Issue Brief

U.S. High School Cybersecurity Competitions

Building Cyber Talent Through Extracurricular Activities

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Executive Summary

The United States faces a growing number of threats in the cyber domain, from security breaches to economic espionage and ransomware attacks, that harm both private and public entities and disrupt critical services. The cost to the U.S. economy resulting from cyberattacks is steep, and attributing, responding to, and remedying the damage is an ongoing challenge for the government and U.S. companies.[1] In this environment, well-trained cyber talent is a strategic national asset. Today, however, nearly six hundred thousand cybersecurity positions remain vacant across the public and private sectors.[2] To partially address this need, the National Institute of Standards and Technology has partnered with academia and the private sector to form the National Initiative for Cybersecurity Education (NICE). This initiative has highlighted the urgent need to build and develop a workforce capable of protecting U.S. public services, industries, and citizens against cyber threats. One of the initiative's components is to use cyber competitions as a way to help its participants develop cyber skills in simulated, but realistic situations.

Cybersecurity competitions extend to the high school level—which, as this report suggests, may be an underutilized area for developing cybersecurity talent earlier in talent development pipelines. In 2021, only 11,000 students participated in the nation's largest cybersecurity competition for high school students, which is only 0.07 percent of high schoolers. This is similar to the low percentage of students enrolled in Advanced Placement Computer Science courses, which hovers around 1 percent even after recent significant growth in student participation.[3] For reference, the Centers for Disease Control and Prevention reports that nearly 57 percent of high school students participate in at least one team sport.[4]

If the United States aims to outcompete other countries in critical emerging technologies, it will need a well-educated and thriving cyber talent pool. China, for example, has wasted little time in mandating both information technology education and artificial intelligence coursework at the high school level.[5] In fact, China has even begun integrating Python, a computer programming language, into its *Gaokao* exam, the nationally standardized college entrance exam taken by roughly ten million Chinese students each year. When preparing the next generation of cyber experts, it becomes increasingly clear that today's U.S. educational efforts are falling short.

To better understand these challenges, this report examines U.S. high school cybersecurity competitions, their reach, and their impact on students' educational and professional development. Cybersecurity competitions could play a valuable role in developing future cyber practitioners, but can they be expanded to more schools and individuals? To answer this question, this report takes a close look at two of the largest and well-known U.S. high school cybersecurity competitions, finding that a cluster of schools repeatedly dominate these competitions. These same schools are often performing above the U.S. national averages when comparing factors like educational offerings, student proficiency, and socioeconomic status. To gain a sense of how these factors might affect student performance, we interviewed 12 coaches and mentors from 10 high schools.

Overall, our research presents three main observations. First, the availability of computer science (CS) and related coursework is not necessarily tied to successful student participation in competitions. At the same time, however, a second finding reveals that educator or professional mentorship is necessary to support student interest and participation in cybersecurity competitions. With a shortage of K-12 CS teachers, this may be one of the toughest challenges.[6] Finally, support for local and regional cyber competitions can help level an unbalanced national playing field and increase participation rates.

Introduction

For the last three years, a student-led club at Del Norte High School in California has won one of the largest high school cybersecurity competitions in the United States. The Air Force Association's CyberPatriot competition, which is now on its fourteenth season, challenges students to find and fix cybersecurity vulnerabilities on a virtual operating system while maintaining critical operations. Del Norte's students are a select few out of the thousands who rigorously practice, train, and compete in CyberPatriot. It pays off, according to Del Norte's team coach, who says his students are getting into college with scholarships.[7] In a recent survey released by CyberPatriot, 502 out of the 3,242 current and former participants who responded are either enrolled in college or have already earned a degree in a cybersecurity field.[8]

This report explores how high school cybersecurity competitions can serve as a potential resource to strengthen the domestic cyber workforce. Currently, there is no comprehensive assessment of high school cybersecurity competitions in the United States, their outcomes, or potential accessibility gaps. Cybersecurity competitions provide a unique opportunity for high school students of varying skill levels to convene, exchange knowledge, build expertise, and create innovative solutions to existing problems. For some, competitions may offer cybersecurity education not available through formal schooling. For others, it may be a valuable career development resource for postsecondary education or a job in cybersecurity. Considered in this way, cybersecurity competitions can strengthen the U.S. technological innovation base by developing and educating a workforce in a field that is chronically short on talent.[9]

This report begins with a discussion of the types of cybersecurity competitions. It then examines recent winners of these competitions and describes contributing factors that might have led to their strong performances. Lastly, it details participation requirements and barriers to entry for various cybersecurity competitions and the challenges this may pose to certain demographics of U.S. high school students.

Methodology

We scoped the data collection and analysis to two national cybersecurity competitions, the Air Force Association's CyberPatriot National Youth Cyber Defense Competition and Carnegie Mellon University's picoCTF, which are two of the largest and well-known recurring cybersecurity competitions specifically geared toward high school students in the United States. Additionally, each recurs annually and has an abundance of publicly-available demographic data compared to other competitions.

However, we recognize the wide variety of cybersecurity competitions and sought to identify other types of competitions for U.S. high school students (see Table 1). Though not an exhaustive list, in Table 1 we highlight some national competitions that take place annually, like picoCTF and CyberPatriot.

Additionally, we expanded our analysis with interviews with coaches, mentors, and educators from top-performing high schools in the CyberPatriot and picoCTF competitions. In total, we interviewed 12 high school coaches and educators from 10 schools with registered teams. We recognize our interview pool is small, and therefore it is challenging to extrapolate any broad conclusions or recommendations from these interviews alone. Response and participation rates among educators were below 25 percent. Nevertheless, their experiences and perspectives from leading and coaching high school teams in cybersecurity competitions provide insights and takeaways otherwise not found in our quantitative analysis.

High School Cybersecurity Competitions

Cybersecurity competitions and challenges are supplemental educational opportunities that allow students to practice and demonstrate classroom skills in solving real-world problems. In some cases, preparing for and participating in competitions may be a student's first exposure to CS or cybersecurity concepts.[10] Different styles of competitions emphasize various cyber applications and skills, some of which are not taught in basic CS curricula.[11]

In the 2021–2022 competition cycle of CyberPatriot, at least 11,000 high school students were enrolled.[12] These participants have an opportunity to compete against students from around the country, but they only represent about 0.07 percent of currently enrolled U.S. high school students.[13] There are, of course, more cybersecurity competitions available to U.S. students. Other competitions exist locally or in different formats. Some challenges are in self-paced module formats, and therefore require no team registration or school involvement and confer no awards or prizes. Other competitions are available at chapter-affiliated high schools, but it is not clear whether or not they take place annually.

More competitions are geared toward college students and professionals. There are also many unique competitions or challenges that are open to anyone, meaning high school students could enter and compete. Therefore, we selected seven competitions to serve as a sample.

Table 1: Select National Cybersecurity Competitions Open to High School Students That Are Hosted Annually

Competition	Host	2021 Participant Totals
CyberPatriot National Youth Cyber Defense Competition[14]	Air Force Association, Center for Infrastructure Assurance and Security (founding partner)	~11,000 high school students ~12,693 registered participants
picoCTF[15]	Carnegie Mellon University	~15,000 registered participants
National Cyber League[16]	National Cyber League, Cyber Skyline, Inc.	3,301 registered teams
tjctf[17]	Thomas Jefferson High School for Science and Technology	768 registered teams
MITRE eCTF[18]	The MITRE Corporation	N/A
Redpwn CTF[19]	Redpwn	1,418 registered teams
Computer Science and Information Technology[20]	Technology Student Association	N/A

Different styles of competitions emphasize various cyber applications and skills. Capture the flag (CTF) is the most popular type of cybersecurity competition and is generally divided into two categories: jeopardy or attack and defend. In jeopardy, participants either complete challenges or answer questions which return flags for success. Within the competition, fixing a vulnerability may be as obvious as giving a user a stronger password. For more obscure vulnerabilities, competitors may have to execute a detailed set of instructions that reveal hidden files or delete malicious downloads. In the attack and defend style of competition, the objective is to take and maintain control of as many of the targets as possible.[21] Other types of competitions include hack-a-thons, invention marathons (where participants find solutions to a specific problem), and linguistics (where participants decipher foreign or synthetic language-based puzzles).

Some competitions structure their challenges allowing the participants to develop skills in demand by many potential employers. For example, the National Cyber League generates scouting reports that show each individual participant's national

rank, performance scores, and accuracy of completion. These align with both the NICE framework and CompTIA, which is a well-recognized industry skill certification.

For CyberPatriot, teams may participate in online practice rounds before competing in the six-hour scored rounds held once a month on weekends from October to February.[22] Qualifying teams receive an all-expenses-paid trip to the national finals. PicoCTF, now hosting its eighth competition, operates similarly. Students may compete individually or form teams. Participants are tested in CTF challenges covering six domains of cybersecurity, including cryptography, web exploitation, and forensics. Smaller competitions are held throughout the year, but the annual competition series runs for two weeks in the spring.

Both competitions prioritize cybersecurity education over competition and provide extensive educational and practice materials for novice students or those who want to strengthen their skills. PicoCTF operates picoGym, which is a noncompetitive online practice space where participants can work through challenging problems. CyberPatriot also runs cybersecurity summer camps, an Elementary School Cyber Education Initiative and Literature series, and offers self-paced courses in topics like network security and programming. These programs and learning materials can provide a useful starting point for students and educators who lack access to in-school resources.

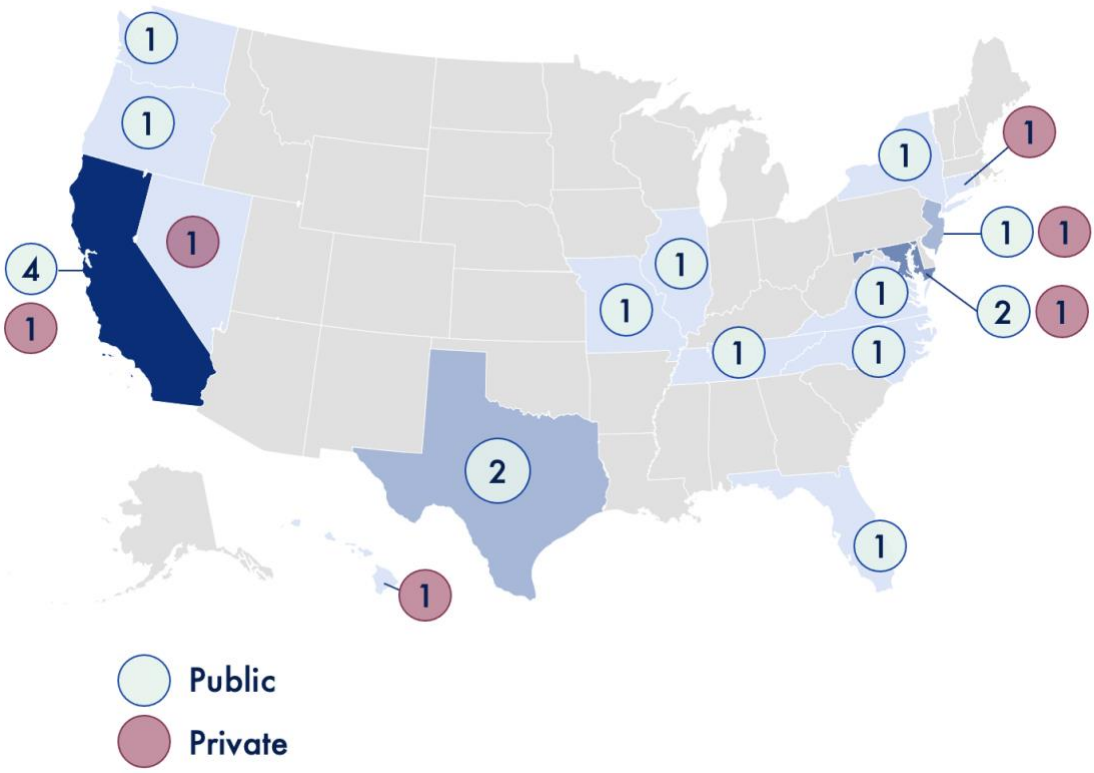
Trends

A cluster of nationally-ranking high schools dominated the leaderboards of CyberPatriot and picoCTF. Shared characteristics indicate they are well-equipped with the educational and financial resources to elevate their performance in competitions. In total, we examined 24 high schools. Some of these schools are repeat top performers or have multiple teams, but we only count the school once in those instances. Of the 24 schools, 18 are public high schools, eight of which are designated as magnet schools. The other six schools are private institutions. There is one vocational school that serves both adult learners and high school students; it is not included in further analysis due to lack of comparable factors. Our analysis and comparisons are based on the 18 public schools due to a lack of consistent public data for the private schools.

High School Type and Location

Based on location data from the National Center for Education Statistics (NCES), 10 schools are located in suburbs, six in cities, and two in towns with populations ranging from 5,700 to 34,800.[23] Almost all of the 18 schools are located in cities on the East and West Coasts like Los Angeles, CA; San Diego, CA; and Alexandria, VA. However, data also shows some disbursement of top performers outside of these regions, like Chesterfield, MO and Cookeville, TN. Both of these states' teams come from towns and from magnet schools. Broadly, there is little representation from schools in the Midwest or rural communities. For added perspective, we collected state distribution data from 2018 to 2021 for all registered teams in three competition seasons of CyberPatriot. The states with the most registered teams are California (3,466), Texas (1,976), and Virginia (1,271). The next seven out of the top 10 are Florida, Maryland, Colorado, Michigan, South Carolina, Illinois, and Georgia.[24]

Figure 1: Location of 24 Top-Performing High Schools



Source: CSET analysis of CyberPatriot data.

Availability of CS and Related Courses and Student Proficiency

All 24 public and private high schools offer several CS and related courses. The number of CS-related courses that each school offers ranges from two to 13. All except one school offer at least one of the two Advanced Placement CS courses (AP CS Principles and AP CS A). The one exception was a school that replaced its AP courses with its own equivalent versions that still equip students for AP exams.[25] The 18 public schools are also above national averages in AP enrollment.[26] Publicly available data shows that the average AP enrollment of these top competitor schools is 51 percent.[27] Data for private school AP enrollment is inconsistent. Nationally, AP enrollment is much lower at an estimated 17 percent in 2020.[28] Enrollment of public high school students in AP CS courses is even smaller at only 1.2 percent.[29]

> *"The students have an interest. Today's generation of students are digital students. They are curious to know how [cybersecurity] works. Whether in a rural environment, urban, or in the suburbs, this can work. It's just a matter of who's gonna get it started."*
>
> *-Coach of a CyberPatriot team*

Alongside AP courses, offerings vary from broader topics such as introductory programming, data structures, and algorithms to more specialized concepts such as artificial intelligence, computer vision, application development, networking, video game design, and cybersecurity. Additionally, exactly half of the top-performing schools offer Career Technical Education or similar career pathway programs that offer a sequence of courses, certifications, and internship opportunities specific to CS, information technology, and/or cybersecurity.

Availability of Extracurricular Activities

Top performing schools also have access to a wide variety of extracurricular clubs and activities, which are often the avenue for students who join their school's competition team. Among the 24 top public and private schools, at least 19 appear to offer a variety of CS and cybersecurity-oriented clubs and student organizations. Some of these clubs include hack clubs, app and web development clubs, Girls Who Code clubs, and even competition-specific training clubs. Four schools do not appear to offer specific CS or cybersecurity-oriented clubs according to their available lists online, but

this does not necessarily mean that the clubs do not exist.[30] One school's club list is not publicly available.[31]

Socioeconomic Factors

Lastly, we examined macro socioeconomic data to compare to national averages. Again, most of these top-performing schools are located in regions with above-average household incomes. Based on U.S. census data and the county location for all 24 schools, the average household broadband internet subscription is 86.8 percent.[32] This is slightly higher than the U.S. average of 82.7 percent. At $80,264, the median household income for the counties' 24 schools is well above the U.S. national average of $62,843.[33] Of the 24 schools and their representative counties, the county with the lowest median income of $44,259 is Putnam County, Tennessee. The county with the highest median income of $124,831 is Fairfax County, Virginia. However, both schools in these counties are magnet schools and they likely provide a broader array of educational offerings than their county counterparts.

Interview Feedback

While publicly available data on these top-performing schools provides some insight, the picture remains incomplete. We attempted to contact all 24 schools to provide more detail, but we only received responses from four schools. To supplement, we also contacted additional schools located in underrepresented states to gain a fuller sense of what barriers might exist in these trends.[34] In our interviews with 12 educators and coaches, we asked the following questions to gain a sense of what trends are barriers to participation and how they might be overcome.

Is CS, Cybersecurity, or Related Coursework a Factor for Success?

The availability of CS coursework is a consistent indicator among schools participating in CyberPatriot and PicoCTF competitions, but is it necessary to participate in or achieve some degree of success in these competitions? Currently, only 51 percent of U.S. public high schools offer a foundational CS course. Disparities in access persist as rural schools, urban schools, and schools with large portions of economically disadvantaged students.[35] While foundational CS courses generally do not teach topics directly covered in cybersecurity competitions, they do provide exposure to basic concepts for students that can make it easier to apply practical cybersecurity concepts.

Even if schools offer CS coursework, enrollment is disproportionate across racial and gender lines. Nationally, female students make up only 31 percent of high school

students enrolled in foundational CS while making up approximately 49 percent of the student body.[36] Hispanic and Latino high school students, representing 26 percent of the student body and 19 percent of CS enrollments, are even less likely than their white and Asian peers to enroll in foundational CS, even when they attend a school that offers it.[37] When examining competition participation, similar patterns exist. For CyberPatriot's 2021 competition, only 26.5 percent of respondents were female, and only 16 percent of PicoCTF's registrants were female.[38] CyberPatriot does attempt to incentivize female participation by waiving team registration fees if the team is all-female, a Title I institution, or part of the All-Service Division like the Junior Reserve Officer Training Corps.[39]

> *"The competitions encourage students to excel in the classroom."*
>
> *-High School Computer Science and Cybersecurity Educator*

Eight educators suggested that previous exposure or familiarity with CS and cybersecurity concepts is certainly helpful but not necessary to participate in competitions like CyberPatriot and picoCTF. For example, at least three educators mentioned that their outreach for both cybersecurity competitions and education usually begin in local middle schools. These students typically have little to no experience with cybersecurity topics. One coach said his middle school teams have been national champions in CyberPatriot without a single CS or cybersecurity class.

The other three educators said that without formal exposure to cybersecurity topics, it would be challenging to initially participate. All three of these teachers recommended starting with training materials and resources available through competitions like CyberPatriot and picoCTF.

Extracurricular Activity or Classroom Instruction?

Because competitions are supplemental education opportunities, schools approach them differently. Three coaches likened competitions to regular high school athletics, meaning there is an extracurricular effort and time commitments are required from both students and their coaches. The top-performing schools have dedicated competition or cybersecurity clubs, which leads us to assume that these schools have at least one educator or mentor with experience or familiarity with cybersecurity topics. However, nine educators say that preparation and competition occur outside of regular classroom instruction, and eight indicated that the preparation and competition is

primarily student-led. Two teachers incorporated competition participation into their curriculum. Three suggested that the extracurricular nature of competition is a fun incentive to encourage students to actually enroll in formal cybersecurity or related classes.

Did You Face Any Challenges When Participating in a Competition?

If access to CS curriculum or extracurricular opportunities are not necessarily a factor for success, what other challenges might a school face? This question is particularly important when considering what barriers an under-resourced school might need to overcome. Generally, answers reflected two main concerns: support and resources.

At a bare minimum, students need access to quality technology. This was a concern shared by seven teachers. For CyberPatriot, students are encouraged to use at least one Windows 64-bit operating system running version 8.1 or higher with at least 8GB of RAM. It requires additional software installations but they are free for registered participants.[40] CyberPatriot's requirements exceed those required by picoCTF in which eligible students are able to enter the competition using just internet access and a web browser.[41] According to CyberPatriot's website, the most common difficulty teams encounter is a school firewall blocking or restricting access to certain webpages or software installations.[42] Four teachers indicated from previous experience that convincing a school or district administration can also be a challenge, but five teachers said that their respective school districts were very supportive. In some cases, district or administration officials instigated the idea of competing in CyberPatriot.

Additionally, an important yet overlooked factor is the availability of reliable internet access and computing resources. As previously mentioned, only 82.7 percent of Americans have home internet access. The NCES offers a different perspective. According to 2019 data, 95 percent of three-to-eighteen-year-olds had some home internet access.[43] While 88 percent of these three-to-eighteen-year-olds had internet access through a computer, at least 6 percent only had internet access through a smartphone. One coach mentioned that his high school partnered with another high school in Alaska where high-speed internet access was not always guaranteed.

Conclusion: Promising Prospects

Investments in cybersecurity education and talent development will help ensure the United States has the skilled workforce that it needs to drive its next technological breakthroughs. To that end, U.S. policymakers, industry, and organizations have a renewed focus on enhancing the country's competitive edge, especially to include

areas that may have been overlooked or underfunded.[44] This report aims to shed light on the dynamics that allow high schools to be successful in cybersecurity competitions. There is still much more to explore, such as local and state-sponsored cyber competitions, as well as opportunities for college and postsecondary students. This report also sought to reveal any gaps in opportunity or barriers to access for U.S. high school students, such as competition prerequisites, IT technology, and any other resources needed for students and schools to participate in cybersecurity competitions.

Based on this, we present the following observations:

Previous CS or cybersecurity experience is not necessarily required, but skilled mentorship remains important. Every educator we interviewed emphasized the importance of qualified or invested teachers and supportive school administrations or districts. Interestingly, not every teacher had a specific background in CS or cybersecurity. Some were simply interested in the subject, and others developed the skills over the course of their careers and began to teach basic introductory courses.

However, the guidance that a student might otherwise receive from a qualified or an experienced mentor in this field cannot be overlooked. For some schools, it may be more difficult to hire an experienced CS educator given shortages of K-12 teachers in this field.[45] One teacher we interviewed said that his state mandates a CS curriculum, but other high schools in the district are struggling to hire qualified teachers. Shortages like this are likely more widespread and suggest one of the potential difficulties in scaling high school opportunities more broadly. Hiring more skilled educators or mentors could help to bridge this gap.

A more positive trend is the accelerated progress by U.S. public high schools to expand access to CS coursework. Today, 51 percent of high schools offer a foundational CS course compared to only 35 percent as recently as 2018.[46] In 2016, 22 states did not allow CS courses to count toward high school graduation. This restriction is not found in any states today.[47] In fact, 23 states now require high schools to offer CS coursework.[48] As evidenced by these upward trends, collective advocacy efforts exist and appear to be increasingly effective. The annual State of Computer Science Education report from Code.org outlines steps for CS expansion developed by a coalition of teachers, nonprofits, corporations, researchers, and government. Six states have adopted the framework in its entirety.[49]

High school cyber competitions are incentivizing cyber education and new opportunities. In a CyberPatriot follow-on survey, an encouraging 84 percent of competition alumni elected a STEM program as their field of study, with nearly a

quarter of those in cybersecurity.[50] Perhaps the most useful is a student's potential exposure to job or academic opportunities. In our interviews, we explored the kinds of professional exposure or opportunities that are made available to students who compete in these national competitions. The answers we received were unanimously encouraging, suggesting that participation in cybersecurity competitions resulted in early college acceptances, scholarships, job opportunities, and demonstrable real-world skills. At the national level, major competitions like CyberPatriot and National Cyber League align their challenges with industry skills and federal initiatives. The top performers of these competitions, even at the high school level, are pools of talent. These participants are demonstrating useful and critical cyber skills, even though many participants do not yet have college degrees.

Collaboration and local partnerships have an impact. In our research, recruitment and practice for cybersecurity competitions were often compared to high school sports. Most high school sports teams compete in local or regional conference competitions before advancing to state-wide competitions. CyberPatriot also has state finals before national finals. In that regard, focusing efforts on cybersecurity competitions at the local and regional levels would uplift schools with less access to the same resources as the top-performing schools, and could level the competition among peer schools. One educator suggested that more incentives and emphasis should be placed locally to encourage schools in under-represented states to participate.

> *"Cybersecurity education should be for everyone, regardless of high-performing or low-performing schools."*
>
> *-Coach of a CyberPatriot Team*

Four schools out of the 24 top performers actually organize and facilitate cybersecurity competitions for other U.S. and international high school students.[51] One of these schools packaged their cybersecurity curricula to reach local high schools so that less well-resourced schools can utilize the learning materials without establishing their own curricula. Another school partnered with a high school in Alaska to train and prepare for a season of CyberPatriot.

In sum, this report provides a look into one aspect of cyber education in the United States—high school cybersecurity competitions. They are just one of the many ways to train and educate the future cybersecurity workforce. However, their contribution is an important one as the demand for cyber talent continues to surpass supply.[52] High

school cybersecurity competitions are one way for interested students to practice and hone real-world skills, and in the process, create a recruitable talent pool for academia, industry, and the public sector.

Appendix: List of Top Performing High Schools

School	Location	Type
Choate Rosemary Hall	Wallingford, CT	Private
Loyola Blakefield High School	Townson, MD	Private
Harvard-Westlake	Los Angeles, CA	Private
Newark Academy	Livingston, NJ	Private
Faith Lutheran High School	Las Vegas, NV	Private
Iolani School	Honolulu, HI	Private
Atkins Academic and Technology High School*	Winston-Salem, NC	Public
Tigard High School	Tigard, OR	Public
Montgomery Blair High School*	Silver Spring, MD	Public
Scarsdale High School	Scarsdale, NY	Public
Del Norte High School♦	San Diego, CA	Public
Rolling Meadows High School	Rolling Meadows, IL	Public
Suncoast Community High School*	Riviera Beach, FL	Public
Poolesville High School*	Poolesville, MD	Public
Plano West Senior High School	Plano, TX	Public
West-Windsor Plainsboro High School North	Plainsboro, NJ	Public
Dos Pueblos High School	Goleta, CA	Public
Troy High School*♦	Fullerton, CA	Public
Mission San Jose High School	Fremont, CA	Public
Cookeville High School*♦	Cookeville, TN	Public
Parkway West High School	Chesterfield, MO	Public
Interlake High School	Bellevue, WA	Public
Liberal Arts and Science Academy	Austin, TX	Public
Thomas Jefferson High School for Science and Technology*♦	Alexandria, VA	Public

Source: CSET analysis of CyberPatriot and picoCTF 2018-2020 results.

* Magnet school.

♦ Repeat top performer.

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Endnotes

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[26] Sixteen schools have publicly available data on AP enrollment and two schools do not. Tigard and Scarsdale High Schools do not offer AP courses. Instead, Tigard offers International Baccalaureate (IB) pathways and Scarsdale offers its own version of the AP system.

[27] We used data from Niche.com, an educational resource.

[28] According to the National Center for Education Statistics, in 2020 the total enrollment for public school students in grades 9-12 was 15.3 million. Of those students, the total number enrolled in AP courses for the same year was 2.6 million. Therefore, we can determine that in 2020 roughly 17 percent of public school students in grades 9-12 were enrolled in at least one AP course.

[29] College Board, AP Program Summaries 2019-2021, accessed January 18, 2022, https://secure-media.collegeboard.org/digitalServices/pdf/research/2020/Program-Summary-Report-2020.pdf; and https://secure-media.collegeboard.org/digitalServices/pdf/research/2021/2021-ap-program-summary-report.pdf.

[30] Tigard High School, Dos Pueblos High School, Suncoast Community High School, and Cookeville High School.

[31] Scarsdale High School.

[32] CSET analysis of U.S. Census Quick Fact data.

[33] CSET analysis of U.S. Census Quick fact data.

[34] Alabama, Arkansas, Louisiana, New Jersey, and Wyoming.

[35] "2021 State of CS Report," Code.org, accessed January 28, 2022, https://advocacy.code.org/stateofcs.

[36] Code.org, "2021 State of CS Report."

[37] Code.org, "2021 State of CS Report." This report acknowledges that participation rates for some states are missing and so the total female participation rate may be higher or lower.

[38] "Air Force Association's CyberPatriot, "Registration Report," accessed January 28, 2022, https://www.uscyberpatriot.org/Documents/Fact%20Sheets/CP13%20Registration%20Report%202020-2021.pdf; "2021 CTF Competition Summary," PicoCTF.org, accessed February 15, 2022.

[39] Air Force Association's CyberPatriot, Fee Waiver Information, accessed January 24, 2022, https://www.uscyberpatriot.org/Pages/Registration/Fee-Waiver-Information.aspx.

[40] Teams are required to download and use VMware Workstation Player 16.1.2 and CISCO Packet Tracer 8.0.1.

[41] Carnegie Mellon University, "PicoCTF: General FAQ," accessed July 20, 2022, https://picoctf.org/get_started.html.

[42] Air Force Association's CyberPatriot, "Technical Specifications."

[43] National Center for Educational Statistics, Children's Internet Access at Home, accessed January 24, 2022, https://nces.ed.gov/programs/coe/indicator/cch.

[44] The White House, "The Biden Administration Launches the National Artificial Intelligence Research Resource Task Force," June 10, 2021, https://www.whitehouse.gov/ostp/news-updates/2021/06/10/the-biden-administration-launches-the-national-artificial-intelligence-research-resource-task-force/.

[45] "CS Teacher Landscape," Computer Science Teachers of America, accessed June 3, 2022, https://csteachers.org/page/cs-teacher-landscape.

[46] Code.org, "2021 State of CS Report."

[47] "Computer Science for All," National Archives and Records Administration, accessed January 28, 2022, https://obamawhitehouse.archives.gov/blog/2016/01/30/computer-science-all.

[48] "State of Computer Science Education - CS Advocacy," accessed January 28, 2022, https://advocacy.code.org/2018_state_of_cs.pdf.

[49] Alabama, Arkansas, Idaho, Indiana, Maryland, and Nevada.

[50] Scott King, Air Force Magazine, "Solving America's Cyber Tech Workforce Shortages," December 3, 2021, https://www.airforcemag.com/article/afa-in-action-6/

[51] Montgomery Blair High School (MD), West Windsor-Plainsboro High School (NJ), Thomas Jefferson High School for Science and Technology, and Loyola-Blakefield (MD).

[52] "Cybersecurity Supply and Demand Heat Map," CyberSeek, accessed June 3, 2022, https://www.cyberseek.org/heatmap.html.