Computational Thinking: A Digital Age Skill for Everyone

The National Science Foundation has assembled a group of thought leaders to bring the concepts of computational thinking to the K–12 classroom.

A group of high school students cluster around a computer looking at a series of graphs and charts on the screen and talking quietly but intently. They are collaborating with a group of students in South America using Skype. Together they have gathered data and created a model depicting the rate of deforestation of the rain forests around the world. Today they are discussing the changes they need to make to their data representation and algorithm before running their simulation. These students are engaged in what is called computational thinking.

What Is Computational Thinking?

Jeanette Wing described computational thinking (CT) as a way of “solving problems, designing systems, and understanding human behavior by drawing on the concepts fundamental to computer science.” She noted that computational thinking involves some familiar concepts, such as problem decomposition, data representation, and modeling, as well as less familiar ideas, such as binary search, recursion, and parallelization. She also argued that “computational thinking is a fundamental skill for everyone, not just for computer scientists. To read, writing, and arithmetic, we should add computational thinking to every child’s analytical ability.”

Wing’s article gave rise to an often controversial discussion and debate among computer scientists, cognitive researchers, and educators regarding the nature, definition, and application of CT. While many people have proposed revisions and refinements to Wing’s original description, so far no single, widely accepted definition of computational thinking has emerged. As a result, PK–12 educators who recognize the importance of CT and want to help students acquire these skills have lacked a clear and practical definition to guide their work.

How Can We Make CT Accessible?

In 2009, the National Science Foundation (NSF) funded a project titled Leveraging Thought Leadership for Computational Thinking in PK–12. Led jointly by ISTE and the Computer Science Teachers Association (CSTA), the project is intended to make the concepts of computational thinking accessible to educators by providing an operational definition, a shared vocabulary, and relevant, age-appropriate examples of computational thinking tied to current educational objectives and classroom practices.

A year ago, the project convened a diverse group of educators with an interest in CT from higher education, PK–12, and industry to help define a common language surrounding computational thinking, articulate the challenges and opportunities of integrating it throughout PK–12 education, and identify the most promising practices and strategies for moving computational thinking from concept to deep integration.

From that meeting a consensus emerged regarding the essential elements of CT, its importance as a learning objective for all students, and how it might be introduced into the PK–12 educational environment. The outcomes of the meeting were summarized and synthesized into a tentative “operational definition” of CT—that is, a description of its components that educators can use to build CT skills across the curriculum through all grade levels and content areas.

Learn More

To learn more about how to teach the concepts and vocabulary of computational thinking in PK–12 classrooms, please visit iste.org/computational-thinking or the CSTA website at http://csta.acm.org. Check back in a few months to find curriculum resources, vocabulary tools, and a toolkit for leaders.

Computational thinking is a problem-solving process that includes:

- Formulating problems in a way that enables us to use a computer and other tools to help solve them
- Logically organizing and analyzing data
- Representing data through abstractions, such as models and simulations
- Automating solutions through algorithmic thinking (a series of ordered steps)
- Identifying, analyzing, and implementing possible solutions with the goal of achieving the most efficient and effective combination of steps and resources
- Generalizing and transferring this problem-solving process to a wide variety of problems

These skills are supported and enhanced by a number of dispositions or attitudes that are essential dimensions of CT, including:

- Confidence in dealing with complexity
- Persistence in working with difficult problems
- Tolerance for ambiguity
- The ability to deal with open-ended problems
- The ability to communicate and work with others to achieve a common goal or solution

More than 82% of the 697 respondents agreed or strongly agreed that this definition captured the essential elements of CT. An additional 9% confirmed that the definition would do as a means to build consensus in the PK–12 community. On the basis of this survey and feedback from educators gathered through conference presentations and other informal data collection, project leaders have begun implementing the next phase of the project, which involves...
It is a unique combination of thinking skills that, when used together, provide the basis of a new and powerful form of problem solving. It is more tool oriented. It makes use of familiar problem-solving skills such as trial and error, iteration, and even guessing in contexts where they were previously impractical but which are now possible because they can be automated and implemented at much higher speeds.

**How Is CT Different?**

In these examples, students are learning computational thinking skills in nontraditional settings so that they can be internalized and can be easily transferred from one setting to another. These students are developing skills that can be applied in a variety of situations—in other classes, in the workplace, and in their hobbies—from a variety of perspectives and in an authentic setting. As more and more teachers emphasize computational thinking or mathematical thinking?

**Mr. Davis’ ninth grade language arts class is studying the diatonic scale and the concept of pitch. Now the students are using Scratch to create a virtual xylophone that will correctly reproduce the scale. Through observation, the students recognize that each bar of the xylophone behaves in the same manner, but the pitch varies for each bar. These students are learning the CT concept of representing data through abstractions of literary elements, such as plot structure, setting, figurative language, tone, and point of view, as well as identifying, analyzing, and implementing possible solutions. Additionally, they are experiencing the CT disposition of persistence in working with difficult problems.**

Ms. Martinez’s sixth grade social studies class is studying the Roman Empire. Students will compare events in an ancient Roman child’s life to their own life experience by writing responses on the Ancient Roman Life Blog. They will also identify the lifestyle of ancient Roman children and compare it to their own. The teacher calls attention to the vocabulary of “modeling” and “simulation” and asks students to reflect on other activities in which they have used these concepts and skills. She also asks them to reflect on where they might use them in the future, including their careers. These students are learning the computational thinking concepts of representing data through abstractions, such as models and simulation, and logically organizing and analyzing data. They are also exploring ways of transferring these skills to other contexts.

Ms. Lee’s seventh grade class is looking at a series of diagrams her students have created to portray floor plans of their school and homes. In the diagrams, each room is labeled as a node and each pathway out of the building is labeled as a node. Students are discussing the options for escape routes in the event of a fire. As the students and Ms. Lee look over the diagrams, they hear a conversation among the students describing how the diagrams are an abstraction of the actual rooms in a home or school building that enables them to represent all the possible escape routes. The students are preparing to create an algorithm to calculate the safest and fastest routes from the buildings.

This question has given rise to much debate but, as yet, no widely accepted consensus. The participants in the workshops sponsored by the ISTE/CSTA project proposed that CT differs from critical thinking and mathemat-