2016).

These findings align with the Tobey, Pusey, & Burley (2014) and Bashir, Lambert, Guo, Mermon, & Halevi (2015) results. The research seems to conclude that students who are given the opportunity to learn cybersecurity skills (i.e. hack) and then are given the opportunity to utilize those skills in a team competition environment are more likely to go into STEM and cybersecurity career fields. CyberPatriot teaches member the skills necessary to successfully compete, which in turn builds their confidence and positive feelings towards the cybersecurity career field. One piece of the puzzle is missing, however. The mentorship aspect of CyberPatriot is also likely to influence members in a positive way. Real-world people who have the skills and compassion to mentor youth replace the media-influenced stereotypes of the computer scientist.

Mentorship is especially important in today's school systems where school counselors are overburdened with tasks unrelated to career counseling. New York State has an average of a 624-to-1 counselor to student ratio, which means counselors must strictly prioritize their time (ASCA, 2014). School administrators generally expect counselors to conduct student scheduling, testing and disciplinary actions first, so career counseling often goes by the wayside (NACAC, 2005). While not a fix to the underfunding of school counseling resources, outside mentors from technology fields would help give a face to a misunderstood career field. Some career exploration may be included in freshman seminar (freshman transition) classes, but there are no set standards or guidance from higher education administration in most states, including in New York. This would be an appropriate venue for mentors to engage with students.

Recommendations and Conclusion

New York State has a critical shortage of cybersecurity professionals. The shortage will not fix itself. Not enough high school graduates in New York are going on to major in cybersecurity or computer science, therefore, not enough new professionals are being created. New York has to start cultivating a culture of computer science and cybersecurity for all in every New York public school. The CSforAll efforts in NYC, the addition of CS as a math credit towards graduation, and the development cybersecurity pathways all show that New York is making some effort toward a remedy. However, is New York doing all it can to encourage, inspire, and provide the tools to its youth to fill this gap? The definitive answer is "no."

While state policy makers have given some aid in the form of grants to expand P-TECH, which is laudable, the number of students who will leave the program to go into cybersecurity is negligible. Allowing students to use a computer science class for a graduation credit is an important step, but it is moot if the schools do not offer computer sciences classes. There are a number of solutions that can each help one part of the pipeline break, but to make a real difference multiple changes must be implemented.

These recommendations will be divided into two parts. The first set is computer science-specific recommendations from Code.org. The second set is cybersecurity-specific recommendations.

Computer Science Recommendations

Code.org has published a list of nine recommendations to "make computer science fundamental to K-12 education." They suggest that their recommendations are meant to be a "menu of best practices" as not all states might be in a position to adopt them all (Code.org, 2016). They then released a snapshot of each state's progress towards this menu of computer science recommendations. Of the nine, New York has met (☑) three and not met (☒) six. A more detailed description of these recommendations for NYS can be found in Appendix B (Code.org, 2016). The following list is in a different order than the original Code.org list.

☑ Implement clear certification pathways for computer science teachers.

☑ Allow computer science to satisfy a core graduation requirement.

☑ Allow computer science to satisfy an admission requirement at institutions of higher education.

☒ Establish dedicated computer science positions in State and Local Education Authorities.

☒ Create a state plan for K-12 computer science.

☒ Define computer science and establish rigorous computer science standards.

☒ Allocate funding for rigorous computer science teacher professional learning and course support.

☒ Create programs at institutions of higher education to offer computer science to preservice teachers.

☒ Require that all secondary schools offer computer science with appropriate implementation timelines

Ideally, New York should implement all of these strategies, but with limited resources, this might be unreachable in the near-term. The crucial first step is to dedicate a computer science (and cybersecurity) offices at the state level and within NYSED. This office would be responsible for accomplishing the next two crucial steps to:

- Create a state plan for K-12 computer science.
- Define computer science and establish rigorous computer science standards.

It is important to not reinvent the wheel. The CSTA and ACM has spent years of collaboration to create rigorous computer science standards, recently updated as the *CSTA K–12 computer science standards* (CSTA & ACM, 2016), which align with the *K–12 Computer Science Framework* (K–12 Computer Science Framework Steering Committee, 2016b). These standards should be adopted with little revision as New York's K–12 computer science standards.

The next recommendations were not explored in this paper, but nonetheless, any long-term education strategy must involve the funding and recruitment of teachers. The final recommendation will take the longest to implement correctly:

- Require that all secondary schools offer computer science with appropriate implementation timelines

As with any mandate, legislature and state education policy makers must carefully craft all aspects of the policy. The unintended consequences of unfunded mandates in school systems can sometimes be catastrophic. This mandate is too important to not fully fund. Computer science and cybersecurity are fields of study that dramatically and regularly evolve. Policy makers should consider granting sustained funding to offset any unforeseen needs after initial grants are given.

Cybersecurity Education Recommendations

- Form a task force to evaluate the success of current career pathways that support cybersecurity. This task force would best fall under the office of computer science and cybersecurity from the previous recommendation section.
- Give targeted grants to schools, P-TECHs, and BOCES programs that expand their pathways to include cybersecurity.

- Create a state-level CyberPatriot Advisor (or within the NYSED office of computer science and cybersecurity) to advocate for new CyberPatriot clubs and CyberCamps throughout the state. The advisor would additionally assist schools by helping to get cybersecurity training materials and mentors to them.

Conclusion

The purpose of this research was to examine what New York is doing to help eliminate its cybersecurity employment gap. While several districts and entities are proactively implementing programs and pathways, they are doing it in isolation from one another. New York State needs to coordinate these efforts under one umbrella, whether that be at the state government level, at the NYSED level, or both. There is simply not the time, nor the resources, for the wheel to be reinvented over and over. Computer scientists and cybersecurity professionals are some of the top innovators in society. They have freely provided the resources for states to take and use with minimal need to change them. New York needs to step up and benefit from this. If New York does not, the only ones to benefit will be the criminals behind their computers.

Future Research Recommendations

All but one of the career pathways discussed in this paper have been built from scratch within the last 2-5 years (P-TECH, PSLA, BOCES Cybersecurity program). The research on their outcomes is obviously, non-existent. It is important to stridently study each cohort longitudinally so that programs can be adjusted, if necessary.

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Appendices

Appendix A –Public Service Leadership Academy (PSLA) Career Academies & Programs

First Responder Academy

- Law Enforcement/Emergency Management Pathway
- Fire Rescue Pathway
- Emergency Medical Technician Pathway
- Forensic Science/Crime Scene Investigations Pathway

Homeland Security Academy

- Computer Forensics Pathway
- Cybersecurity Pathway
- Geospatial Intelligence Pathway

Military Security Academy

- Navy JROTC Pathway

Entrepreneurial Academy

- Cosmetology/Barbering Pathway
- Electrical Trades Pathway

Appendix B – Code.org : What can NY do to Improve Computer Science Education?

☒ New York has not yet created a state plan for K-12 computer science. A plan that articulates the goals for computer science, strategies for accomplishing the goals, and timelines for carrying out the strategies is important for making computer science a fundamental part of a state's education system.

☒ New York does not yet have rigorous computer science standards publicly available across K-12. Computer science has often been confused with broader technology education in schools. The state could strengthen its computer science programs by publicly adopting discrete standards for computer science focused on both the creation and use of software and computing technologies at all levels of K-12 education. These standards can be guided by the concepts, practices, and recommendations in the K-12 Computer Science Framework, found at http://www.k12cs.org.

☒ New York does not yet provide dedicated funding for rigorous computer science professional development and course support. Although funds may be available via broader programs, the state can strengthen its computer science programs by creating specific opportunities to bring computer science to school districts, such as matching fund programs.

☑ New York has clear certification pathways for computer science teachers.

☒ New York has not yet established programs at institutions of higher education to offer computer science to preservice teachers. The computer science teacher shortage can be addressed by exposing more preservice teachers to computer science during their required coursework or by creating specific pathways for computer science teachers.

Appendix B – continued

☒ New York does not yet have dedicated computer science positions in state or local education authorities. Creating a statewide computer science leadership position within the state education authority can help expand state-level implementation of computer science education initiatives. Similar positions at the local level could support districts' expansion of course offerings and professional development.

☒ New York does not yet require that all secondary schools offer computer science. The state can support the expansion of computer science courses by adopting policies that require schools to offer a computer science course based on rigorous standards, with appropriate implementation timelines and allowing for remote and/or in-person courses.

☑ New York allows computer science to count for a core graduation requirement. Find out how New York allows computer science to count towards graduation at http://bit.ly/1Is6YXS.

☑ New York allows computer science to count as a core admission requirement at institutions of higher education.