A Vision for K–12 Computer Science

A Vision for K–12 Computer Science

The K–12 Computer Science Framework represents a vision in which all students engage in the concepts and practices of computer science. Beginning in the earliest grades and continuing through 12th grade, students will develop a foundation of computer science knowledge and learn new approaches to problem solving that harness the power of computational thinking to become both users and creators of computing technology. By applying computer science as a tool for learning and expression in a variety of disciplines and interests, students will actively participate in a world that is increasingly influenced by technology.

The Power of Computer Science

The power of computers stems from their ability to represent our physical reality as a virtual world and their capacity to follow instructions with which to manipulate that world. Ideas, images, and information can be translated into bits of data and processed by computers to create apps, animations, or autonomous cars. The variety of instructions that a computer can follow makes it an engine of innovation that is limited only by our imagination. Remarkably, computers can even follow instructions about instructions in the form of programming languages.

A computer is an engine of innovation that is limited only by our imagination.

Computers are fast, reliable, and powerful machines that allow us to digitally construct, analyze, and communicate our human experience. More than just a **tool,** computers are a readily accessible **medium** for creative and personal expression. In our digital age, computers are both the paint and the paintbrush. Computer science education creates the artists.

Schools have latched on to the promise that computers offer: to deliver instruction, serve as a productivity tool, and connect to an ever-increasing source of information. This belief that computers can improve education is apparent in the number of one-to-one device initiatives seen in our nation's school districts. Despite the availability of computers in schools, the most significant aspect of computing has been held back from most of our students: learning how to create with computers (i.e., computer science).

Literacy provides a relevant context for understanding the need for computer science education. From a young age, students are taught how to read so that they can be influenced by what has been written but also to write so that they can express ideas and influence others. Although computing is a powerful medium like literacy, most students are taught only how to use (i.e., read) the works of computing provided to them, rather than to create (i.e., write) works for themselves. Together, the "authors" who have worked in the computing medium over the last few decades have transformed our society. Learning computer science empowers students to become authors themselves and create their own poems and stories in the form of programs and software. Instead of being passive consumers of computing technologies, they can become active producers and creators. In our digital age, you can either "program or be programmed" (Rushkoff, 2011, p. 1).

In our digital age, computers are both the paint and the paintbrush. Computer science education creates the artists.

A Vision for K–12 Computer Science

From the abacus to today's smartphones, from Ada Lovelace's first computer program to Seymour Papert's powerful ideas, computing has dramatically shifted our world and holds promise to help improve education. Computer science's ways of thinking, problem solving, and creating have become invaluable to all parts of life and are important beyond ensuring that we have enough skilled technology workers. The K–12 Computer Science Framework envisions a future in which students are informed citizens who can

- critically engage in public discussion on computer science topics;
- develop as learners, users, and creators of computer science knowledge and artifacts;
- better understand the role of computing in the world around them; and
- learn, perform, and express themselves in other subjects and interests.

This vision for computer science education is best understood by imagining one of the paths that Maria (a student) could take during her K–12 computer science experience:

- In elementary school, Maria learns how to instruct computers by sequencing actions like puzzle pieces to create computer algorithms that draw beautiful designs. From a young age, she understands that computing is a creative experience and a tool for personal expression.
- In middle school, Maria grows more sophisticated in her use of computing concepts and understanding of how computing works. She uses the computer, as well as computational ideas and processes, to enhance learning experiences in other disciplines. Computing serves as a medium for representing and solving problems.
- In high school, Maria sees opportunities within her community and society for applying computing in novel ways. The concepts and practices of computer science have empowered her to create authentic change on a small and large scale and across a wide variety of interests.

This vision holds promise to enhance the K–12 experience of all students while preparing them for a wide variety of post-secondary experiences and careers. Students who graduate with a K–12 computer science foundation will go on to be computationally literate members of society who are not just consumers of technology but creators of it. They will become doctors, artists, entrepreneurs, scientists, journalists, and software developers who will drive even greater levels of innovation in these and a variety of other fields, benefiting their communities and the world. The K–12 Computer Science Framework is dedicated to making this vision of computer science education accessible to all.

Not just consumers of technology but creators.

The Case for Computer Science

The ubiquity of personal computing and our increasing reliance on technology have changed the fabric of society and day-to-day life. Regardless of their future career, many students will be using computer science at work; by one estimate, more than 7.7 million Americans use computers in complex ways in their jobs, almost half of them in fields that are not directly related to science, technology, engineering, and math (STEM) (Change the Equation, 2015). Unfortunately, K–12 students today have limited opportunity to learn about these computer science concepts and practices and to understand how computer science influences their daily lives.

When fewer than half of schools teach meaningful computer science courses (Google & Gallup, 2015b), the huge disparity in access often marginalizes traditionally underrepresented students, who already face educational inequities. This opportunity gap is reflected in an alarming lack of diversity in the technology workforce (e.g., Information is Beautiful, 2015; Sullivan, 2014). The majority of computer science classes are offered only to high school students, yet research in other STEM fields has repeatedly shown that stereotypes (Scott & Martin, 2014) about who is good at or who belongs in those fields are established from a very young age. Addressing these messages earlier and providing earlier access to computing experiences can help prevent these stereotypes from forming (Google, 2014). Early engagement in computer science also allows students to develop fluency with computer science over many years (Guzdial, Ericson, McKlin, & Engelman, 2012) and gives them opportunities to apply computer science to other subjects and interests as they go through school (Grover, 2014). The lack of opportunity is particularly discouraging, given public opinion and recent job statistics on computer science:

- Americans believe computer science is as important to learn as reading, writing, and math (Horizon Media, 2015).
- Most parents want their child's school to offer computer science (Google & Gallup, 2015b).
- Since 2010, computer science ranks as one of the fastest growing undergraduate majors of all STEM fields (Fisher, 2015), and Advanced Placement (AP®) Computer Science is the fastest growing AP exam, despite being offered in only 5% of schools (Code.org, 2015).
- Jobs that use computer science are some of the highest paying, highest growth (Bureau of Labor Statistics, 2015), and most in-demand jobs that underpin the economy (The Conference Board, 2016).
- Computer science is defined as part of a "well-rounded education" in the Every Student Succeeds Act (2015).

What Is Computer Science?

Computing education in K–12 schools includes computer literacy, educational technology, digital citizenship, information technology, and computer science. As the foundation for all computing, 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" (Tucker et. al, 2006, p. 2). The K–12 Computer Science Framework organizes this body of knowledge into five core concepts representing key content areas in computer science and seven practices representing actions that students use to engage with the concepts in rich and meaningful ways.

Computer science is often confused with the everyday use of computers, such as learning how to use the Internet and create digital presentations. Parents, teachers, students, and local and state administrators can share this confusion. A recent survey shows that the majority of students believe that creating documents and presentations (78%) and searching the Internet (57%) are computer science activities (Google & Gallup, 2015a). Parents, teachers, and principals are almost as bad at delineating the difference between traditional computer literacy activities and computer science, and actually more parents than students believe that doing a search on the Internet is computer science (Google & Gallup, 2015a). This confusion extends to state departments of education. A survey of individuals responsible for state certification areas concluded,

> Many states did not seem to have a clear definition or understanding of the field "Computer Science" and exhibited a tendency to confuse Computer Science with other subject areas such as: Technology Education/Educational Technology (TE/ET), Industrial or Instructional Technology (IT), Management Information Systems (MIS), or even the use of computers to support learning in other subject areas. (Khoury, 2007, p. 9)

These misconceptions about computer science pose serious challenges to offering high-quality computer science experiences for all students. The K–12 Computer Science Framework clarifies not only what computer science is but also what students should know and be able to do in computer science from kindergarten to 12th grade. Computer science builds on computer literacy, educational technology, digital citizenship, and information technology. Their differences and relationship with computer science are described below.

- Computer literacy refers to the general use of computers and programs, such as productivity software. Previously mentioned examples include performing an Internet search and creating a digital presentation.
- Educational technology applies computer literacy to school subjects. For example, students in an English class can use a web-based application to collaboratively create, edit, and store an essay online.

- Digital citizenship refers to the appropriate and responsible use of technology, such as choosing an appropriate password and keeping it secure.
- Information technology often overlaps with computer science but is mainly focused on industrial applications of computer science, such as installing software rather than creating it. Information technology professionals often have a background in computer science.

These aspects of computing are distinguished from computer science because they are focused on using computer technologies rather than understanding why they work and how to create those technologies. Knowing why and how computers work (i.e., computer science), provides the basis for a deep understanding of computer use and the relevant rights, responsibilities, and applications.

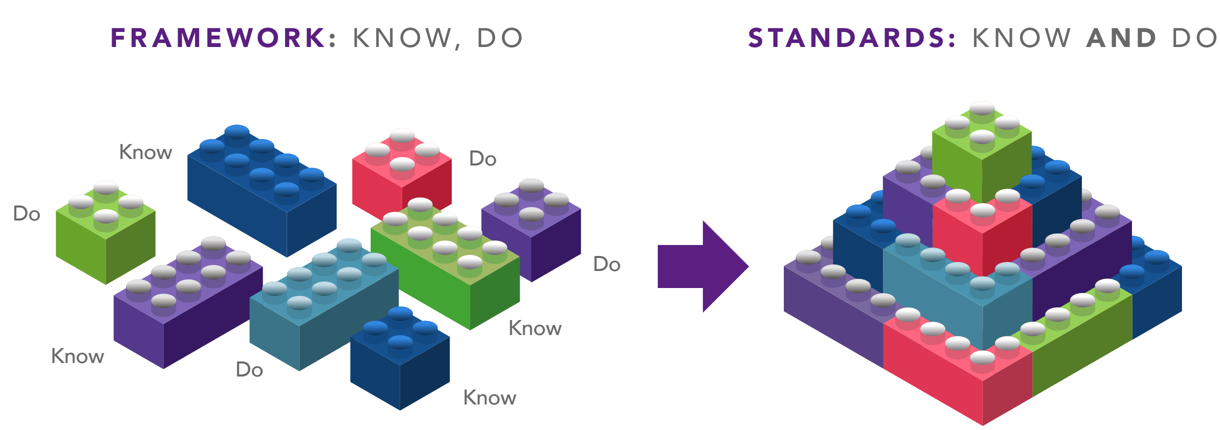
Password security is a topic that illustrates the intersection between computer science and the other aspects of computing. A student who knows how to program a computer to iterate over all of the words in a list (i.e., array) in a split second is a student who will probably not use a dictionary word for a password. In this case, understanding why and how computers work ultimately helps students make good decisions about their use of computers.

Computer science is the foundation for computing. The framework envisions a future in which being computer literate means knowing computer science.

Scope and Intended Audience

The concepts and practices of the K–12 Computer Science Framework are not specific, measurable performance expectations in the form of standards, nor are they detailed lesson plans and activities in the form of curriculum. Instead, the K–12 Computer Science Framework is a high-level guide that states, districts, and organizations can use to inform the development of their own standards and curricula. As illustrated in Figure 1.1, the framework provides building blocks of concepts (that students should know) and practices (that students should do) which can be used to create standards (performance expectations of what students should know and do).

Figure 1.1: Building blocks for standards



It should also be made clear that the framework does not provide the full scope of computer science content for advanced topics of study. The framework describes a baseline literacy for all students, so those who elect to study computer science more deeply may look to honors, AP, or specialized courses in career and technical education programs that include content beyond the framework.

The framework does not prescribe expectations for specific courses. It does not provide grade level-specific outcomes, nor does it define course structure (the scope and sequence of topics in a particular course) or course pathways (the scope of topics and sequence across multiple courses). The five core concepts of the framework were not designed to serve as independent units in a course or separate topics defining entire courses; instead, the framework's concepts and practices are meant to be integrated throughout instruction.

The framework's concepts and practices are meant to be integrated throughout instruction.

The framework was written for an audience with diverse backgrounds, including educators who are learning to teach computer science. This audience includes

- state/district policymakers and administrators;
- standards and curriculum developers (with sufficient computer science experience);
- current and new computer science teachers, including teachers from other subject areas and educators in informal settings; and
- supporting organizations (nonprofits, industry partners, and informal education).

Principles Guiding the Framework

The following principles guided the development of the framework:

1. Broaden participation in computer science.
2. Focus on the essential.
3. Do not reinvent the wheel.
4. Inform with current research and guide future research.
5. Align to nationally recognized frameworks.
6. Inspire implementation.

Broaden Participation in Computer Science

First and foremost, the K–12 Computer Science Framework is designed for all students, regardless of their age, race, gender, disability, or socioeconomic status. The structure and content of the framework reflect the need for diversity in computing and attention to issues of equity, including accessibility. The choice of *Impacts of Computing* as one of the core concepts and *Fostering an Inclusive Computing Culture* as one of the core practices make diversity, equity, and accessibility key topics of study, in addition to interweaving them through the other concepts and practices.

Focus on the Essential

The K–12 Computer Science Framework describes a foundational literacy in computer science, rather than an exhaustive list of all computer science topics that can be learned within a K–12 pathway. Although the framework describes what computer science is essential for all students, educators and curriculum developers are encouraged to create a learning experience that extends beyond the framework to encompass students' many interests, abilities, and aspirations. Additionally, the framework attempts to use jargon-free, plain language that is accessible to instructors and the general public. Where technical terms are used, they are deemed necessary to stay true to disciplinary vocabulary and to fully illustrate the relevant concepts.

Do Not Reinvent the Wheel

The K–12 Computer Science Framework is based on a history of professional research and practice in computer science education. The framework is influenced by the work of professional organizations like the Computer Science Teachers Association (CSTA Standards Task Force, 2011) and frameworks from math, science, and technology education (e.g., ISTE, 2016). Nationally recognized course frameworks like the Advanced Placement Computer Science Principles curriculum framework (College Board, 2016) and the Association for Computing Machinery's curriculum guidelines for undergraduate computer science programs provided a vision for students who may continue to advanced computer science studies. Computer science frameworks from other countries—the United Kingdom (England Department for Education, 2013), Germany (Hubwieser, 2013), Poland (Sysło & Kwiatkowska, 2015), and New Zealand (Bell, Andreae, & Robins, 2014)—were used to benchmark the concepts and practices of the framework.

Inform With Current Research and Guide Future Research

The framework reflects current research in computer science education, including learning progressions, trajectories, and computational thinking. Where specific computer science education research is lacking, the framework relies on the existing knowledge base of the practitioner community and research from other related content areas to guide decisions such as the developmental appropriateness of particular concepts. Remaining questions have guided a research agenda that will inform future revisions to the framework.

Align to Nationally Recognized Frameworks

Developing a framework for computer science education involves both defining a subject new to most schools and relying on established structures and processes used in the development of other education guidelines. Because this framework will exist alongside those from other subjects, the K–12 Computer Science Framework is intentionally structured in a similar way as other frameworks, such as the Framework for K–12 Science Education (NRC, 2012). The use of a lens of concepts and practices to view and describe K–12 computer science provides greater coherence across subject areas. The K–12 Computer Science Framework also mirrored the development process of other community-driven efforts. Transparency and inclusion were emphasized throughout the entire development process via public summaries, monthly updates, forums/webinars, conversations with stakeholders, advisor workshops, community previews, and public review periods. A summary of public feedback and subsequent revisions to the framework can be found in **Appendix A**.

Inspire Implementation

Whether a state or district is already in the process of implementing computer science for all students, or has just begun, the K–12 Computer Science Framework provides a coherent vision for inspiring further efforts. The framework contains chapters that provide guidance on a variety of key implementation steps, such as developing standards, preparing teachers, and creating curriculum that reflects the concepts and practices of the framework. Policy and implementation must go hand in hand to provide high-quality computer science opportunities for all students.

Summary

The goal of this project has been to provide a high-level framework for K–12 computer science education by identifying the core concepts and practices of computer science and describing what those concepts and practices look like for students at various grade bands. The framework provides guidance to states, districts, and organizations that want to design their own standards, curriculum, assessments, or teacher preparation programs. Computer science education is an evolving field with a growing research body at the K–12 level and many lessons to be learned as education systems take steps to increase computer science opportunities. The community that has developed and supported this project believes that the K–12 Computer Science Framework is an initial step to inform, inspire, and drive the implementation work required to make the vision of the framework a reality—computer science for all students.

References

Bell, T., Andreae, P., & Robins, A. (2014). A case study of the introduction of computer science in NZ schools. *ACM Transactions on Computing Education (TOCE), 14*(10), 10:1–10:31. doi: 10.1145/2602485

Bureau of Labor Statistics. (2015). *Employment projections* [Data file]. Retrieved from http://www.bls.gov/emp/tables.htm

Change the Equation. (2015, December 7). The hidden half [Blog post]. Retrieved from http://changetheequation.org/blog/hidden-half

Code.org. (2015, July 2). Computer science is the fastest growing AP course of the 2010s [Blog post]. Retrieved from http://blog.code.org/post/123032125688/apcs-2015

College Board. (2016). *AP Computer Science Principles course and exam description.* New York, NY: College Board. Retrieved from https://secure-media.collegeboard.org/digitalServices/pdf/ap/ap-computer-science-principles-course-and-exam-description.pdf

Computer Science Teachers Association Standards Task Force. (2011). *CSTA K–12 computer science standards, revised 2011*. New York, NY: Computer Science Teachers Association and Association for Computing Machinery. Retrieved from http://www.csteachers.org/resource/resmgr/Docs/Standards/CSTA_K-12_CSS.pdf

The Conference Board. (2016). *National demand rate and OES employment data by occupation* [Data file]. Retrieved from https://www.conference-board.org/

England Department for Education. (2013, September 11). National curriculum in England: Computing programmes of study. Retrieved from https://www.gov.uk/government/publications/national-curriculum-in-england-computing-programmes-of-study/national-curriculum-in-england-computing-programmes-of-study

Every Student Succeeds Act of 2015, Pub. L. No. 114-95. 20 U.S.C.A. 6301 (2016).

Fisher, A. (2015, February 10). The fastest-growing STEM major in the U.S. *Fortune.* Retrieved from http://fortune.com/2015/02/10/college-major-statistics-fastest-growing/

Google. (2014). *Women who choose computer science—what really matters: The critical role of encouragement and exposure.* Mountain View: CA. Retrieved from https://www.google.com/edu/resources/computerscience/research/

Google & Gallup. (2015a). *Images of computer science: Perceptions among students, parents, and educators in the U.S.* Retrieved from http://g.co/cseduresearch

Google & Gallup. (2015b). *Searching for computer science: Access and barriers in U.S. K–12 education.* Retrieved from http://g.co/cseduresearch

Grover, S. (2014). *Foundations for advancing computational thinking: Balanced designs for deeper learning in an online computer science course for middle school students* (Doctoral dissertation). Stanford University, CA.

Guzdial, M., Ericson, B. J., McKlin, T., & Engelman, S. (2012). A statewide survey on computing education pathways and influences: Factors in broadening participation in computing. *Proceedings of the Ninth Annual International Conference on International Computing Education Research* (pp. 143–150). New York, NY. doi: 10.1145/2361276.2361304

Horizon Media. (2015, October 5). Horizon Media study reveals Americans prioritize STEM subjects over the arts; science is “cool,” coding is new literacy. *PR Newswire.* Retrieved from http://www.prnewswire.com/news-releases/horizon-media-study-reveals-americans-prioritize-stem-subjects-over-the-arts-science-is-cool-coding-is-new-literacy-300154137.html

Hubwieser, P. (2013). The Darmstadt model: A first step towards a research framework for computer science education in schools. In I. Diethelm & R. T. Mittermeir (Eds.), *Informatics in Schools: Sustainable Informatics Education for Pupils of All Ages. Proceedings of the 6th International Conference on Informatics in Schools: Situation, Evolution, and Perspectives (ISSEP 13), Oldenburg, Germany* (pp. 1–14). doi: 10.1007/978-3-642-36617-8_1

Information is Beautiful. (2015). *Diversity in tech: Employee breakdown of key technology companies.* Retrieved from http://www.informationisbeautiful.net/visualizations/diversity-in-tech/

International Society for Technology in Education. (2016). *ISTE standards for students.* Retrieved from https://www.iste.org/resources/product?id=3879&childProduct=3848

Khoury, G. (2007). *Computer science state certification requirements. CSTA Certification Committee report*. Retrieved from the Computer Science Teachers Association website: https://csta.acm.org/ComputerScienceTeacherCertification/sub/TeachCertRept07New.pdf

National Research Council. (2012). *A framework for K–12 science education: Practices, crosscutting concepts, and core ideas.* Committee on a Conceptual Framework for New K–12 Science Education Standards. Board on Science Education, Division of Behavioral and Social Sciences and Education. Washington, DC: The National Academies Press.

Rushkoff, D. (2010). *Program or be programmed: Ten commands for a digital age.* New York, NY: OR Books.

Scott, A., & Martin, A. (2014). Perceived barriers to higher education in science, technology, engineering, and mathematics. *Journal of Women and Minorities in Science and Engineering, 20*(3), 235–256. doi: 10.1615/JWomenMinorScienEng.2014006999

Sullivan, G. (2014, May 29). Google statistics show Silicon Valley has a diversity problem. *The Washington Post.* Retrieved from https://www.washingtonpost.com/news/morning-mix/wp/2014/05/29/most-google-employees-are-white-men-where-are-allthewomen/

Sysło, M. M., & Kwiatkowska, A. B. (2015). Introducing a new computer science curriculum for all school levels in Poland. In A. Brodnik & J. Vahrenhold (Eds.), *Informatics in Schools: Curricula, Competences, and Competitions. Proceedings of the 8th International Conference on Informatics in Schools: Situation, Evolution, and Perspectives* (ISSEP 2015), Ljubljana, Slovenia (pp. 141–154). doi: 10.1007/978-3-319-25396-1_13

Tucker, A., McCowan, D., Deek, F., Stephenson, C., Jones, J., & Verno, A. (2006). *A model curriculum for K–12 computer science: Report of the ACM K–12 task force curriculum committee* (2nd ed.). New York, NY: Association for Computing Machinery.