SREB

The Report of the SREB Commission on
Computer Science and Information Technology

Bridging the Computer Science Education Gap:

Five Actions States Can Take

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Inside

The Southern Regional Education Board works with states to improve education at every level, from early childhood through doctoral education. A nonprofit, nonpartisan organization based in Atlanta, SREB was created in 1948 by Southern governors and legislators to help leaders in education and government advance education to improve the social and economic life of the region. Member states are Alabama, Arkansas, Delaware, Florida, Georgia, Kentucky, Louisiana, Maryland, Mississippi, North Carolina, Oklahoma, South Carolina, Tennessee, Texas, Virginia and West Virginia.

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Bridging the Computer Science Education Gap: Five Actions States Can Take

The Report of the SREB Commission on Computer Science and Information Technology

A Message From Governor Asa Hutchinson

I believe computer science is for everyone. As such, one of my first priorities as the 2015-16 chair of the Southern Regional Education Board was to launch a special Commission on Computer Science and Information Technology. This document is the Commission's final report, and I hope the five actions it recommends are helpful to your state.

In 2015, Arkansas became the first state to pass comprehensive legislation requiring computer science courses to be taught in every public high school. I am proud to report that six months later these courses were in place in time for the 2015-16 school year. As a result, more than 4,000 Arkansas students have enrolled in computer science courses, with 550 taking more than one. That's an increase of 260 percent in one year. The state is also achieving success in enrolling more girls and students of diverse ethnic backgrounds: Arkansas saw a 609 percent increase in African-American girls taking coding classes.

To help make high-quality computer science learning opportunities a reality for our schools, **I set aside $5 million to launch this initiative** and address the state's computer science teacher shortage. That investment has helped us train hundreds of teachers who are now offering computer science instruction in real and virtual classrooms across the state.

What are the keys to Arkansas's early success? These and other achievements have been possible because of broad public knowledge of the state's commitment to computer science, strong legislative support, generous funding, educational leadership and an enthusiastic response from Arkansas students.

National and state leaders now recognize the importance of computer science and information technology to our state and regional economies. The knowledge and skills students learn in computer science and IT classes are essential to every industry, from manufacturing to agriculture to medicine. Computing skills are changing our students from being technology consumers to becoming creators and innovators in the global economy.

Arkansas is leading the way in extending computer science learning opportunities to all students, and we're just getting started. I challenge SREB states and the nation to do the same.

Asa Hutchinson, Governor of Arkansas

2015-16 Chair, Southern Regional Education Board

Chair, SREB Commission on Computer Science and Information Technology

Executive Summary

In the global labor market, computational thinking skills and knowledge of computer science are required in nearly all career fields. What's more, jobs in computer science, information technology (IT) and related fields represent a large and growing sector of the economy. By 2020, as many as 4.6 million out of 9.2 million jobs in science, technology, engineering and math (STEM) fields will be computer-related, according to the Association for Computing Machinery. Labor market economists at the Georgetown University Center on Education and the Workforce estimate that over 70 percent of these jobs will require a bachelor's degree or higher. And most will pay well. The average median salary of jobs in computer science and IT was $81,430 in 2015, according to the U.S. Bureau of Labor Statistics.

However, the nation is not on track to meet labor market demand in computing fields. Code.org projects that, by 2020, the United States may have 1 million more computing jobs than qualified individuals to fill them. Meeting demand in these innovation-intensive fields will require states to greatly expand and diversify their college-degreed computing workforce.

The Southern Regional Education Board's Commission on Computer Science and Information Technology met in 2015 and 2016 to determine how states can help more young people — especially girls, black and Hispanic students, and students from low-income families — learn computer science, explore exciting computing careers, and for some, start journeys toward those careers while in high school.

By taking the five actions outlined in this report, states can help more youth learn computer science and develop computational thinking skills, not just those students considering STEM careers. Computer science offers students much more than the knowledge of how computers work or the skills needed to build a device, write code or manage data. Computer science builds high-level literacy, math, problem-solving and technological skills and advances productivity in every discipline, industry and profession.

The full report expands on the abbreviated action steps laid out below.

Action 1: Develop state computer science standards for K-12.

- Work in partnership with secondary and postsecondary educators, experts and industry leaders to develop K-12 computer science standards that include the essential concepts and practices students should master in the elementary and middle grades and high school.
- Develop or adopt standards-based, developmentally appropriate computer science curricula that appeal to diverse learners in the elementary and middle grades.
- Require all high schools to offer students access to rigorous, standards-based computer science courses, such as Exploring Computer Science and Advanced Placement Computer Science Principles.
- Provide funding at the state, district and school levels to support expanded computer science learning opportunities in schools.
- Extend early and frequent opportunities for K-12 students and their families — especially girls, black and Hispanic students, and students from low-income families — to explore computer science and computer science-related careers.

Action 2: Lay the groundwork for learning computer science.

- Throughout K-12, integrate and teach the essential literacy skills that students need to master grade-appropriate computer science standards.
- Throughout K-12, integrate and teach the essential math concepts and skills that students need to master grade-appropriate computer science standards.

- Provide targeted interventions and readiness courses to students who need extra help mastering the grade-level literacy and math skills needed for success in computing fields.
- Require students to take four years of math aligned with their career and college goals.
- Support K-12 academic and computer science teachers in designing interdisciplinary, project-based instruction and assignments that engage students in applying literacy, math and computational thinking skills to solve problems.

Action 3: Create clear pathways to computing careers.

- Charge a state career pathway advisory council with developing pathways that meet identified workforce needs in computing fields.
- Build career pathways consisting of four or more courses that connect seamlessly to postsecondary programs in high-demand career fields, such as cybersecurity, informatics and software development.
- Redesign the high school senior year to allow students who meet college-readiness benchmarks to earn college credits that transfer to associate and bachelor's degrees and to help struggling students prepare for college.
- Include computer science and computer science-related career pathways in state accountability and funding systems.

Action 4: Prepare great computer science teachers.

- Recruit teachers with the content knowledge, interest, passion and willingness to learn and explore computer science alongside their K-12 students.
- Offer teaching endorsements to new computer science teachers who complete a two- to four-week, full-day summer institute, led by a master teacher, in which they learn their curriculum by completing the same projects and assignments as their students.
- Create clear pathways to teacher certification and licensure to ensure that all teachers, regardless of their backgrounds, have the appropriate content knowledge and pedagogical skills needed to teach standards-based computer science and IT curricula.
- Leverage federal, state, foundation and private sector funds to support intensive, ongoing professional development on computer science and IT content knowledge and the pedagogical skills needed to manage diverse learners, create assessments and embed literacy and math in student-driven, project-based instruction and assignments.
- Partner with other states, national and regional organizations, the Educational Testing Service or other licensing exam providers to design a new computer science Praxis or other standardized assessment that measures teachers' mastery of the most current content knowledge and pedagogical knowledge required to teach computer science.

Action 5: Educate communities about computer science and computing careers.

- Embed career advisement and exploration across K-12 as a means of educating students, parents and communities about computer science and computing careers.
- Encourage employer partners to invest in the computing and IT workforce of the future.
- Enact legislation to recognize communities that improve computer science education and meet workforce needs in computing fields.

Bridging the Computer Science Education Gap: *Five Actions States Can Take*

Educating Youth for a Digital World

Consider this: Children born since the early 1990s have never known a world in which computer and information technologies are not essential to almost every aspect of their lives. The collective knowledge of humankind can be accessed with the tap of a finger. Innovations in computer science help us create, heal, transform and understand ourselves and our world. But such technologies are also vulnerable to misuse, at the cost of the privacy of our personal data.

Computer science education is vital to navigating the exciting and sometimes dangerous digital world.[1] But far too many young people, particularly low-income and minority youth,[2] lack opportunities to explore the impact of computer and information technologies on their lives and to become savvy consumers, creators and innovators of computing technologies.

> *"Children today are born and raised with an aptitude for technology. We simply need to get out of their way. So many obstacles for young people are based on obsolete policies and regulations we don't need. We need to allow them to explore, engage and challenge themselves to succeed."*
>
> — **Henry Johnson**, Assistant State Superintendent for Curriculum, Assessment and Accountability, Maryland State Department of Education

The Southern Regional Education Board, led by its 2015-16 chair, Arkansas Governor Asa Hutchinson, convened a group of state legislators, secondary and postsecondary education leaders, and experts — the Commission on Computer Science and Information Technology — to address the question of how to extend computer science learning experiences to students.

> *Far too many young people, particularly low-income and minority youth, lack opportunities to explore the impact of computer and information technologies on their lives and become savvy consumers, creators and innovators of computing technologies.*

Computer science can no longer be considered an optional component of K-12, or offered only to students considering careers in science, technology, engineering and math (STEM) fields. Computer science offers students much more than the knowledge of how computers work or the skills needed to build a device, write code or manage data. It builds lifelong learning skills that hold value in every academic discipline, industry and profession.[3] Computer science knowledge also advances our national productivity and wealth.

Terminology Matters: Defining Computer Science and IT

Although well-established at the postsecondary level, computer science and IT are sometimes confused at the K-12 level with other commonly used education terms.[4] Such terms include *educational technology*, the use of computers as a learning tool in instruction; *computer literacy* or *digital literacy*, the knowledge of how to use computer technology in an informed way; *IT fluency*, the ability to learn changing technologies[5] and use those technologies to synthesize and express new information;[6] and *computational literacy*,[7] the use of analytic skills to solve computing problems.

A component of STEM,[8] the discipline of **computer science** is "the study of computers and algorithmic processes, including their principles, their hardware and software designs, their applications and their impact on society."[9] Computer scientists blend theoretical knowledge and hands-on programming skills to create software, develop new uses for computer technologies and solve computing problems.[10]

Information technology emphasizes the practical application of technology, specifically the "selection, creation, application, integration and administration of computing technologies" to meet users' needs.[12] IT professionals in every industry manage and maintain software, networks, communications and media and support the users of those technologies.[13]

> *"Computer science is not about point and click skills. It is a discipline with a core set of scientific principles that can be applied to solve complex, real-world problems and promote higher-order thinking. In short, knowledge of computer science is now as essential to today's educated student as any of the traditional sciences."*
>
> — Computer Science Teachers Association Curriculum Improvement Task Force[11]

Computer science and IT encompass other computing disciplines:

- *Cybersecurity*, also known as *information assurance and security*,[14] involves protecting hardware, software, networks and data from cyberattacks. Cyber jobs may be classed as computer science or IT.
- *Information systems* blends technical IT elements with business functions and focuses on the design and implementation of data management solutions.[15]
- *Informatics*, which shares elements of information systems,[16] focuses on the design of structures and systems for analyzing and managing data to inform decision-making.[17]
- *Computer engineering* grew out of electrical engineering and focuses on the design, construction and maintenance of computer devices and systems used by industry and consumers.[18]
- *Software engineering* involves designing, developing and maintaining software systems by applying math and computer science principles to engineering design practices. Project management skills and quality assurance principles help software engineers meet clients' needs.[19]

Where the Jobs Are: The Computing Labor Market

In the global labor market, knowledge of computer science, computer literacy and computational thinking skills are required in nearly all careers. Further, jobs in computer science, IT and related fields are a large and growing sector of the economy. The Association for Computing Machinery estimates that by 2020, as many as 4.6 million out of 9.2 million STEM jobs will be computer-related.[20] By 2020, nearly 3.8 million jobs will be computer science-related, with about 70 percent requiring a bachelor's degree or higher.[21] Millions more jobs in fields like advanced manufacturing, business and medicine will also require individuals to possess high-level computing skills in areas like software development, programming and network maintenance.[22] Such jobs have been described as requiring "double-deep skills" — significant computing expertise in addition to knowledge of the field.[23]

Overall, jobs in computing fields pay well and are in high demand. As of 2015, the average median salary of jobs in computer science and IT was $81,430 a year — more than double the $36,200 median salary of all jobs.[24] One 2014 study found that software developer jobs ranked at the top of all jobs advertised online, at a mean salary of $92,000 annually.[25]

TABLE 1:
Computer Science-Related Occupations - Projected Workforce Needs by 2020

Occupation	Education Level by Occupation								Total
	High School		Some College		Associate		Bachelor's		
	Number	Percent	Number	Percent	Number	Percent	Number	Percent	
Computer systems analysts	13,810	2	99,240	17	0	0	484,700	81	597,800
Computer software developers, applications	17,610	3	42,990	7	35,520	6	496,870	84	593,000
Computer support specialists	82,150	15	127,580	24	94,630	18	233,950	43	538,310
Network system and data communication analysts	36,760	8	106,930	24	40,350	9	270,380	60	454,420
Computer software developers, system software	13,460	3	32,870	7	27,150	6	379,850	84	453,330
Network and computer systems administrators	29,690	8	86,360	24	32,590	9	218,370	60	367,000
Computer programmers	29,970	8	32,270	9	43,200	12	253,080	71	358,530
Computer specialists, all other	25,290	12	30,430	14	25,350	12	130,700	62	211,770
Database administrators	3,370	3	8,240	7	6,810	6	95,220	84	113,640
Operations research analysts	5,110	8	3,620	6	5,670	9	49,300	77	63,690
Computer and information scientists, research	2,490	8	7,230	24	2,730	9	18,280	60	30,720
Total	**259,710**	**7**	**577,760**	**15**	**314,000**	**9**	**2,630,700**	**70**	**3,782,210**

Source: Modified from Carnevale, A. P., Smith, N., & Strohl, J. (2013). *Recovery: Job growth and education requirements through 2020.* Washington, DC: Georgetown University Center on Education and the Workforce.

Some jobs in **informatics** (business systems analysts, information architects), **health informatics**[26] (medical coding specialists, physicians certified in clinical informatics) and **cybersecurity**[27] (forensics experts, security code auditors) are so new that Bureau of Labor Statistics data do not capture them. Nevertheless, the need for individuals in all three fields is high. In recent years, health informatics jobs grew at a rate of 36 percent, compared to 9 percent for health care jobs overall.[28] Major data breaches at corporations like Anthem, The Home Depot and Target sparked a 91 percent growth in cyber jobs in the United States[29] and sent salaries soaring to $100,000 per year or more.[30] To meet demand, U.S. Defense Secretary Ashton Carter has said, "cyber may one day become the sixth service branch."[31]

By 2020, the United States may have 1 million more computing jobs available than people to fill them.

Nationwide, employers in every industry report struggling to find individuals with the requisite computing skills. By 2020, the United States may have 1 million more computing jobs available than people to fill them.[32] As a result, many American businesses are recruiting overseas. In 2015, the U.S. Citizenship and Immigration Services office received approximately 233,000 applications for H-1Bs — skilled-worker visas that allow U.S. employers to employ foreign workers in specialty occupations for up to six years. Only 85,000 such visas are allotted each year, mainly in STEM fields.[33]

The college-degreed computing workforce is small, lacks diversity and must rapidly expand if the United States is to meet labor market demand. By one estimate, only 2.4 percent of college graduates have degrees in computer science.[34] Just 8 percent of college graduates with degrees in computer science are black,[35] 8 percent are Hispanic and 18 percent are women.[36] Less than 1 percent of the technical employees of top Silicon Valley companies like Dropbox, Facebook and Google are black.[37]

What must we do to help more young people — especially girls, black and Hispanic students, and students from low-income families — learn computer science and explore and choose exciting careers in computing fields?

Five Actions States Can Take to Bridge the Computer Science Learning Gap

Given these facts, the question before the Commission was clear: **What must we do to help more young people — especially girls, black and Hispanic students, and students from low-income families — learn computer science and explore and choose careers in computing fields?**

In this report, SREB's Commission on Computer Science and Information Technology offers states five actions they can take to extend computer science learning opportunities to students. These five actions also show states how to teach computer science and computational thinking skills in ways that deepen students' mastery of core academic subjects.

Careful planning must underpin each of these five actions. States would be wise to involve many stakeholders in considering the intended and unintended consequences of expanding access to computer science education. Establishing equitable access to computer science education is the shared responsibility of secondary and postsecondary educators, government officials, economic and workforce development agencies, employer partners, parents and community members. Supported by thoughtful planning and smart policies, these five actions can help states close the computer science opportunity gap and ensure that their citizens have the skills they need to thrive in a digital world.

Computational thinkers have the power to create technology, not just consume it.

Learning computer science can help launch students on journeys toward college credentials and degrees, great jobs and secure economic futures. Computer science cultivates creative, inquisitive minds and fosters transferrable reasoning and critical-thinking skills that empower individuals to understand and solve problems in their communities.[38]

Expanding access to computer science will require a sea change in education. States will develop rigorous standards that shape the design of curricula, instruction and teacher preparation and professional development. Elementary and middle grades schools will teach literacy, math and problem-solving skills in the context of computer science in every class and grade. Middle grades schools and high schools will reorganize around developing engaging assignments that build students' academic, technical and technological skills as they expand their career and college horizons. Interdisciplinary teacher teams will co-plan and co-teach lessons. Postsecondary, community and employer partners will build career pathways leading to credentials, degrees and workplace success. Colleges and universities will increase enrollment, retention and completion by integrating their computer science and IT programs with high schools.

"There has to be a revolution in the K-12 school system. There should be reading, writing, arithmetic and computer science."

— **Rajshekhar Sunderraman**, Professor and Acting Chair, Department of Computer Science, Georgia State University[39]

Change comes at a cost, and most states, school districts and schools have scarce resources — money, time and talent — to devote to new initiatives. Policymakers and educators know that when a new curricular component is introduced, other components may be pushed to the side. Given the centrality of computing technologies to our daily lives, integrating computer science across K-12 and beyond makes good educational and economic sense. The time for computer science is now. Members of SREB's Commission on Computer Science and Information Technology urge states to make computer science education a priority. These five actions can help.

Action 1:
Develop State Computer Science Standards for K-12

Despite the overwhelming need to produce more graduates with the credentials and degrees needed in computing fields, computer science remains "marginalized"[40] or nonexistent in American schools.

Nationwide, only three states — **Arkansas, Texas** and **West Virginia**, all in the SREB region — require all high schools to offer computer science. No state requires students to take computer science to graduate from high school.

All too often, students' choices are limited to low-level technology courses like keyboarding and computer applications,[41] or to a course in coding — what one recent report calls only a fraction of what real computer science entails.[42] Few schools offer college-preparatory courses — for example, Advanced Placement Computer Science A. Out of the nearly 4.5 million AP exams taken in 2015, just 48,994 — 1 percent — were AP CS A exams.[43]

TABLE 2:
Computer Science in SREB States

SREB State	All High Schools Required to Offer CS	Clear CS Teacher Cetification Pathways	Clear CS Curriculum Standards
Alabama	No	No	No
Arkansas	Yes	Yes	Yes
Delaware	No	No	No
Florida	No	Yes	Yes
Georgia	No	Yes	No
Kentucky	No	Yes	No
Louisiana	No	Yes	No
Maryland	No	Yes	No
Mississippi	No	Yes	No
North Carolina	No	No	No
Oklahoma	No	No	No
South Carolina	No	Yes	No
Tennessee	No	No	No
Texas	Yes	Yes	Yes
Virginia	No	Yes	No
West Virginia	Yes	Yes	No

Source: Code.org/promote. Updated October 11, 2016.

Most states need to create K-12 standards for computer science.[44] Only **Arkansas, Florida, Indiana, Massachusetts, New Jersey** and **Texas** have fully developed such standards. And most state computer science curricula are not aligned with the K-12 computer science standards created by the Computer Science Teachers Association.[45] In fact, most state college- and career-readiness standards omit computer science entirely.[46]

Meeting the goal of helping students access quality computer science education begins with creating computer science standards, and SREB states are rising to meet this need.

SREB states are participating in a collaborative effort to create a **K-12 computer science framework** that states and school districts can use to design their own grade-level standards, curricula, lessons, assessments and professional development.[47] **Arkansas, Georgia, Maryland** and **North Carolina** are among the 14 states that are participating in the initiative. Other SREB states, including **South Carolina** and **Virginia**, have expressed interest in using the framework to develop their own standards.[48]

The framework is designed to help students:

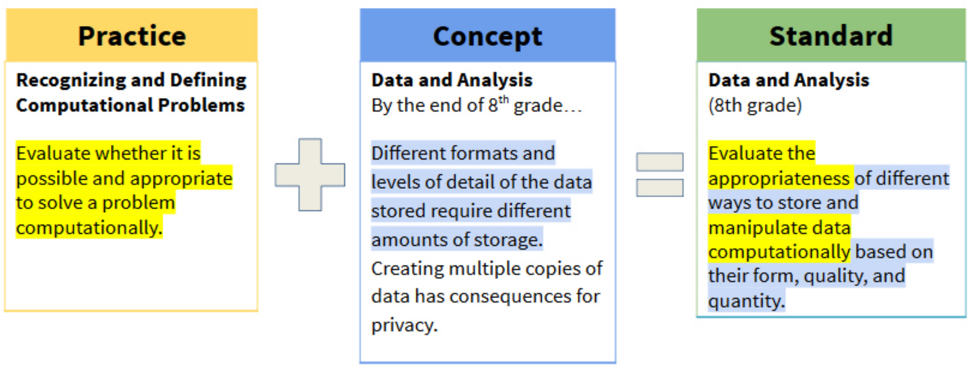
- Become informed citizens who can critically discuss computer science-related topics.
- Develop as learners, users and creators of computer science knowledge and artifacts.
- Better understand the role of computing in the world around them.
- Learn, perform and express themselves in other subjects and interests.[49]

Computer Science: What Should Students Know?

The K-12 computer science framework outlines *five core concepts* and *seven practices* educators and experts believe students should know as they exit grades two, five, eight and 12, as shown in the Appendix. Concepts and practices emphasize the physical and theoretical elements of computer science. The framework also offers guidance on developing standards, creating and implementing curricula, embedding computer science learning opportunities in different subject areas, and ensuring equity, diversity and accessibility.

States can use the framework to generate a measureable standard for a specific grade by combining a core concept with a specific practice, as Figure 1 shows. Teachers in any subject area can use the framework to create assignments through which students come to understand the concepts by engaging in the practices. Following the example in Figure 1, an eighth-grade art teacher might design an assignment in which students create personal digital art galleries after determining which image type — such as jpeg, gif or png — delivers the best image quality using the least space.

FIGURE 1:
How the K-12 computer science framework can inform the development of state standards[50]



Selecting Standards-Based Curricula and Instructional Resources

States can use the computer science standards they develop to create or adopt curricula that appeal to students of different genders, races, socioeconomic backgrounds and ability levels.

In this report, the Commission offers states several examples of well-supported, standards-based, low- or no-cost curricula for elementary and middle grades students. It also identifies two high school computer science curricula endorsed by the National Science Foundation (NSF). States can also use **external resources** to identify standards-based curricula:

- **Code.org reviews third-party elementary, middle and high school curricula** for quality, accessibility, outcomes, affordability and completeness.[51] Reviewed providers must offer affordable partnerships, proven scale and support, quality curricula and professional development.
- **SREB's rubric for evaluating third-party curricula**[52] includes computer science concepts and principles; the literacy, math and problem-solving skills students need for success in computing fields; and the elements of strong career pathways.[53]

Perseverance and Problem Solving

One-hour weekly **Code.org labs** help students at **West Hoke Elementary School** in **Raeford, North Carolina**, learn problem-solving skills that translate to their language arts, math and science classes. Says Principal A. J. Hammond: "Once they understand what they are doing, it goes like wild fire." Self-paced modules help students develop literacy and math skills and cultivate logic and reasoning. Young students use a drag-and-drop interface to create simple games. As they gain advanced writing skills, older students design complex games and apps in an after-school robotics club.

- **The Computer Science Teachers Association reviews third-party curricula** for alignment with CSTA standards and conducts curriculum reviews for state education departments upon request.[54]
- **LeadCS.org**, developed with NSF support, compiles tools and resources for K-12 schools that are seeking to offer computer science education.[55]
- **States may wish to review international models**, such as the United Kingdom's curriculum.[56]

Introducing Elementary School Students to Computer Science

In the elementary grades, students can learn computer science concepts and cultivate problem-solving skills through hands-on activities in their art, language arts, math, science and social studies classes.[57] The youngest students can develop computational thinking skills by solving puzzles, sorting and managing data, using digital media to create and illustrate stories, and creating games with drag-and-drop programming tools. Students in the upper elementary grades can work together to develop apps, explore careers and discuss the social and ethical issues of computing.

Designed for children between the ages of 4 and 10, **Code.org's Computer Science Fundamentals** is a free online four-course curriculum aligned with the CSTA's K-12 standards.[58] Teachers can deliver each 20-lesson course as a unit or over a semester. An online learning platform allows students to design and debug games at their own pace; other activities do not require a computer. Code.org offers educators free supplies and one-day professional development workshops in over 60 cities.

Code.org's CS Fundamentals: Sample Course Content

Course 1 (ages 4-6 – early readers) - Internet safety, loops and events, sequences

Course 2 (ages 6+ – beginner readers) - algorithms, binary code, conditionals, debugging

Course 3 (ages 8+) - digital citizenship, functions, nested loops, problem decomposition

Course 4 (ages 10+) - abstraction, algorithmic problem-solving, functions with parameters, variables

Developed by Harvard Graduate School of Education researchers with support from the NSF, **Creative Computing**[59] is a six-unit introduction to programming in Scratch, a visual programming language. Offered for free under a Creative Commons license, Creative Computing introduces elementary schoolers to concepts like sequences, loops, conditionals and operators and uses hands-on activities to teach problem-solving skills. ScratchEd's website offers teachers news, discussions, workshops and resources organized by education level, content type and language.

Engaging Middle Grades Students in Interdisciplinary Studies

Middle grades students flourish when their studies are challenging, meaningful and personally relevant.[60] In these years, students should understand computing devices and networks, consider how computing aids communication and use computational thinking skills to solve community problems.[61] Project-based learning, group activities and interdisciplinary approaches appeal to middle grades students.

Endorsed by the NSF, the standards-based **Bootstrap**[63] curriculum teaches math and programming by harnessing students' natural interest in gaming. Offered across two 20- to 25-hour courses, Bootstrap helps students design sophisticated computer games using concepts from algebra and geometry (e.g., coordinate planes, the Pythagorean theorem) and computer science (e.g., data structures, functions). Research shows Bootstrap improves student outcomes in algebra.[64]

Computer Science for All in Chicago

In December 2013, **Chicago Public Schools** launched Computer Science for All,[62] an effort to bring computer science to students in all grades. CS4All includes:

- Code.org's **CS Fundamentals** for K-5 students
- **CS in Algebra** and **CS in Science** for middle grades students
- **Exploring Computer Science** and **AP Computer Science Principles** for high school students

In February 2016, CPS became the first school district in the nation to add computer science as a core graduation requirement — separate from math and science — for all students beginning with the class of 2020.

Bootstrap's developers offer free curricula, teacher resources, discussion forums and downloadable student workbooks on their website. Partnering schools and districts receive two- to three-day workshops, visits and support from Bootstrap trainers.[65]

Bootstrap and **Project GUTS**[66] (Growing Up Thinking Scientifically) partnered with **Code.org** to develop two interdisciplinary computer science modules for the middle grades. **CS in Algebra** includes 20 hands-on lessons that apply algebra and geometry to game design.[67] **CS in Science** offers over 20 lessons that teach computer science within the context of the life, earth and physical sciences.[68] Course frameworks, lessons, teacher manuals, student workbooks and videos are free on the Code.org website. Teachers in partner districts must participate in professional development to offer either course.

SREB and **West Virginia** are developing project-based assignments in various subjects, including computer science and informatics, that prompt middle grades students to read complex texts, prepare written designs, keep engineering notebooks, learn science and math, and use technology.

Expanding High School Students' Understanding of Computer Science

Commission members urge states to require all high schools to offer students access to rigorous, standards-based computer science courses. To ease the initial burden of implementing such courses statewide, states can allow districts to offer them in different settings, including regular or regional high schools, technology centers, community and technical colleges, or teacher-facilitated online courses.

Two **National Science Foundation-funded introductory high school curricula** — Exploring Computer Science and AP Computer Science Principles — may encourage more students to explore computer science and computing careers.[69]

> *"ECS focuses on the creative nature of computing and uses technology as a tool for solving problems rather than studying the tool itself. Throughout the course we talk about the relevance of computer science and its impact on society. All students are looking for things that are interdisciplinary in nature."*
>
> — **Gail Chapman**, Director of National Outreach, Exploring Computer Science

Field-tested by many of the same University of California, Los Angeles researchers who studied the mechanisms and beliefs that steer underrepresented minorities away from computer science,[70] **Exploring Computer Science**[71] is a yearlong standards-based curriculum focused on three big ideas and six computational thinking practices related to the "creative, collaborative, interdisciplinary and problem-solving nature of computing,"[72] as shown in Columns 3 and 6 of the Appendix. ECS' six units feature project-based assignments that emphasize the real-world impact of computing technologies on individuals and society.[73] States, districts and schools may obtain a free review copy of the curriculum; to implement it, they must secure a license and provide ECS professional development. Teachers who lack district support may use the curriculum for free.[74]

The College Board's college-preparatory **AP Computer Science Principles** curriculum framework[76] takes an interdisciplinary, inquiry-based approach to introducing students to computer science concepts and practices, as shown in Columns 2 and 5 of the Appendix. AP CSP was also developed to appeal to diverse students with a more general interest in computer science and STEM. Unlike **AP Computer Science A**, which teaches

Integrating Computing, Robotics and STEM

Developed by researchers at the **University of California, Davis, C-STEM**[75] blends project-based instruction in math, programming, robotics and 3D modeling with after-school activities, camps and competitions for K-14 students. C-STEM's K-12 pathway in **Information and Communications Technologies** prepares students for admission to any UC campus:

- Elementary students learn robotics and math through coding activities.
- Middle grades students take computer programming and robotics courses.
- High school students take computer programming and robotics, AP CSP, a cyber-physical systems capstone and math integrated with computing and robotics.

Teachers receive syllabi, lessons, assignments, videos and materials. C-STEM training includes a two-day academy, a one-week summer institute and a train-the-trainer program.

programming in Java,[77] AP CSP allows teachers to teach different programming languages. In addition to an end-of-course exam, AP CSP includes teacher-administered performance tasks.[78]

The College Board publishes its curriculum framework, planning and pacing guides, and other resources online. It also endorses third-party providers — for example, **Beauty and Joy of Computing, Code.org, Mobile CS Principles, Project Lead the Way** and **Thriving in Our Digital World** — whose courses adhere to its framework, standards and assessment.[79] Schools wishing to offer AP CSP or AP CS A must submit a course audit form and syllabus for approval; participation in a College Board training and attendance at an AP Summer Institute are encouraged.[80]

Delaware incorporates Exploring Computer Science and AP CSP in two career and technical education career pathways. In computer science, students explore core concepts, principles and computational thinking in ECS before learning to program in AP CSP and AP CS A.[81] In the state's Cisco Certified Networking Academies, students take AP CSP or AP CS A plus courses on routing, switching, scaling and connecting networks.[82]

Maryland now allows computer science courses like ECS and AP CSP to count toward the state's one-credit technology education graduation requirement.[83] Such courses greatly expand students' technology education choices and encourage them to try computer science.

Extending Enrichment and Exploratory Experiences to All Students

The Commission urges states and districts to offer early and frequent opportunities for K-12 students to explore computer science through school clubs, competitions, camps, summer immersion programs, work experiences and other activities. Parents, community organizations and employers can help schools extend such opportunities to students.

Since the first Computer Science Education Week in December 2013, more than 282 million people have participated in Code.org's **Hour of Code**, a one-hour self-guided tutorial in which students create games featuring Minecraft, Star Wars and Disney characters using the Blockly programming language. Schools can extend learning beyond that first hour with Code.org's **Code Studio**, an online hub where teachers and students can pick from a range of 20-hour courses for students between the ages of 4 and 18.

West Virginia State Delegate Paul Espinosa at an Hour of Code event at Wildwood Middle School, December 14, 2015.

When offering such opportunities, states should consider serving boys and girls separately, in mixed-gender groups *and* with their families. Girls Who Code[84] offers clubs and summer programs that reduce the intimidation factor associated with computer science for many girls. A majority of the more than 10,000 girls served say they plan to major or minor in computer science in college.[85] One **Maryland** county adopted an after-school app development program for girls in the middle grades that appeals to the different style of gaming many girls enjoy. Grant funding also allowed Maryland public libraries to sponsor family coding nights to get parents and children excited about computer science.

The Commission encourages states to track participation in computer science courses and extracurricular activities. States lack significant data on the full range of opportunities available to students. And many schools enhance their computer science curricula with after-school programs that may not be accessible to the students who need them most. By tracking participation, states can take steps to ensure equitable access to after-school activities and link more of the school community into the learning process.

Additional Actions States Can Take:

Work in partnership with secondary and postsecondary educators, experts and industry leaders to develop K-12 computer science standards that include the essential concepts and practices students should master in the elementary and middle grades and high school.

- Align computer science standards and assignments so they reinforce foundational literacy, math and problem-solving skills and help students meet grade-level literacy and math benchmarks.

Develop or adopt standards-based, developmentally appropriate computer science curricula that appeal to diverse learners in the elementary and middle grades.

- Introduce elementary school students to computer science through hands-on activities embedded in key content areas, such as art, language arts, math, science and social studies.
- Adopt project-based, interdisciplinary computer science courses or curricular modules in the middle grades that appeal to adolescents' need for challenging, relevant studies.
- Evaluate the effectiveness of computer science-related curricula by tracking student outcomes and using data to adapt curricula, pedagogy and assessments to meet student needs and reflect the standards of the field.

Require all high schools to offer students access to rigorous, standards-based computer science courses, such as Exploring Computer Science and AP Computer Science Principles. After an initial period of implementing computer science curricula throughout K-12, require high school students to either complete a rigorous computer science course or demonstrate competency in computer science to graduate.

- Give districts and schools the flexibility to offer computer science courses in regular or regional high schools, at technology centers, on college campuses or through online courses.
- *Encourage high schools to relocate essential computer literacy skills, like keyboarding and basic computer applications, to the elementary and middle grades*.
- Ensure the equitable distribution of funding for professional development, curriculum implementation, hardware, software and internet access.[86]

Provide funding at the state, district and school levels to support expanded computer science learning opportunities in schools.

- Fund dedicated computer science staff at the state and district levels who will work with schools to scale up computer science curricula. Charge these staff with supporting the development and implementation of standards-based curricula, professional development, community outreach and extracurricular activities.
- Support schools by equitably funding the IT infrastructure and educational technology staff needed to expand computer science learning opportunities.
- Encourage postsecondary, community and employer partners to contribute funds, materials or in-kind support to schools that offer computer science education.

Extend early and frequent opportunities for K-12 students and their families — especially girls, black and Hispanic students, and students from low-income families — to explore computer science and computer science-related careers.

- Provide schools with funding and release time for teachers to support computer science clubs, competitions, camps, summer immersion programs, work experiences and other learning experiences for students.
- Offer learning opportunities to single-gender and mixed-gender groups and families.
- Track student participation in computer science learning experiences in and out of school to ensure wide participation.

Action 2:
Lay the Groundwork for Learning Computer Science

A strong academic foundation is essential to learning computer science in the elementary and middle grades, high school and beyond. Yet many American students have poor academic skills. Only 28 percent of ACT-tested graduating high school students meet ACT's college-readiness benchmarks in English, reading, math and science.[87] Among students with an interest in STEM, which includes computer science, just 36 percent meet readiness benchmarks in all four areas.

Poor literacy and math skills hinder students from completing degrees and pursuing careers in computing fields. SREB's Commission on Community Colleges reports that about 50 percent of first-year community college students test into at least one developmental reading or math course, and of those requiring more than one, less than 10 percent will complete a credential.[88]

The challenge is clear: States must help students meet grade-level standards in literacy, math and science. They can do so by incorporating opportunities to enhance academic and critical-thinking skills across K-12 curricula, not just in computer science courses or learning experiences.

What Skills Do Students Need?

Computer science is fundamentally about solving problems,[89] **a process that requires high-level literacy skills**, like the ability to perform research, read complex texts, define problems and explain the steps of a solution. Software developers need strong writing skills to create user guides, for example.

Literacy skills are also essential to **coding** or **programming**, the practice of using **programming languages** to write instructions that tell software, apps and websites what to do. Similar to human languages, programming languages are comprised of text or symbols with specific meanings that are governed by precise grammatical rules. Programming languages make it easier for people to create algorithms that can be translated into binary code, the language of 0s and 1s computers understand.[90]

01000011 01101111 01100100
01101001 01101110 01100111
00100000 01101001 01110011
00100000 01100110 01110101
01101110 00101110

Mathematical literacy is critical to computer science. Although math is essential to all STEM careers,[91] computer science draws most of its core concepts — including binary numbers, definitions, functions, graphs, linear algebra, logic, probability, proofs, sets and vectors — from such mathematical fields as **algebra, geometry, calculus, statistics** and **discrete math**.[92] For example, students creating a video game in which characters move and interact on a two-dimensional playing field are using algebra and geometry to plot positive and negative points on the quadrants of a Cartesian coordinate plane.

SREB maintains that students benefit from taking four years of high school math aligned with their career and college goals.[93] A high school student who wants to earn a bachelor's degree in computer science or information science, for example, needs to take courses above Algebra II, like pre-calculus, calculus, statistics, finite math or discrete math. At the postsecondary level, ABET-accredited undergraduate computer science programs are required to offer discipline-related math beyond pre-calculus, namely "discrete [math], calculus, linear algebra, numerical methods, probability, statistics, number theory, geometry or symbolic logic."[94]

By contrast, a student who is pursuing an associate degree in an IT field may benefit from four years of math that includes Algebra I and II, geometry, statistics and other career-related advanced math courses.[95] A study of nine popular first-year community college programs, including computer programming and IT, found that most programs required Algebra I, geometry, statistics and middle school math. Researchers noted that programming required the highest levels of math communication, problem solving and reasoning skills.[96]

Commission members urge states to consider carefully not only the different levels of math preparation required by various computing careers, but also under what conditions computer science might take the place of math or science in graduation requirements. Commission members suggest that states seeking to prepare more individuals for highly skilled jobs in computer science should raise the bar for math achievement. As such, states should consider whether substituting an introductory computer science course for a higher math course might jeopardize a student's ability to pursue advanced degrees and careers in high-demand computing fields.

"There is a deep and beautiful connection between mathematics and many areas of computer science."

— Joint Task Force on Computing Curricula[97]

Arkansas designed Computer Science and Mathematics to help students use math, programming and algorithms to solve problems.[98] Depending on the certification of the teacher who offers it, the course can count either as a fourth math credit, a career-focused credit or a computer science flex credit.[99] **Although flex credits may be a good option for some students, the Arkansas Department of Education advises schools to counsel students and parents who are considering computing-intensive majors to complete a four-course advanced math pathway**.

Computer scientists also must be able to solve problems creatively and collegially, tackle complexity and ambiguity confidently, and consider the social and ethical implications of their work.[100] Real-world projects help students cultivate such qualities as they build computational thinking skills. Similar to the scientific method or the engineering design process, computational thinking involves:

- Formulating problems in a way that enables [individuals] to use a computer and other tools to 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[101]

Strategies for Strengthening Literacy, Math and Problem-Solving Skills

Commission members urge states to adopt instructional strategies that develop students' literacy, math and problem-solving skills from the earliest grades through high school.

When offered throughout the K-12 curriculum, **project-based learning** spurs creativity and helps students make the connection between what they learn in the classroom and the real world. In this interdisciplinary approach to instruction, teachers support students in taking ownership of their work.[102]

Schools can incorporate **literacy and math skills in every subject area and grade** using research-based professional development frameworks, such as the **Literacy Design Collaborative**[103] and the **Mathematics Design Collaborative**,[104] which enhance students' literacy achievement and content knowledge and develop students' procedural fluency and math reasoning skills. SREB is helping **Kentucky** middle grades schools link LDC and MDC to the Kentucky Framework for Teaching.

States can also adopt **readiness courses and other targeted interventions** that help struggling students meet literacy and math benchmarks before enrolling or even while enrolled in high school computer science courses. States can use approved readiness assessments — for example, the ACT Aspire in eighth or ninth grade or the ACT in 10th or 11th grade — to identify students who need extra help as they transition from the middle grades to high school or from high school to higher education.

- SREB's **Ready for High School courses**[105] offer an early intervention for underprepared ninth-graders. Students in Ready for High School Literacy develop, defend and write about ideas in different subjects. Students in Ready for High School Math learn how to use math formulas and concepts to solve real-world problems.
- **Arkansas, Georgia, Kentucky, North Carolina** and **Tennessee** worked with SREB to design **Literacy Ready** and **Math Ready**, which help 11th- and 12th-graders master essential literacy and math skills in preparation for college-level studies.

Some states mandate including **scientific problem-solving skills** in computer science courses that count as a science credit toward graduation. The **Virginia General Assembly** passed legislation in 2014 allowing a computer science course to count as laboratory science[106] if its curriculum includes a significant experimental component. Students must learn how to develop a testable question based on a review of research, form a hypothesis to drive a test, manipulate variables under controlled conditions, use systematic methods to organize and analyze data, and present and defend their conclusions and findings. In 2016, the Virginia General Assembly added **computer science and computational thinking skills** to the state's Standards of Learning.[107]

Steven Staples, Superintendent of Public Instruction, Virginia Department of Education

SREB's **Advanced Career curricula**, including pathways in **Health Informatics** and **Informatics**,[108] develop students' critical thinking, problem solving and communication skills. Postsecondary and industry partners designed each four-course pathway to enhance students' academic skills as they learn how to use data to make better decisions in business, medicine and other fields. Assignments emphasize teamwork and project management.

Additional Actions States Can Take:

Throughout K-12, integrate and teach the essential literacy skills that students need to master grade-appropriate computer science standards.

- Adopt computer science curricula featuring project-based assignments that require students to read, think and write about challenging texts.
- Ensure K-12 teachers are able to prepare students for success in computer science by providing them with professional development on designing lessons and assignments that engage students in reading, thinking and writing about challenging texts in their disciplines.

Throughout K-12, integrate and teach the essential math concepts and skills that students need to master grade-appropriate computer science standards.

- Adopt computer science curricula featuring project-based assignments that require students to apply math reasoning, logic and problem-solving skills from such subjects as algebra, geometry, statistics, calculus, finite math and discrete math.
- Ensure K-12 math teachers are able to prepare students for success in computer science by providing them with professional development on using formative assessment lessons to help students develop procedural fluency and deepen math reasoning and understanding.

Provide targeted interventions and readiness courses to students who need extra help mastering the grade-level literacy and math skills needed for success in computing fields.

- Offer interventions as stand-alone courses, co-requisite courses or just-in-time modules.

Require students to take four years of math aligned with their career and college goals. Counsel students pursuing computing degrees and careers to take math aligned with their goals.

- For computer science and related disciplines, four years of math should include Algebra II and additional advanced courses like pre-calculus, calculus, statistics, finite math and discrete math.
- For IT and more applied computing fields, four years of math should include Algebra II, geometry, statistics and other advanced math courses related to the field.

Support K-12 academic and computer science teachers in designing interdisciplinary, project-based instruction and assignments that engage students in applying literacy, math and computational thinking skills to solve problems.

- Ensure that computer science and core academic teachers have time to engage in shared professional development and to co-plan lessons, activities and assignments.

Action 3:
Create Clear Pathways to Computing Careers

Labor market demand for individuals with credentials and degrees in computing fields far outstrips our current capacity to produce them. At the same time, too few students are graduating ready to earn these credentials and degrees. Career pathways can help more young people transition from high school to higher education and careers in computer science or fields that require significant computing know-how.

SREB states are designing career pathways that help more students successfully transition from high school to postsecondary studies and great careers in computer science and related fields. Career pathways expand learning opportunities because students see their studies as a gateway to credentials of real value. SREB's *Credentials for All* report[109] offers states policies and practices for building strong career pathways.

The Commission urges states to design pathways that help students secure postsecondary credentials and degrees in high-demand computing fields. A critical first step is for state boards of education and state workforce boards to jointly convene career pathway advisory councils charged with creating state and regional strategic plans that identify workforce shortages, establish a vision for increasing postsecondary attainment, offer guidelines for regional career pathways and establish benchmarks for program quality. Advisory councils should include stakeholders from secondary and postsecondary education, labor departments, economic and workforce development agencies, workforce boards, industry, parent-teacher associations and the community.

Rewarding Schools for Offering Industry Certifications

Florida uses weighted funding, accountability points and bonuses to reward schools for each student who earns a Gold Standard industry certification aligned with an associate degree program at a state college or university.[110] The Cisco Certified Network Associate Security (CCNA® Security) certificate, for example, counts for three college credits toward an Associate in Applied Science or Associate in Science degree in IT Security, Networking Services Technology or Computer Engineering Technology.

Other advisory council roles include:

- Developing, adopting or redesigning career pathways to meet labor market demand
- Evaluating career pathways for quality
- Creating career pathway road maps that illustrate the on- and off-ramps students can take to computing degrees and jobs
- Identifying and adopting measures of students' mastery of computer science knowledge. Measures include:
  - third-party industry certification exams, such as CompTIA A+ or Cisco Certified Network Associate Security certifications
  - validated assessments, such as AP exams
  - other alternative measures, such as state-approved end-of-course exams and dual enrollment courses
- Redesigning the senior year of high school to give college-ready students a jump-start on a credential or degree

Essential Elements of Computing Career Pathways

High-quality career pathways begin with a sequence of at least four pathway courses — taught along with college-ready academics — and connect seamlessly to postsecondary education. States can offer career pathway courses in different settings, such as:

- career academies, early college high schools, and accelerated senior-year programs
- shared-time technology centers or full-time technical high schools
- online or blended instructional programs — for example, massive open online courses (MOOCs), virtual high schools and online university courses[111] — that bring rigorous courses to advanced students, geographically isolated schools and schools without a computer science teacher

Career pathways allow students to earn college credits and satisfy graduation requirements simultaneously. Most colleges and universities accept passing AP exam scores, like AP CS A, toward general education or major requirements. Most states also offer **dual enrollment** or **dual credit programs**[112] that allow students to earn high school and college credits at the same time, saving them time and money on the path to a degree.[113] As Table 3 and Figure 2 show, SREB's **High Schools That Work model**[114] allows college-ready seniors to complete up to 30 credits of dual enrollment courses — equal to a first year of college studies — toward an associate or bachelor's degree.

States can take steps to ensure that dual enrollment courses add value to students' high school and college experiences. First, states can work with two- and four-year institutions to ensure that **dual enrollment credits transfer to a broad range of associate and bachelor's degrees**.

Second, states can **counsel students and parents about dual enrollment and credit transfer policies**, which confuse many students.[115] A high school student who is interested in pursuing a bachelor's degree in cybersecurity, for example, needs to know whether a community college dual enrollment course counts toward an Associate of Science degree, which transfers to bachelor's degree programs, or toward a terminal, workforce-ready Associate of Applied Science degree.

Third, states can ensure that **dual enrollment courses meet accreditation guidelines**. Postsecondary accreditation organizations, like the Southern Association of Colleges and Schools,[116] as well as

Criteria for High-Quality Dual Enrollment Courses

- Enrolled students meet literacy and math readiness benchmarks.
- Courses count for high school and college credit.
- Courses are taught to the same level of rigor and using the same curricula, syllabi, materials and assessments as on the college campus.
- Courses are taught at the same pace and on a similar schedule as on the college campus.
- Courses are taught by college faculty or accredited high school teachers.

accreditation boards for computer science and related disciplines, like ABET and the Association for Computing Machinery, set criteria for the kinds of courses that can be offered for college credit and where and by whom they can be taught.

Fourth, states can incentivize two- and four-year colleges and universities to **create stronger pipelines to their credential and degree programs** by allowing eligible high school seniors to complete a substantial portion of their first year of postsecondary studies before graduating, as in the HSTW accelerated career pathways model. The Commission urges states to help colleges and universities expand their computing programs and reduce the budgetary and staffing constraints associated with extending access to those programs to high school seniors.[117]

In **Virginia**, Newport News Public Schools, Hampton City Schools, Thomas Nelson Community College and Old Dominion University are creating pathways to careers in cybersecurity, computer modeling and simulation, and computer science by extending 2+2 programs — through which high school juniors and seniors take courses for high school and college credit at TNCC — into ODU bachelor's degrees.

Career Pathways in Computer Science

The Commission urges states to adopt Exploring Computer Science or a similar broad-based, civics-oriented course as an introduction to computing pathways. Some SREB states, **Delaware**, for example, offer both ECS and AP Computer Science Principles. **Arkansas** uses its own introductory courses.[118] Other states may choose curricula like Code.org's problem-based CS Discoveries for students in grades six through nine.[119]

Table 3 illustrates career pathway course sequences in software development and Advanced Career Informatics. In ninth grade, students in both pathways might take ECS or a similarly accessible course as an introduction to computer science concepts and principles. In 10th grade, **applied courses** — such as the introductory computer animation, digital media, game design or robotics courses many schools already offer — entice students to pursue further study in computer science.

In 11th and 12th grade, career pathway course work becomes more challenging. A student pursuing a software development pathway, for example, might complete an **intensive two-course sequence** in a specific programming language or two courses in different languages. As Table 3 shows, under the HSTW model, **dual enrollment courses** accelerate students' progress toward an associate or bachelor's degree. Across grades, ongoing experiential learning culminates in a senior-year internship or capstone project.

TABLE 3:
Sample Career Pathway Course Sequences in Software Development and Advanced Career Informatics

Pathway	Grade 9	Grade 10	Grade 11	HSTW Accelerated Grade 12 / 13*
Software Development	ECS	Applied Course (e.g., Intro to Digital Media, Animation, Robotics, AP CSP)	Programming Language I (e.g., AP CS A, Java I, C++ I, Python I, Visual Basic I)	Intro to Algorithmic Design I** Critical Reading & Composition Precalculus Mathematics Liberal Arts Elective
			Programming Language II (e.g., Java II, C++ II, Python II, Visual Basic II)	Intro to Algorithmic Design II UNIX/Linux Fundamentals Rhetoric & Composition Calculus I
Advanced Career Informatics	ECS	Computers, Networks & Databases	Databases in the Cloud	Intro to Algorithmic Design I*** Critical Reading & Composition Basic College Mathematics Liberal Arts Elective
		Design for the Digital World	Developing a Cloud Presence	Intro to Algorithmic Design II UNIX/Linux Fundamentals Rhetoric & Composition Calculus for Business Administration & Social Sciences

Notes. * College-ready seniors take dual enrollment courses toward an associate of applied science, associate of science or bachelor of science degree. ** and *** Modified from the University of South Carolina's Computer Science and Computer Information Systems Technical College Transfer Credit guides.

Career pathway course sequences are flexible so high school students can deepen their skills in one field or pursue new interests in another. At the undergraduate level, multiple entry points into and through computer science programs accommodate students with different levels of computing knowledge, as well as students who are transferring to or from other colleges or programs.[120]

Career Pathways in Health Informatics and Informatics

Ohio and **Kentucky** worked with SREB to co-develop **Advanced Career Health Informatics** and **Informatics** pathways that take a hands-on approach to teaching students how to design information management systems that convert data into new knowledge and applications in health and business. In Health Informatics, students use IT, data analysis software and statistics to address public health data mining, electronic community health initiatives and rehabilitative gaming. Informatics students prepare for careers as human-computer interface designers, information systems managers or usability analysts.

Career Pathways in Cybersecurity

States have standards-based options to choose from in cybersecurity and cyberforensics. The **National CyberWatch Cente**r[121] at Prince George's Community College in Maryland develops high school and community college curricula that articulate with two- and four-year degree programs and help students acquire industry credentials in cyber defense, network forensics, network and systems security administration, and secure software development. The **Advanced Cyberforensics Education Consortium**[122] at Florida's Daytona State College works with schools in **Florida, Georgia, North Carolina** and **South Carolina** to offer hands-on curricula in cybersecurity and cyberforensics for younger students and high schoolers.

Georgia's Augusta University united with two technical colleges, two area chambers of commerce, two school districts, the Central Savannah River Area Alliance and nearby Fort Gordon — the new home of the U.S. Army Cyber Command Headquarters — to form the **Alliance for CyberSecurity Education**.[123] The Cyber College of the Cyber Center of Excellence at Fort Gordon[124] authored the second and third cybersecurity courses of a three-course cybersecurity pathway[125] approved by the state for all high schools. Augusta University is supporting teachers in schools offering the pathway.

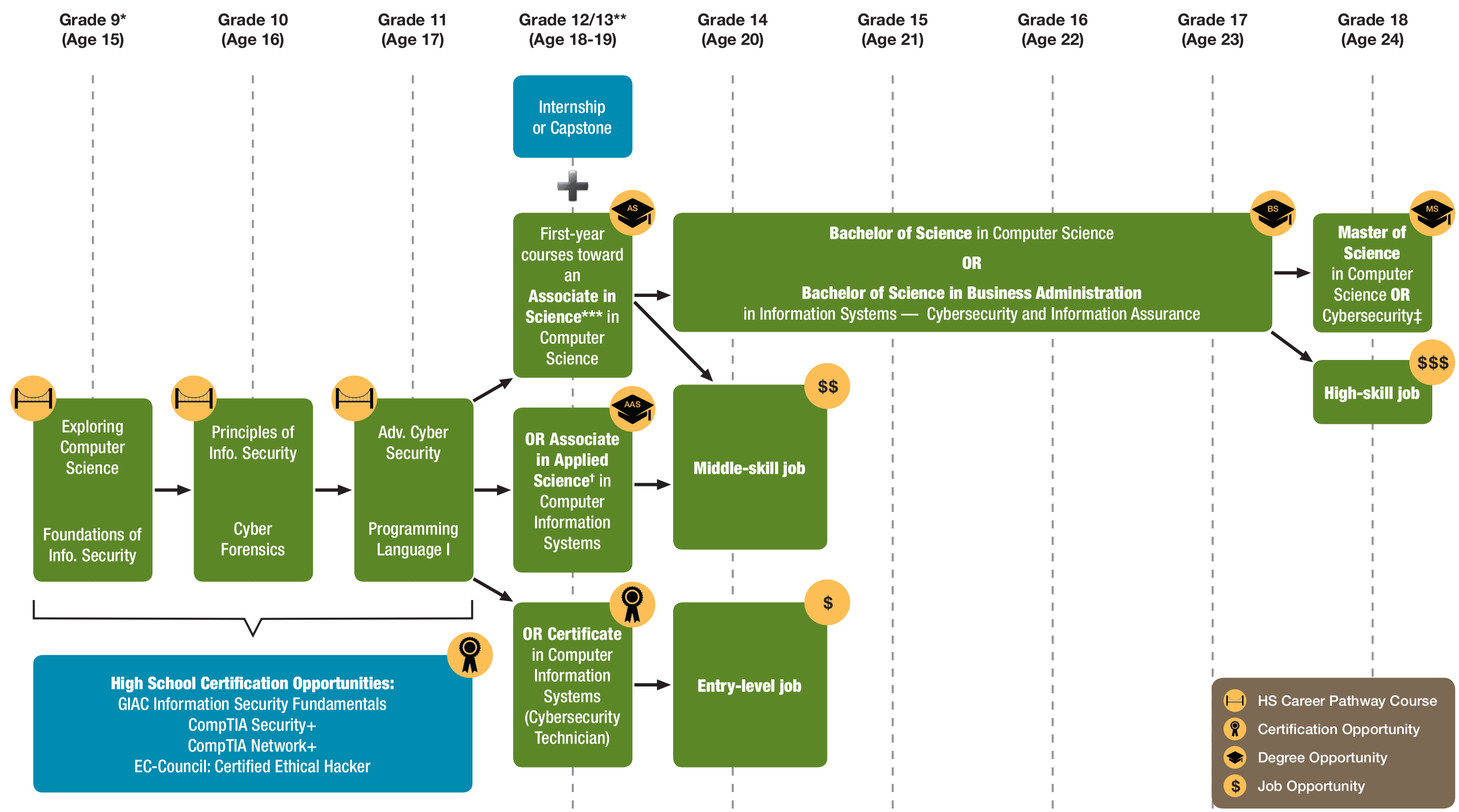
Georgia's Cybersecurity Skills Gap

The Chancellor of the **University System of Georgia** convened two task forces to study skills gaps and design pathways in **health informatics** and **cybersecurity**. The cyber task force uncovered a striking skills gap in the state.[126] In 2014, just 2,300 graduates out of about 300,000 enrolled students at 30 USG institutions were in IT-related fields. Of these, USG identified only 46 graduates qualified for 8,220 available cyber jobs in the state. Most cyber jobs require a bachelor's degree, and many require financial and regulatory knowledge and security clearance.

Huntsville City Schools collaborated with the **Alabama Department of Education** to develop a four-course cybersecurity curriculum.[127] Middle grades and high school cybersecurity teachers attend five-day summer camps hosted by the University of Alabama, Huntsville. In 2015, the Air Force Association named the district a CyberPatriot Center of Excellence. CyberPatriot competitions encourage youth to pursue STEM careers. Figure 2 illustrates the varied paths a Huntsville cyber student might take to college credentials and degrees and good jobs.

South Carolina's Charleston County School District is participating in the **Consortium Enabling Cybersecurity Opportunities and Research**,[128] a U.S. Department of Energy-funded partnership of national laboratories and 13 Historically Black Colleges and Universities. CECOR partners are developing K-20 career pathways that close the cyber skills gap. Students at Charleston's Lowcountry Tech Academy complete a cyber course sequence and engage in work-based learning.[129] Seven state HBCUs offer training for CCSD teachers and summer camps for CCSD students.[130]

FIGURE 2:
Cybersecurity Career Pathway Options



Notes. * This hypothetical pathway illustrates courses a cybersecurity student in Huntsville, Alabama, might take. The pathway begins with Exploring Computer Science and includes the four-course Computer Sciences — Cyber Security sequence offered in Huntsville City Schools' Cyber Academy plus at least one course in a programming language.

** Under the new HSTW model, for example, students who meet literacy and math readiness benchmarks can complete up to 30 college credits in an accelerated 12th/13th year. Students who do not meet benchmarks take co-requisite readiness courses and career pathway courses.

*** The AS at Northeast Alabama Community College is a transfer degree. NACC's Computer Information Systems Department is home to the Center for Information Assurance, designated as a National Center of Academic Excellence in Information Assurance Education — Two Year. National Centers of Academic Excellence are sponsored by the Department of Homeland Security and the National Security Agency.

† NACC's AAS degree is a two-year terminal degree intended for students making an immediate entry into the workforce. Alabama's Articulation and General Studies Committee established a statewide general studies curriculum that articulates transfer credits across two- and four-year public institutions. All courses in Areas I - IV (general education requirements) transfer to all institutions; only some AAS Area V courses (e.g., degree requirements, occupational specialty requirements, core courses, electives) may transfer to a four-year institution. AAS students are advised to use the Statewide Transfer & Articulation Reporting System to create a transfer guide for their major.

‡ The MS in Cybersecurity offered by the University of Alabama, Huntsville, features tracks in Computer Science, Computer Engineering and Management. The University of Alabama, Huntsville, has recognized National Centers of Academic Excellence in Information Assurance Education, in Cyber Defense Education and in Cyber Defense Research.

Supporting Career Pathways in Computing Fields

States can support pathways like these by including computer science and career readiness-related measures in their accountability systems.[131] State longitudinal data systems can help states track outcomes and market computing careers to students and parents. States can also reward students who study computer science by awarding college credits or weighted grade-point averages for rigorous computer science courses.

Commission members report that some students may avoid career pathways because they fear completing one will harm their chances of securing an academic merit scholarship. States can encourage more students to pursue pathways in computer science or other fields by including pathway completion in scholarship eligibility requirements. States can also offer special scholarships that target underrepresented students who pursue computing degrees.

Additional Actions States Can Take:

Charge a state career pathway advisory council with developing pathways that meet identified workforce needs in computing fields. Jointly appointed and overseen by the state board of education and state workforce board, council members should include secondary and postsecondary education leaders, state career and technical education directors, labor department and economic and workforce development agency officials, employers, parents and community members. State councils should:

- Create a state career pathway strategic plan and establish guidelines for regional councils.
- Develop, adopt or redesign pathways in high-demand computing fields and create road maps that illustrate college and career options in those fields.
- Set performance metrics and outline a process for auditing pathways for rigor, quality and positive student outcomes, such as pathway completion, credential and degree attainment, and employment in high-skill, high-wage, high-demand jobs.
- Promote access and equity by identifying strategies that encourage girls, black and Hispanic students, and students from low-income families to pursue computer science and computer science-related careers.
- Identify, evaluate and approve industry certification exams, validated assessments and other measures of student mastery of computer science concepts and practices.
- Prioritize the investment of federal, state and private-sector funds in computing pathways.

Build career pathways consisting of four or more courses that connect seamlessly to postsecondary programs in high-demand career fields, such as cybersecurity, informatics and software development. Career pathways:

- Begin with Exploring Computer Science or a similarly accessible introductory course.
- Feature college-level courses, such as AP and dual enrollment courses, that satisfy graduation requirements and accelerate postsecondary attainment.
- Allow students to engage in experiential learning, such as internships and capstone projects.
- Offer flexibility, allowing students to explore different interests or develop deep knowledge and skills in a specific field.
- Take a project-based approach to integrating computer science and academic skills.

Redesign the high school senior year to allow students who meet college-readiness benchmarks to earn college credits that transfer to associate and bachelor's degrees and to help struggling students prepare for college.

- Use state-approved assessments to determine students' readiness for college studies.

- Enroll struggling students in co-requisite readiness courses and career pathway courses.
- Work with postsecondary institutions and accreditation organizations to ensure that dual enrollment credits transfer across associate, bachelor's and graduate degree programs.
- Educate students and parents about AP, dual enrollment and credit transfer options.

Include computer science and computer science-related career pathways in state accountability and funding systems.

- Adopt career-readiness indicators that assess and reward districts, schools and teachers for increasing the percentage of students in computing fields who complete career pathways; earn college credits, industry credentials or postsecondary degrees; participate in experiential learning; meet college- and career-readiness benchmarks; and pursue college degrees.
- Use weighted funding to prioritize investment in high-demand career pathways.
- Identify rigorous computer science and IT courses that can be offered for dual credit and carry extra weight in the high school GPA.
- Ensure that eligibility requirements for merit-based, state academic scholarships include the completion of career pathways in all fields, including computing fields.
- Create special scholarships for underrepresented students who pursue computing degrees.

Action 4:
Prepare Great Computer Science Teachers

Great teachers are key to kindling student interest in computer science and putting more young people on a path to careers in computing fields. Great teachers not only impart the essential knowledge, skills and dispositions needed to learn computer science, they also empower students to use computer science to solve problems in their communities.[132]

Whatever their background, great computer science teachers are creative, enthusiastic and reflective about their practice. Gail Chapman, director of national outreach for Exploring Computer Science, believes that the best way to identify potential computer science teachers is to recruit problem-solvers — teachers with an interest and passion for technology who learn alongside their students.

"We can't put just any teacher in a room to teach these classes… We need to make sure that teachers are culturally competent so they can relate to a diverse student body. We need to recruit more minorities to teach computer science. Students need to see people in front of them who look like they do."

— **Brenda Gilmore**,
Tennessee State Representative

Computer science teachers need strong initial training, ongoing professional development and opportunities to collaborate with teachers in other subject areas. Although many new Exploring Computer Science teachers have no formal computer science training, they build confidence during two years of professional development. In their first summer institute, teachers focus on ECS' first two units and model inquiry-based learning. Teachers receive training on the other four units during the year, then engage in learning communities with new and veteran ECS teachers in a second summer institute.

"We need to move away from teaching computer science only in computer science classrooms and start thinking of our teachers as a team. Teachers should work together and articulate their curricula so students understand how each subject builds upon the other."

Donna Johnson, Executive Director, Delaware State Board of Education

Interdisciplinary teacher collaboration is essential to advancing academic achievement in all areas, not just computer science. To do this, principals must provide time for teacher teams to co-plan or co-teach courses in computer science and other subjects.

Barriers to Teacher Certification in Computing Disciplines

Many states are experiencing shortages of skilled teachers in most subject areas, not just computer science. However, teacher shortages in computer science and related fields may have serious and far-reaching consequences for our national economy and security. By one estimate, the United States needs at least 10,000 more computer science teachers to bring quality computer science courses to all high schools.[133]

Without the ability to attract or prepare qualified teachers, schools and districts cannot offer computer science. In a recent survey,[134] 44 percent of principals and 57 percent of superintendents cited an inability to find skilled teachers as a reason for not offering computer science. However, 40 percent of principals from schools not offering computer science said that a teacher at their school could teach such courses, a sign that other barriers — resources or certification requirements, for example — may prevent schools from offering computer science.

Common Routes to Teaching

Research shows that most computer science teachers enter the classroom as:

- new teachers working toward their first certification
- new teachers with industry experience but no teaching experience
- veteran teachers certified in another area but with computer science teaching experience
- veteran teachers certified in a non-computer science area[135]

For both new and veteran teachers, acquiring a computer science certification can be frustrating. Most states lack postsecondary teacher preparation programs in computer science, and many offer a confusing array of certifications, endorsements and licensures that vary based on which K-12 academic department offers computer science.[136] Such certifications may not include computer science content or pedagogies.[137] Some state certification systems require teachers to complete courses not offered at state universities or lack an alternative for teachers from industry.[138]

At present, only **Arkansas** and **Wisconsin** require computer science teachers to complete the **computer science Praxis exam** as a measure of their readiness to teach. Originally developed by the Educational Testing Service for **Texas**, the computer science Praxis assesses the knowledge, skills and abilities of grade four-12 teachers in technology applications, computational thinking skills and programming.[139] In 2015, just 26 teachers nationwide took the computer science Praxis.[140]

The Commission urges education leaders, computer science organizations, policy groups, industry leaders and others to **collaborate with ETS to develop a new multistate computer science Praxis** focused on higher-level programming and computational thinking skills for grade seven-12 teachers.

Strategies for Preparing and Supporting Computer Science Teachers

Overall, more SREB states are meeting the challenge of clarifying the certification process and supporting computer science teachers with ongoing professional development. As Table 2 shows, as of October 2016, 11 of SREB's 16 states offer straightforward paths to computer science certification that include options for new and veteran middle grades and high school teachers.

To support these efforts, the Commission urges states to develop **multi-faceted certification, induction and professional development systems** that help new and veteran teachers acquire computer science content knowledge and master the pedagogical skills needed to engage diverse learners.

"Requiring all new teachers to have had at least one significant computer science course or experience prior to licensure, regardless of the discipline in which they will teach, would be immensely helpful in building a sustainable pool of teachers in the future."

— **Mark R. Nelson**, Executive Director, Computer Science Teachers Association

Commission members advise states to embed computer science content in pre-service preparation programs for elementary and middle grade teachers. Two university-based STEM teacher preparation programs offer potential models:

- **North Carolina State University**'s undergraduate elementary education program, for example, prepares teachers in all disciplines to deliver STEM-focused instruction.[141] Candidates must complete at least 27 credits of STEM-related courses and two pedagogical methods courses.
- The **UTeach** STEM teacher preparation program at the **University of Austin** allows students who are pursuing degrees in computer science, engineering, math or science to acquire a secondary teaching certification without adding time to their programs.[142] UTeach integrates STEM content with inquiry-based, problem-based and project-based learning pedagogies.

Commission members recognize that such multifaceted systems may take years to design and implement fully. As a short-term solution, states can offer **two- to four-week, full-day summer institutes**, led by a master teacher, in which new computer science teachers learn their curriculum by completing the same projects and assignments as their students. Daily activities include time for participants to reflect on the facilitation strategies modeled by the master teacher.

Teachers preparing to teach one of SREB's **Advanced Career pathways**, for example, attend a two-week summer institute in which they learn each course's technical content, technology, software and embedded math; practice incorporating literacy skills in instruction; tackle the course's hands-on projects; and acquire strategies for managing classrooms and assessing student learning. Teachers who complete the summer institute typically receive a state endorsement to teach the AC curriculum. Ongoing support includes in-service training, professional learning communities and additional summer institutes.

States need the support of accreditation and certification organizations to expand the computer science teacher talent pool. Commission members recommend that states collaborate with the Council for the Accreditation of Educator Preparation[143] to update teacher preparation programs to include computer science content knowledge and instructional practices. States can also work with the National Board of Professional Teaching Standards to add computer science to its slate of 25 certificate areas for National Board Certified Teachers.[144]

Federal and state agencies, computer science and educational organizations, state and district leaders, and global technology companies — for example, Apple, Facebook, Google and Microsoft — are committed to supporting teacher preparation as part of a multistate **Computer Science for All**[145] initiative:

- The **National Science Foundation** is investing $120 million over the next five years to support teacher professional development and ECS and AP CSP curriculum implementation. Out of this investment, $5 million will go to pilot-testing other professional development approaches.

- The **Corporation for National and Community Service** is providing up to $17 million over the next three years to support teacher training in computer science.
- **Code.org** will offer computer science training to 25,000 teachers in 2016, having already exceeded its goal of training 10,000 teachers in 2015 by 1,000 teachers.
- The Computer Science Teachers Association's **Continuous Professional Development Pipeline program**[146] will include:
  - A developmental pre-assessment that determines where teachers need support and generates personalized professional development road maps
  - A digital badging or portfolio system that tracks and authenticates earned continuing education units (CEUs) and professional development
  - Certificates in specific content areas, such as the online eight-hour CEU cybersecurity education certificate co-developed with the Cyber Innovation Center and LifeJourney[147]

SREB States' Strategies for Preparing Computer Science Teachers

Arkansas is revising its teacher certification and licensure pathways to align with its new K-12 computer science standards and is employing several strategies to enlarge the teacher talent pool:

- In the summer of 2016, the **Arkansas Department of Education** directed about $1 million to support **two professional development areas**: (a) preparation for the computer science Praxis for high school teachers and (b) training for master teachers on the state's K-8 standards and coding block for grades seven or eight.[148]
- The department's three-pronged approach to teacher preparation includes (a) **retraining teachers** through week-long boot camps and ongoing engagement in virtual professional learning communities,[149] (b) working with postsecondary institutions to create **computer science teacher education pathways**, such as the Computer Science Education for Teacher Licensure program at Arkansas Tech[150] and (c) offering a **nontraditional route to computer science licensure**.[151]
- The **Arkansas Department of Career Education** chose a licensure approach for its new three-year Mobile Applications Development pathway[152] to attract teachers. Whether they come from backgrounds in art, business or STEM, any teachers who attend the state's training may receive a licensure to teach the MAD pathway in grades seven-12.

The **Alabama State Department of Education** is partnering with **Code.org** and **A+ College Ready** to prepare at least 50 new AP computer science teachers in 2016-17 — doubling the number of qualified computer science teachers in the state.[153] Over two years, Code.org will provide about $500,000 in curricula and professional development. A+ College Ready is recruiting teachers to participate in training, which includes a five-day summer workshop, 10 days of training during the school year, and access to online resources and weekend study sessions.

Maryland offers **two routes to computer science teacher certification**: a general secondary content area certification for those in traditional teacher preparation programs[154] and a Standard Professional Certificate offered by a Maryland Approved Alternative Preparation Program for teachers who are entering the classroom as career-changers.[155] State colleges and universities are convening regional summer institutes in which K-12 and college faculty work together to incorporate computational thinking skills into computer science, math, science and other disciplines.

Henry Johnson, Assistant State Superintendent for Curriculum, Assessment and Accountability, Maryland State Department of Education

Certified **Kentucky** teachers who hold a computer science endorsement for grades eight-12 are eligible to teach AP computer science courses, as are certified teachers with a specialization in math. AP computer science teachers in the AdvanceKentucky network of schools[156] — a statewide math-science partnership between the Kentucky

Science and Technology Corporation, the Kentucky Department of Education, the National Math and Science Initiative and other organizations — participate in five-day summer institutes and two-day fall trainings in their first two years. Support includes mentoring, teaming across middle and high schools, and stipends for professional development.

Additional Actions States Can Take:

Recruit teachers with the content knowledge, interest, passion and willingness to learn and explore computer science alongside their K-12 students. The teacher talent pool may include traditionally prepared teachers from computing fields, traditionally prepared teachers from other fields, alternatively certified teachers from industry and part-time adjuncts.

- Recruit teachers who reflect the diverse populations of their schools.
- Consider creative approaches to recruiting and compensating computer science teachers, such as:
  - sign-on bonuses, 12-month salaries or special stipends for certified teachers or teachers with industry experience in high-demand fields;
  - student loan forgiveness programs for recent graduates; and
  - flexible schedules for part-time teachers who wish to maintain careers in industry.

Offer teaching endorsements to new computer science teachers who complete a two- to four-week, full-day summer institute, led by a master teacher, in which they learn their curriculum by completing the same projects and assignments as their students.

- Ensure that follow-up support includes at least one year of in-service professional development, offered quarterly in person or monthly online; opportunities to participate in communities of practice; and additional summer institutes.

Create clear pathways to teacher certification and licensure to ensure that all teachers, regardless of their backgrounds, have the appropriate content knowledge and pedagogical skills needed to teach standards-based computer science and IT curricula.

- Commission a panel of secondary and postsecondary educators, employers and experts to review the state certification and licensure system against recognized standards in computing disciplines, accreditation guidelines for postsecondary computing programs[157] and workforce needs.
- Partner with the Council for the Accreditation of Educator Preparation to embed computer science content knowledge and pedagogical skills in teacher preparation programs.
- Work with postsecondary institutions to embed computer science in elementary and middle grades teachers' pre-service preparation programs and in-service endorsement programs.
- Offer flexible certification options to computer science and IT teachers who lack certification.
- Work with neighboring states to create teacher certification reciprocity agreements.
- Incentivize veteran teachers to acquire certifications or endorsements in computer science.
- Use Title II funds authorized by the STEM Education Act[158] to train computer science teachers.
- Capitalize on the Every Student Succeeds Act[159] provision that allows states to build innovative teacher preparation programs.

Leverage federal, state, foundation and private sector funds to support intensive, ongoing professional development on computer science and IT content knowledge and the pedagogical skills needed to manage diverse learners, create assessments and embed literacy and math in student-driven, project-based instruction and assignments.

- Ensure that computer science and IT teachers receive release time and funding to attend summer institutes and professional development trainings, design courses, participate in interdisciplinary professional learning communities and engage in industry externships.
- Provide release time, funding and support for academic teachers to participate in interdisciplinary professional development with computer science and IT teachers.
- Encourage teachers to work in interdisciplinary teams with postsecondary and employer partners to design computer science assignments that strengthen students' literacy and math skills.
- Adopt online learning management systems that allow teachers to access training, coaching, professional learning communities and standards-based resources and instructional materials.

Partner with other states, national and regional organizations, ETS or other licensing exam providers to design a new computer science Praxis or other standardized assessment that measures teachers' mastery of the most current content knowledge and pedagogical knowledge required to teach computer science.

Action 5:
Educate Communities About Computer Science and Computing Careers

Knowledge, access, equity and awareness are the most challenging barriers to computer science education. Too few students know about emerging career opportunities in computer science. Many may not know anyone with a job in a computing field or receive no encouragement to pursue computer science courses or degrees. TV and media reinforce the stereotype that only white and Asian males work in computer science,[160] discouraging girls, black and Hispanic students, and students from low-income families from exploring the field.[161] Further, studies show that black and Hispanic students, especially in under-resourced schools, have fewer opportunities to learn computer science.[162]

Yet American parents have positive views of computer science and computing careers. According to a recent Google and Gallup poll, two-thirds of parents — and three-quarters of the lowest-income parents — support required computer science courses.[163] American parents also agree that education should be rigorous, relevant and prepare young people for college and careers.[164]

Despite strong parental support, surveys show that principals and superintendents are not aware of a high demand for computer science.[165] Nor do they believe their schools have the time or the teachers to devote to computer science. Further, less than half of teachers, principals and superintendents believe computer science is a top priority for their school boards.

The Commission recommends that states **create career exploratory school cultures and recognize communities that cultivate computing talent** as a means of educating school leaders and the community about the value of computer science and computing careers.

Creating Career Exploratory School Cultures

Commission members advocate for the inclusion of career advisement and hands-on career exploration across K-12 curricula. Starting in elementary school and the middle grades, students need to learn about and see value in all forms of postsecondary attainment, including apprenticeships, industry credentials and postsecondary certificates, credentials, associate and bachelor's degrees, and beyond. However, for many states, convincing parents, teachers and school personnel that anything less than a bachelor's degree can help a student secure a good job is a hard sell.

Virginia School Blends Coding, College and Career Experience

In the fall of 2016, 80 Virginia ninth-graders will start high school and potentially launch careers as computer programmers, software developers and system engineers at the **Richmond Regional School for Innovation (CodeRVA)**. A consortium of 13 Richmond-area school systems secured a $50,000 state innovation planning grant to work with community colleges and industry partners to design CodeRVA. As 9th and 10th graders, CodeRVA students will take core academic and computer science courses. In 11th and 12th grade, students may complete any remaining coursework needed to graduate or acquire an associate degree while completing 400 hours of paid work experience at an area IT company. CodeRVA will begin enrolling larger classes in 2017-18.[166]

Awareness of computer science and computing careers needs to start with what Arkansas State Representative Bill Gossage calls "**the gatekeepers**" — the superintendents and principals who make curricular decisions. **Parent-teacher associations** and **economic and workforce development agencies** are powerful allies that can educate school leaders and communities about the computer science and IT-related jobs found in all industries.

At the school level, **teacher advisement systems** transform school cultures because they make career counseling the purview of every teacher and use **experiential learning** to introduce students to career opportunities.

Teacher Advisement Systems

Research shows the benefit of continuous career exploration and counseling that engages teachers, counselors and other adults in helping students plan for their futures.[167] In teacher advisement systems, teachers and counselors work together to design assignments that help students identify their interests. Starting in eighth grade, students and parents annually prepare and revise individual graduation plans that organize course work around students' evolving aspirations. Career exploration courses,[168] websites and career fairs expose middle grades and high school students to jobs and show them how career pathways can speed their transition from high school to college. Aptitude and interest inventories like YouScience[169] catalyze students' curiosity about computer science. Throughout K-12, students regularly interact with adults in their communities who introduce them to the world of work.

Industry organizations and experts offer schools resources they can use to introduce students, parents, teachers, counselors and administrators to computing careers:

- Through its **Counselors for Computing** program, the **National Center for Women & Information Technology** provides counselors with professional development and resources they can use to introduce students to cool jobs.[170]
- **Madewithcode.com**, created by **Google** and its partners, features activities and videos that show young women they don't have to become programmers to use computer science in careers in animation, design, fashion, film, medicine and more.
- The **Computer Science Teachers Association** is **developing videos and other multimedia career resources**[171] that highlight women and individuals from different racial, ethnic and national backgrounds with creative jobs in gaming, music, robotics and other fields.
- The **National Science Foundation** funded the development of **Tapestry** workshops that help high school teachers inspire girls and underrepresented minorities to explore computer science.[172]

Experiential Learning

American parents want their children to participate in volunteer opportunities or paid internships while in high school.[173] Experiential learning helps students build confidence, foster soft skills, explore adult responsibilities, identify their talents and make informed decisions about their postsecondary and career options. Experiential learning looks different in every grade:

- In elementary school, children can pretend to be computer animators, digital video producers, game developers or cyberforensics sleuths as they learn computer science concepts and practices in their art, language arts, math, science and social studies lessons.
- In the middle grades, students can interview a professional, take on a service learning project in the community and make field trips to corporate IT departments, software firms, research labs, communication technology providers and military bases. High school career pathway students may work on projects with industry mentors or spend part of the day in internships.
- After high school graduation, apprenticeships and learn-and-earn programs can help young adults complete postsecondary credentials and degrees while earning a good living.

States can support experiential learning by incentivizing employer cooperation, protecting students and the employers who mentor them,[174] **and leveraging existing resources**. Tax credits may entice employers to invest in high school and postsecondary student trainees and partially offset the cost of mentoring K-12 students,[175] contributing to curriculum development and supporting teacher externships. States can also tap the resources of workforce development agencies, nonprofits and chambers of commerce to support regional or district experiential learning coordinators.

Recognizing Communities That Cultivate Computing Talent

The Commission recommends celebrating communities that come together to raise the quality of computer science education and meet workforce needs in computing fields. Two models from SREB states show how this can be accomplished.

In 2014, **Oklahoma** legislators enacted Senate Bill 1181,[176] which outlines criteria for designating **STEM Community School Districts** that harness the power of public-private partnerships[177] to meet needs in the state's STEM-related industries. These STEM Communities unite secondary and postsecondary educators, policymakers, government officials, chambers of commerce, employers, parents and students around a shared goal of improving STEM education and increasing the number of STEM certificate, credential and degree-holders. Five communities carry the designation.[178] Oklahoma State Senator Jim Halligan believes the benefits of this designation extend beyond bragging rights: For little to no cost, the state's STEM Communities unite the partners who make career pathway systems work.

Tennessee's STEM Innovation Network[179] has had a transformative effect on STEM education. The network includes two components:

- STEM Platform Schools serve as demonstration sites for project-based STEM teaching and learning strategies and are supported by area employers.

"As legislators, we have to create the right economic atmosphere for [computer science] initiatives to be successful. The public and private sector have to participate. People started coming to me after [House Bill 1183] passed. Venture capitalists. People who work in the innovation hub. They are hungry for us to help them develop a system that creates growth for companies that need coders and folks involved in computer science. We need to help incubate new companies."

— **Bill Gossage**,
Arkansas State Representative

- Regional STEM Innovation Hubs formalize relationships between school districts, colleges, local STEM industries and community partners. They also support, sustain and spread teaching and learning practices developed in STEM Platform Schools. Partners see their role as fostering new generations of STEM talent and incubating businesses.

Additional Actions States Can Take:

Embed career advisement and exploration across K-12 as a means of educating students, parents and communities about computer science and computing careers.

- Adopt curriculum-based teacher advisement systems that put students' evolving career goals at the center of college and career counseling.
- Create repositories of teacher- and counselor-created lessons that help students explore careers.
- Require students, parents, teachers and counselors to annually revise individual graduation plans that outline students' career goals and the credentials and degrees they need to achieve them.
- Support schools in offering all students career interest and aptitude assessments, multimedia marketing materials and websites about careers in computer science and related fields.
- Draw on the resources of economic and workforce development agencies, parent-teacher associations and other organizations to educate students and parents about computing careers.
- Encourage two- and four-year colleges and universities to develop marketing materials and outreach strategies related to their credential and degree programs in computing fields.
  - Provide bonus funds to institutions that recruit and retain underrepresented students.
  - Recognize postsecondary institutions, professional computing associations and student organizations — including networking groups, sororities and fraternities — that support underrepresented students who are pursuing degrees in computing fields.

Encourage employer partners to invest in the computing and IT workforce of the future.

- Extend tax credits to employers who offer experiential learning opportunities, such as job shadows and internships, to high school students and learn-and-earn programs that make postsecondary education more affordable for working adults.
- Work with insurers, workforce commissions and other agencies to insure underage high school students who participate in experiential learning and to limit employers' liability if a student is injured on the job.
- Draw on the resources of economic and workforce development agencies, chambers of commerce, local nonprofits and community organizations to support experiential learning coordinators.

Enact legislation to recognize communities that improve computer science education and meet workforce needs in computing fields. Overseen by the state career pathway advisory council for computer science, such communities should:

- Gather and analyze educational and employment data related to student attainment of industry credentials and postsecondary degrees in computing fields.
- Create action plans for improving the quality of K-20 computer science education.
- Educate students, parents, schools and the community about computing careers.
- Leverage funding and resources to support districts, schools and postsecondary institutions that offer innovative career pathways in computing fields.
- Collect and use data to continuously improve community computer science education efforts.

Carrying the Message About Computer Science

*Although our states are making great strides toward bridging the computer science education gap, **we can do more**.*

Bridging the gap means investing in high-quality computer science learning experiences that introduce more young people — especially young women, underrepresented minorities and economically disadvantaged students — to the full range of college and career opportunities in computer science. States can do this by:

1. **Developing rigorous standards for computer science education and adopting standards-based curricula, instructional strategies and activities across K-12.**
2. **Helping students master the foundational skills they need to learn computer science.**
3. **Building career pathways that blur the line between high school and college and speed students' progress toward degrees and jobs in computing fields.**
4. **Preparing computer science teachers with a passion for inspiring diverse learners.**
5. **Putting career awareness at the heart of all K-12 curricula and building parent, business and community partnerships that value computer science.**

"This issue is so large that we need everybody. We need more people to carry this message."

— **Brenda Gilmore**, Tennessee State Representative

Balanced with thoughtful planning, these five actions can help states empower students with the knowledge and skills they need to become creators, not just consumers, of computer and information technologies. For some students, the computer science learning experiences they have in elementary school, the middle grades or high school may put them on a path to fulfilling careers in computing fields.

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Appendix

Crosswalk of Computer Science Concepts and Computational Practices

<table>
<tr><th colspan="3">Computer Science Concepts</th><th colspan="3">Computational Practices</th></tr>
<tr><th>Framework for K-12 CS Education – Five Core Concepts*</th><th>AP Computer Science Principles – Seven Big Ideas**</th><th>Exploring Computer Science – Three Themes***</th><th>Framework for K-12 CS Education – Seven Practices*</th><th>AP Computer Science Principles – Six Computational Thinking Practices**</th><th>Exploring Computer Science – Six Computational Practices***</th></tr>
<tr><td>Computing systems</td><td rowspan="2">The internet</td><td rowspan="4">Technology as a tool for solving problems</td><td>Developing and using abstractions</td><td>Abstracting</td><td>Apply abstractions and models</td></tr>
<tr><td>Networks and the internet</td><td>Creating computational artifacts</td><td>Creating computational artifacts</td><td rowspan="2">Design and implement creative solutions and artifacts</td></tr>
<tr><td>Data and analysis</td><td>Data and information</td><td>Recognizing and defining computational problems</td><td rowspan="2">Analyzing problems and artifacts</td></tr>
<tr><td>Algorithms and programming</td><td>Algorithms; Programming; Abstraction</td><td>Testing and refining</td><td>Analyze their computational work and the work of others</td></tr>
<tr><td></td><td>Creativity</td><td>The creative nature of computing</td><td>Communicating about computing</td><td>Communicating</td><td>Communicate computational thought processes, procedures and results to others</td></tr>
<tr><td></td><td></td><td></td><td>Collaborating</td><td>Collaborating</td><td>Collaborate with peers on computing activities</td></tr>
<tr><td>Impacts of computing*</td><td>Global impact</td><td>The relevance of computer science and its impact on society</td><td>Fostering an inclusive and diverse computing culture</td><td>Connecting computing</td><td>Analyze the effects of developments in computing (impact/connections)</td></tr>
</table>

Sources: * http://k12cs.org/ - August 2016 draft. The Computer Science Teachers Association's newly revised standards for K-12 computer science education, released in July 2016, align with these five core concepts and seven practices. See CSTA Standards Task Force. (2016). *Interim CSTA K-12 computer science standards.* New York, NY: CSTA and ACM. http://www.csteachers.org/?page=CSTA_Standards

** https://advancesinap.collegeboard.org/stem/computer-science-principles/course-details.

*** Goode, J., & Chapman, G. (2015). *Exploring computer science.* Eugene, OR: NSF, University of Oregon and UCLA.

Endnotes

[1] Google & Gallup. (2015b). *Searching for computer science: Access and barriers in U.S. K-12 education*. Mountain View, CA, and Washington, DC: Authors. http://csedu.gallup.com/home.aspx

[2] Margolis, J., Estrella, R., Goode, J., Holme, J. J., & Nao, K. (2008). *Stuck in the shallow end: Education, race, and computing*. Cambridge, MA: The MIT Press.

[3] Computer Science Teachers Association Task Force. (2011). *CSTA K-12 computer science standards – Revised 2011*. New York, NY: CSTA. See also CSTA Curriculum Improvement Task Force. (2005). *The new educational imperative: Improving high school computer science education*. New York, NY: Author.

[4] CSTA Task Force, 2011.

[5] CSTA Task Force, 2011.

[6] Wilson, C., Sudol, L. A., Stephenson, C., & Stehlik, M. (2010). *Running on empty: The failure to teach K-12 computer science in the digital age*. New York, NY: Association for Computing Machinery and CSTA.

[7] CSTA Task Force, 2011.

[8] STEM Education Act of 2015, Public Law No. 114-59 (114th Congress, 2015-2016). https://www.congress.gov/bill/114th-congress/house-bill/1020

[9] p. 1, CSTA Task Force, 2011.

[10] Joint Task Force for Computing Curricula. (2005, September 30). *Computing curricula 2005: The overview report covering undergraduate degree programs in computer engineering, computer science, information systems, information technology and software engineering*. New York, NY, and Washington, DC: ACM and Institute of Electrical and Electronics Engineers Computer Society.

[11] p. 13, CSTA Curriculum Improvement Task Force, 2005.

[12] p. 5, ACM. (2005, October). *Computing curricula: Information technology volume*. New York, NY: Author. See also CSTA Task Force, 2011.

[13] CSTA Task Force, 2011; CSTA Curriculum Improvement Task Force, 2005; Joint Task Force for Computing Curricula, 2005.

[14] Joint Task Force on Computing Curricula. (2013, December 20). *Computer science curricula 2013: Curriculum guidelines for undergraduate degree programs in computer science*. New York, NY, and Washington, DC: ACM and IEEE Computer Society.

[15] Joint Task Force for Computing Curricula, 2005.

[16] Topi, H., Valacich, J. S., Wright, R. T., Kaiser, K. M., Nunamaker, J. F., Jr., Sipior, J. C., & de Vreede, G. J. (2010). *IS 2010: Curriculum guidelines for undergraduate degree programs in information systems*. New York, NY, and Atlanta, GA: ACM and Association for Information Systems.

[17] Integrated Postsecondary Education Data System Classification of Instructional Programs. (n.d.) *Informatics* (CIP Code 11.0104). Washington, DC: U.S. Department of Education, Institute of Education Sciences, National Center for Education Statistics. http://nces.ed.gov/ipeds/cipcode/cipdetail.aspx?y=55&cipid=89325

[18] Joint Task Force for Computing Curricula, 2005.

[19] Joint Task Force for Computing Curricula, 2005. See also Joint Task Force on Computing Curricula. (2004, August 23). *Software engineering 2004: Curriculum guidelines for undergraduate degree programs in software engineering*. Washington, DC, and New York, NY: IEEE Computer Society and ACM.

[20] Kaczmarczyk, L., & Dopplick, R. (2014). *Rebooting the pathway to success: Preparing students for computing workforce needs in the United States*. Washington, DC: ACM.

[21] Carnevale, A. P., Smith, N., & Strohl, J. (2013). *Recovery: Job growth and education requirements through 2020*. Washington, DC: Georgetown University Center on Education and the Workforce.

[22] Change the Equation. (2015). *The hidden half: Uncovering the invisible computing workforce*. Washington, DC: Author. http://changetheequation.org/hidden-half Change the Equation found that 7.7 million Americans have jobs requiring high-level computer and IT knowledge and skills — such as developing software, programming in multiple languages and maintaining networks — double the number captured by the BLS. Such jobs were found inside (3.9 million) and outside (3.8 million) STEM fields.

[23] Moschella, M. (2013, September 17). The emerging double-deep economy. *Leading Edge Forum*. https://leadingedgeforum.com/publication/the-emerging-double-deep-economy-2318/ Moschella is cited in Nager, A., & Atkinson, R. D. (2016, May). *The case for improving U.S. computer science education*. Washington, DC: Informative Technology & Innovation Foundation.

[24] U.S. Bureau of Labor Statistics. (2016). *Computer and information technology occupations*. Washington, DC: Author. http://www.bls.gov/ooh/computer-and-information-technology/print/home.htm

[25] Carnevale, A. P., Jayasundera, T., & Repnikov, D. (2014). *The online college labor market: Where the jobs are*. Washington, DC: Georgetown University Center on Education and the Workforce.

[26] Burning Glass Technologies. (2014). *Missed opportunities: The labor market in health informatics*, 2014. Boston, MA: Author.

[27] See http://www.Cyberdegrees.org/jobs for a selection of such jobs and the education and training required to secure them.

[28] The authors used 2007-11 data. Jobs for the Future and Burning Glass Technologies. (2012). *A growing jobs sector: Health informatics*. Boston, MA: Authors.

[29] The authors examined job growth over the period 2010-14. Cybersecurity jobs were found in many industries, including defense, finance, health, manufacturing, professional services and retail. Burning Glass Technologies. (2015). *Job market intelligence: Cybersecurity jobs, 2015*. Boston, MA: Author.

[30] Robertson, J., & Riley, M. (2015, July 9). Inside the Pentagon's boot camp for cyber warriors. *Bloomberg Businessweek*. http://www.bloomberg.com/news/articles/2015-07-09/inside-the-pentagon-s-boot-camp-for-cyberwarriors

[31] Robertson & Riley, 2015.

[32] Readers may review the source data used by Code.org for its analyses of the skills gap in computer science at https://docs.google.com/document/d/1gySkItxiJn_vwb8HIIKNXqen184mRtzDX12cux0ZgZk/pub

[33] Jordan, M. (2015, April 14). Skilled-worker visa applications by U.S. companies reach high. *The Wall Street Journal*. http://www.wsj.com/articles/skilled-worker-visa-applications-by-u-s-companies-reach-high-1429056123

[34] Computer science degree statistics are available from the National Science Foundation at http://www.nsf.gov/statistics/seind12/append/c2/at02-18.xls and http://www.nsf.gov/statistics/seind12/appendix.htm

[35] Carnevale, A. P., Fasules, M. L., Porter, A., & Landis-Santos, J. (2016). *African Americans: College majors and earnings*. Washington, DC: Georgetown University Center on Education and the Workforce. Bachelor's degree holders are adults aged 21-59 with a baccalaureate but no graduate degree. Researchers used 2010-14 *American Community Survey* microdata.

[36] See Kaczmarczyk & Dopplick, 2014. This ACM report uses NSF data and other sources to estimate bachelor's degree completions.

[37] Vara, V. (2016, January 21). Why doesn't Silicon Valley hire black coders? *Bloomberg Businessweek*. http://www.bloomberg.com/features/2016-howard-university-coders/

[38] Nager & Atkinson, 2016.

[39] Davis, J. (2016, June 26). Computer science field rich in jobs. *Atlanta Journal-Constitution*, pp. B1-B3.

[40] See http://Code.org/promote for fact sheets maintained by Code.org for the 50 states and the District of Columbia.

[41] Wilson et al., 2010.

[42] Nager & Atkinson, 2016.

[43] The College Board. (2016). *Program summary report 2015*. New York, NY: Author. https://secure-media.collegeboard.org/digitalServices/pdf/research/2015/Program-Summary-Report-2015.xls

[44] Wilson et al., 2010.

[45] The CSTA's newly revised standards for K-12 computer science education were released in July 2016. See CSTA Standards Task Force. (2016). *Interim CSTA K-12 computer science standards*. New York, NY: CSTA and ACM. http://www.csteachers.org/?page=CSTA_Standards

[46] CSTA Task Force, 2011; Kaczmarczyk & Dopplick, 2014.

[47] The K-12 computer science framework initiative launched in January 2016 with leadership from the ACM, the CSTA, Code.org, the Cyber Innovation Center and the National Math and Science Initiative. See http://k12cs.org/

[48] Pat Yongpradit, personal communication, September 9, 2016.

[49] See http://k12cs.org/faq/

[50] Yongpradit, P. (2016, April). *The K-12 CS framework*. Presentation made at the Spring 2016 meeting of the SREB Commission on Computer Science and Information Technology, Little Rock, Arkansas.

[51] See http://code.org/educate/3rdparty for Code.org's updated listings of third-party curriculum providers. To qualify as "complete," curricula must be standards-based and include syllabi, lesson plans, assignments, validated assessments, professional development support and other resources. In these listings, "proven scale" means that the program is in use in at least 100 schools.

[52] Download the rubric at http://bit.ly/1sOFk13

[53] Bottoms, G., & Sundell, K. (2015). *Credentials for all: An imperative for SREB states*. Atlanta, GA: SREB. http://www.sreb.org/publication/credentials-all-imperative-sreb-states

[54] Mark R. Nelson, personal communication, July 1, 2016.

[55] See http://leadcs.org/title/

[56] See https://www.gov.uk/government/publications/national-curriculum-in-england-computing-programmes-of-study/national-curriculum-in-england-computing-programmes-of-study. A number of organizations, including Computing At School and Apps for Good, are supporting this curriculum with materials and resources for teachers and students in all grades. See http://www.computingatschool.org.uk/ and http://www.appsforgood.org/

[57] CSTA Task Force, 2011.

[58] See https://code.org/educate/curriculum/elementary-school

[59] Brennan, K., Balch, C., & Chung, M. (2014). *Creative computing*. Cambridge, MA: Harvard Graduate School of Education. http://scratched.gse.harvard.edu/guide/

[60] SREB. (2003). *Academic achievement in the middle grades: What does research tell us?* Atlanta, GA: Author. http://publications.sreb.org/2002/02V47_AchievementReview.pdf

[61] CSTA Task Force, 2011.

62 See https://chooseyourfuture.cps.edu/computer-science-for-all/what-is-cs4all/

63 See http://www.bootstrapworld.org/

64 Schanzer, E., Fisler, K., Krishnamurthi, S., & Felleisen, M. (2015). Transferring skills at solving word problems from computing to algebra through Bootstrap. In Decker, A., Eiselt, K., Alphonce, C., & Tims, J. (Eds.), *Proceedings of the 46th Association for Computing Machinery Technical Symposium on Computer Science Education* (pp. 616-621). New York, NY: ACM. See also Wright, G., Rich, P. & Lee, R. (2013). The influence of teaching programming on learning mathematics. In R. McBride & M. Searson (Eds.), *Proceedings of the Society for Information Technology & Teacher Education International Conference 2013* (pp. 4612-4615). Chesapeake, VA: Association for the Advancement of Computing in Education.

65 See http://www.bootstrapworld.org/workshops/

66 See http://www.projectguts.org/

67 See https://code.org/curriculum/algebra

68 See https://code.org/curriculum/science

69 The NSF funds an online community, CS10Kcommunity.org, to support teachers of Exploring Computer Science and AP Computer Science Principles. The goal of the CS10K initiative is to prepare 10,000 computer science teachers in 10,000 U.S. high schools.

70 The Margolis et al. (2008) study was conducted in highly diverse high schools located in the Los Angeles Unified School District.

71 See http://www.exploringcs.org/

72 p. 57, Goode, J., & Chapman, G. (2015). *Exploring computer science*. Eugene, OR: NSF, University of Oregon and UCLA.

73 The developers mapped course content onto the 2011 CSTA standards, the Next Generation Science Standards, International Society for Technology in Education standards, state college- and career-readiness standards, and career and technical education standards from California and Illinois.

74 To download a review copy of the curriculum, visit http://www.exploringcs.org/current-exploring-computer-science-teachers

75 See http://c-stem.ucdavis.edu

76 See https://secure-media.collegeboard.org/digitalServices/pdf/ap/ap-computer-science-principles-curriculum-framework.pdf

77 See http://apcentral.collegeboard.com/apc/public/courses/teachers_corner/4483.html

78 The AP CSP exam is expected to launch in the spring of 2017. Once released, postsecondary institutions will determine whether to accept a passing score on the exam as a computer literacy credit or as the first credit in a computer science degree.

79 See http://apcsp.org/index.php/courses

80 See http://apcentral.collegeboard.com/apc/html/how-to-start-an-ap-course/how-to-start-an-ap-course.html

81 See http://www.doe.k12.de.us/cms/lib09/DE01922744/Centricity/Domain/384/DE_ComputerScience_POS_Application_August%202016.docx for Delaware's computer science program of study.

82 See http://www.doe.k12.de.us/cms/lib09/DE01922744/Centricity/Domain/384/DE__Cisco_Matrix_August%202016.doc for Delaware's Cisco Networking Academy program of study.

83 See http://archives.marylandpublicschools.org/MSDE/divisions/dccr/te.html

84 See http://girlswhocode.com/about-us/

85 Girls Who Code. (2016). *Annual report 2015*. New York, NY: Author. http://www.girlswhocode.com/2015report/

86 The Digital Equity Action Toolkit produced by the CoSN (Consortium for School Networking) offers school districts strategies for increasing access to high-quality broadband connections in their communities. See CoSN. (2016). *Digital equity: Supporting students & families in out-of-school learning*. Washington, DC: Author. http://www.cosn.org/focus-areas/leadership-vision/digital-equity-action-agenda The Federal Communications Commission's E-Rate program seeks to increase access to broadband in schools and libraries: http://lifelinesupport.org/sl/ As of March 31, 2016, the FCC voted to modernize its Lifeline program to include internet access. Lifeline previously only offered discounted landline or mobile telephone service to low-income families. Learn more at the Alliance for Excellent Education: http://all4ed.org/lifeline/ and the FCC: http://lifelinesupport.org/li/

87 ACT. (2015). *The condition of college & career readiness 2015*. Iowa City, IA: Author.

88 SREB. (2015). *Community colleges in the south: Strengthening readiness and pathways*. Atlanta, GA: Author. http://www.sreb.org/publication/community-colleges-south-strengthening-readiness-and-pathways

89 CSTA Task Force, 2011.

90 For a lay-friendly explanation of coding, see http://www.codeconquest.com/what-is-coding/how-does-coding-work/

91 Carnevale, A.P., Smith, N., & Melton, M. (2011). *STEM: Science, technology, engineering, mathematics*. Washington, DC: Georgetown University Center on Education and the Workforce. https://cew.georgetown.edu/wp-content/uploads/2014/11/stem-complete.pdf

92 CSTA Task Force, 2011. See also Wing, J. M. (2002, July). *Mathematics in computer science curricula*. Presentation made at the Sixth International Conference on Mathematics of Program Construction, Dagstuhl, Germany. http://www.cs.cmu.edu/~wing/publications/talk.pdf

93 Bottoms & Sundell, 2015.

94 p. 6, ABET Computing Accreditation Commission. (2015). *Criteria for accrediting computing programs: Effective for reviews during the 2016-2017 accreditation cycle*. Baltimore, MD: Author. ABET, formerly known as the Accreditation Board for Engineering and Technology, is the accrediting body for postsecondary computer science, engineering and engineering technology programs. For an explanation of the relationship between ABET, ACM and other organizations that accredit programs in computer science, IS, IT, computer engineering and software engineering, see http://www.acm.org/acm-ieeecs-coop/accreditation-board

95 ACM Committee for Computing Education in Community Colleges. (2014, October 14). *Information technology competency model of core learning outcomes and assessment for associate-degree curriculum*. New York, NY: ACM.

96 National Center on Education and the Economy. (2013). *What does it really mean to be college and work ready? The mathematics required of first year community college students*. Washington, DC: Author.

97 p. 49, Joint Task Force on Computing Curricula, 2013.

98 Download the curriculum framework from http://www.arkansased.gov/public/userfiles/Learning_Services/Curriculum%20and%20Instruction/Frameworks/Math/Computer_Science_and_Mathematics_12122014.pdf

99 Computer Science and Mathematics counts as a fourth math if it is taught by a math-certified teacher, as mandated by the federal Every Student Succeeds Act and Arkansas legislation. Arkansas teachers can acquire this certification by taking an additional 15 hours of math or by passing the math Praxis. The course counts as one of six required career-focused credits or as a computer science flex credit if it is taught by a licensed business education teacher or by a teacher with a computer science endorsement, acquired by passing the computer science Praxis. Every Student Succeeds Act, Public Law No. 114-95 (114th Congress, 2015-2016). https://www.congress.gov/bill/114th-congress/senate-bill/1177/text

100 CSTA and International Society for Technology in Education. (2011). *Operational definition of computational thinking for K-12 education*. New York, NY, and Arlington, VA: Authors. https://csta.acm.org/Curriculum/sub/CurrFiles/CompThinkingFlyer.pdf See also Joint Task Force on Computing Curricula, 2013.

[101] CSTA and ISTE, 2011. Google designed an online course along with additional resources, such as lesson plans and videos, to help educators integrate computational thinking skills across disciplines. See Google. (2016). *Computational thinking for educators*. https://computationalthinkingcourse.withgoogle.com/ See also Google. (2016). *Exploring computational thinking*. https://www.google.com/edu/resources/programs/exploring-computational-thinking/

[102] Markham, T., Larmer, J., & Ravitz, J. (2003) *Project based learning handbook: A guide to standards-focused project based learning for middle and high school teachers*. Novato, CA: Buck Institute for Education.

[103] See http://ldc.org/

[104] See http://www.sreb.org/page/1631/LDCMDC.html

[105] See http://www.sreb.org/readiness-courses-literacy-math

[106] House Bill 1054, Code of Virginia § 22.1-253.13:4 (2014). http://www.doe.virginia.gov/administrators/superintendents_memos/2015/022-15a.pdf

[107] House Bill 831, Code of Virginia § 22.1-253.13:1 (2016). https://lis.virginia.gov/cgi-bin/legp604.exe?161+ful+HB831ER

[108] See http://www.sreb.org/page/1608/Advanced_Career.html

[109] Bottoms & Sundell, 2015.

[110] See http://www.fldoe.org/academics/career-adult-edu/career-technical-edu-agreements

[111] The Department of Computer Science at Purdue University offers Indiana high school students free online access to Introduction to Object-Oriented Programming. Although not available for credit, the self-paced course can help students test out of a typical first-year programming class. See http://www.purdue.edu/newsroom/releases/2014/Q4/purdue-offers-free-online-computer-programming-course-to-indiana-high-school-students.html

[112] SREB. (2012). *Redesigning dual enrollment to promote college completion: SREB policy brief*. Atlanta, GA: Author. See also Edwards, L., Hughes, K. L., & Weisberg, A. (2011). *Different approaches to dual enrollment: Understanding program features and their implications*. New York, NY. Community College Research Center, Teachers College, Columbia University.

[113] SREB. (2013). *Essential elements of state policy for college completion: Dual enrollment courses and credits*. Atlanta, GA: Author.

[114] See http://www.sreb.org/high-schools-work

[115] Handel, S. J. (2013). *Transfer as academic gauntlet: The student perspective*. New York, NY: The College Board. Handel, S. J., & Williams, R. A. (2012). *The promise of the transfer pathway: Opportunity and challenge for community college students seeking the baccalaureate degree*. New York, NY: The College Board. Sener, J. (2016). *Transfer pathways in cybersecurity education: Challenging routes, promising practices, possible improvements*. Largo, MD: National Cyberwatch Center.

[116] SACS accredits postsecondary institutions in 11 of 16 SREB states: Florida, Georgia, Kentucky, Louisiana, Mississippi, North Carolina, South Carolina, Alabama, Tennessee, Texas and Virginia.

[117] See Nager & Atkinson, 2016, for an analysis of the obstacles facing postsecondary computer science and IT departments.

[118] Arkansas's introductory Essentials of Computer Programming course counts as a career-focused credit or as a computer science flex credit and can be taught by licensed business education teachers or teachers with a computer science endorsement. See http://www.arkansased.gov/public/userfiles/Learning_Services/Curriculum%20and%20Instruction/Frameworks/Computer%20Science/Essentials_of_Computer_Programming.pdf

[119] Currently in development, Code.org's CS Discoveries is being designed for delivery in one or two semesters, as a full-year course or as integrated modules in STEM classes. See https://code.org/educate/csd

[120] Joint Task Force on Computing Curricula, 2013.

[121] The National CyberWatch Center serves states, districts and schools nationwide: http://www.nationalcyberwatch.org/ Both the National CyberWatch Center and the ACE Consortium are designated Advanced Technological Education Centers funded by the NSF. See Patton, M. (2014). *ATE centers impact 2014*. Tempe, AZ: Maricopa Community Colleges. http://www.atecenters.org/wp-content/uploads/PDF/ATEIMPACT_2014.pdf

[122] See http://www.cyberace.org/k12.php

[123] See http://ace.tsjackson.com/ and http://www.augustametrochamber.com/initiatives/alliance-for-cybersecurity-education-ace/

[124] See http://cybercoe.army.mil/

[125] See http://www.gadoe.org/Curriculum-Instruction-and-Assessment/CTAE/Pages/cluster-IT.aspx

[126] See Burning Glass Technologies, 2015, for national and state estimates of the cybersecurity skills gap.

[127] Connor, K. (2015, January 14). Full cyber security program approved at Huntsville City Schools career academies. *WHNT News 19*. http://whnt.com/2015/01/14/cyber-security-program-approved-at-huntsville-city-schools-career-academies/

[128] For an overview of the partnership, see Williams, A. T., Brown, K., Williams, R., & Baylis, T. (2015, November). *The consortium enabling cybersecurity opportunities and research (CECOR) - A K-20 approach*. Presentation made at the 2015 National Initiative for Cybersecurity Education, San Diego, CA.

[129] See http://ltaccsd.sharpschool.net/course_majors/cyber_security

[130] Kerr, A. (2015, January 22). Charleston students to play a key role in cybersecurity workforce initiative. *The Post and Courier*. http://www.postandcourier.com/article/20150122/PC16/150129756/1177

[131] ESSA encourages states to include career readiness measures in their accountability systems.

[132] CSTA Curriculum Improvement Task Force, 2005.

[133] Nager & Atkinson, 2016.

[134] Google & Gallup, 2015b. The authors' sample of 9,693 K-12 principals and 1,865 superintendents was not nationally representative.

[135] Wilson et al., 2010.

[136] Kaczmarczyk & Dopplick, 2014.

[137] Wilson et al., 2010. See also CSTA. (2013). *Bugs in the system: Computer science teacher certification in the U.S.* New York, NY: Author.

[138] Kaczmarczyk & Dopplick, 2014. See also CSTA, 2013.

[139] Educational Testing Service. (2015). *The Praxis study companion: Computer science* (5651). Princeton, NJ: Author.

[140] With a median score of 145.5 and an average performance range of 129 – 170 on a 100 – 200 scale. ETS. (2015). *Understanding your Praxis scores 2015-2016*. Princeton, NJ: Author. https://www.ets.org/s/praxis/pdf/uyps_1516.pdf

[141] See https://ced.ncsu.edu/programs/elementary-education-bachelor/

[142] See https://uteach.utexas.edu/

[143] Formerly known as the National Council for Accreditation of Teacher Education (NCATE).
See http://www.caepnet.org/

[144] See http://boardcertifiedteachers.org/certificate-areas

[145] See https://www.whitehouse.gov/the-press-office/2016/01/30/fact-sheet-president-obama-announces-computer-science-all-initiative-0

[146] Mark R. Nelson, personal communication, April 25, 2016.

[147] See https://prod.lifejourney.us/lifeJourney/registrationRequest?programId=2&role=School&pc=CT

[148] http://www.arkansased.gov/public/userfiles/Learning_Services/Curriculum%20and%20Instruction/Frameworks/Computer%20Science/7th_8th_Grade_Computer_Science_Coding_Block_01152016.pdf

[149] Moix, D. (2016, May). How a French teacher learned to teach CS. *CSTA Voice, 12*(2). https://csta.acm.org/Communications/sub/CSTAVoice_Files/csta_voice_05_2016.pdf

[150] See https://www.atu.edu/catalog/undergraduate/colleges/education/curr_instr/secondary_computer_sci.php

[151] The two-year APPEL (Arkansas Professional Pathway to Educator Licensure) provisional teaching licensure program allows qualified individuals to enter the classroom in their first year of the program provided they have a bachelor's degree in computer science or another field and passing scores on the Praxis CORE and computer science exams. See http://www.arkansased.gov/divisions/human-resources-educator-effectiveness-and-licensure/office-of-educator-effectiveness/arkansas-professional-pathway-to-educator-licensure-appel

[152] See http://ace.arkansas.gov/cte/specialPrograms/perkins/Documents/Perkins%20Presentations%204_3_14/MobileApps%20ProgramOfStudy.pdf

[153] Ganucheau, A. (2016, January 7). Nonprofits team up to expand computer science education in Alabama. *AL.com*. http://www.al.com/news/index.ssf/2016/01/nonprofits_team_up_to_expand_c.html See also Kaczmarczyk & Dopplick, 2014, and Wagner, N. (2016, January 7). Schools placing higher emphasis on computer science. *Shelby County Reporter*. http://www.shelbycountyreporter.com/2016/01/07/schools-placing-higher-emphasis-on-computer-science/#

[154] Code of Maryland Regulations, 13A.12.02.06. Certification in general secondary content areas (Grades 7-12). http://www.dsd.state.md.us/comar/comarhtml/13a/13a.12.02.06.htm

[155] See http://www.marylandpublicschools.org/msde/divisions/certification/progapproval/maapp.htm

[156] See http://www.advancekentucky.com/our-program/elements-of-success/101-our-program/mission/elements-of-success/elements-educators

[157] See, for example, ABET Computing Accreditation Commission, 2015.

[158] STEM Education Act of 2015, Public Law No. 114-59 (114th Congress, 2015-2016).

[159] For a discussion, see Arnett, T. (2016, January 28). ESSA unlocks teacher prep innovation. *The Brown Center Chalkboard*. Washington, DC: The Brookings Institution. http://www.brookings.edu/blogs/brown-center-chalkboard/posts/2016/01/27-essa-teacher-prep-innovation-arnett

[160] Google & Gallup. (2015a). *Images of computer science: Perceptions among students, parents and educators in the U.S.* Mountain View, CA, and Washington, DC: Authors. http://csedu.gallup.com/home.aspx The survey included a nationally representative sample of 1,673 students in grades 7-12, 1,685 parents of students in grades 7-12, and 1,013 teachers of grades 1-12.

[161] Google. (2014). *Women who choose computer science — what really matters: The critical role of encouragement and exposure*. Mountain View, CA: Author. http://static.googleusercontent.com/media/www.wenca.cn/en/us/edu/pdf/women-who-choose-what-really.pdf

[162] Margolis et al., 2008.

[163] Google & Gallup, 2015a. Parents with an annual household income of $54,000 or less were in the lowest income group.

[164] Phi Delta Kappa International & Gallup. (2014). *The 46th annual PDK/Gallup poll of the public's attitudes toward public schools: Part II*. Arlington, VA, and Washington, DC: Authors. Eighty-nine percent of parents agreed that college was either very important or fairly important to their children's futures, 87 percent agreed or strongly agreed that students need to learn more about careers, and 77 percent agreed that students should be prepared for career fields with good jobs.

[165] Google & Gallup, 2015b.

[166] Chesterfield County Public Schools. (2015). *Richmond regional school for innovation – CodeRVA: High school program innovation planning grant*. Midlothian, VA: Author.

[167] Stone, J. R. III, & Lewis, M. (2012). *College and career ready for the 21st century: Making high school matter*. New York, NY: Teachers College Press.

[168] Bottoms, G., & Phillips, I. (2010). *Skills for a lifetime: Teaching students the habits of success*. Atlanta, GA: Author.

[169] See http://www.YouScience.com

[170] See https://www.ncwit.org/project/counselors-computing-c4c to learn more about how the NCWIT supports counselors with recruitment materials, presentations, lessons and posters on two-year, four-year and military pathways to computing careers.

[171] Mark R. Nelson, personal communication, April 25, 2016.

[172] See http://www.nsf.gov/discoveries/disc_summ.jsp?cntn_id=134318 and http://www.cs.virginia.edu/tapestry/

[173] Phi Delta Kappa International & Gallup, 2014.

[174] Bottoms & Sundell, 2015.

[175] In rural or isolated areas, virtual mentorships like those being piloted in SREB's Advanced Career pathways can connect students with industry professionals. http://www.sreb.org/featured/advanced-career-curriculum-pilots-virtual-mentoring-program

[176] Oklahoma – A STEM State of Mind Program, SB 1181 (2014). https://www.sos.ok.gov/documents/legislation/54th/2014/2R/SB/1181.pdf

[177] Bill & Melinda Gates Foundation, Boston Consulting Group, & Harvard Business School. (2014). *Lasting impact: A business leader's playbook for supporting America's schools*. Seattle, WA, and Boston, MA: Authors.

[178] The Coalition for the Advancement of Science and Mathematics Education in Oklahoma oversees applications. Among other requirements, communities must analyze educational and labor market data; create awareness of STEM careers; promote partnerships; develop, fund and execute action plans; and measure and report outcomes. See http://www.casmeo.org/

[179] See http://thetsin.org/about/

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