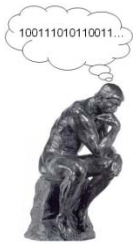




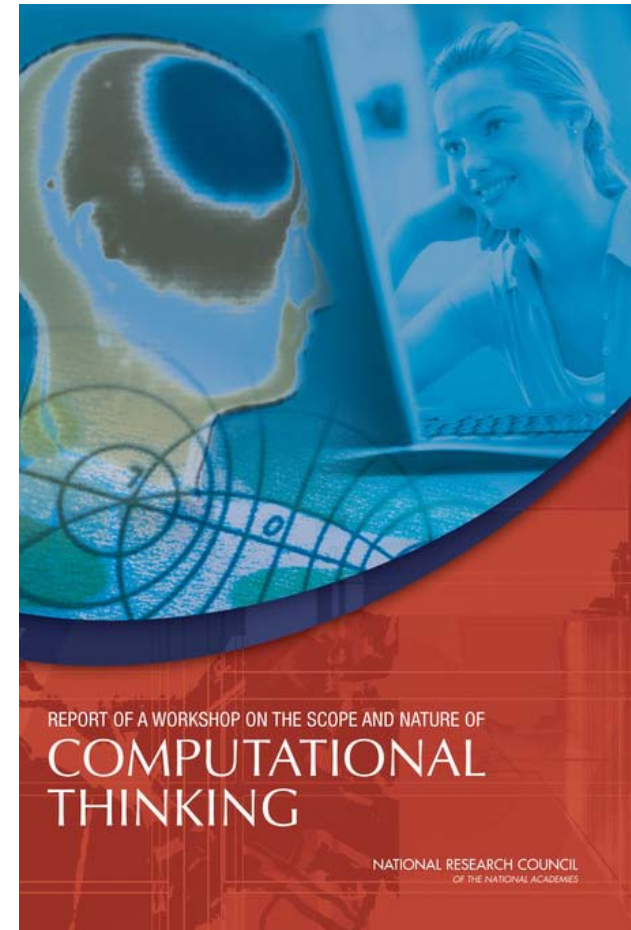
Computational Thinking

NRC Report on Nature/Scope of CT
web site: www.cs.vt.edu/~kafura/CS6604

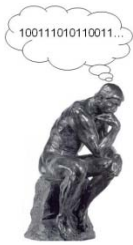


NRC Report

- Sponsored by National Research Council
- First of two reports
- Not intended to produce or reflect a consensus among participants

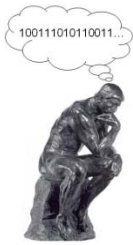


Unless otherwise noted all quotations are from this report.
Page numbers are those in the report not those in the PDF document.



Questions

- What are the scope and the nature of computational thinking?
- How does it differ from other ways of thinking, such as mathematical thinking, quantitative reasoning, scientific thinking, and fluency with information technology?
- What kinds of problems require computational thinking? What are some examples?
- How, if at all, does computational thinking vary by discipline?
- What is the value of computational thinking for nonscientists?
- How, if at all, would widespread facility with computational thinking enhance the productivity of American workers?
- What affordances are provided by new technologies for computational thinking?
- What is the role of information technology in imparting computational thinking skills?
- What parts of computational thinking can be taught without the use of computers? Without the skills of computer programming?



Motivation

- Succeeding in a technological society
- Increasing interest in the information technology professions
- Maintaining and enhancing U.S. economic competitiveness
- Supporting inquiry in other disciplines
- Enabling personal empowerment



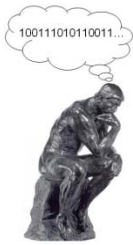
Definition

- “...computational thinking includes a broad range of mental tools and concepts from computer science that help people solve problems, design systems, understand human behavior, and engage computers to assist in automating a wide range of intellectual processes.” [p 3]
- Computer science, of course, has no monopoly on such concepts. For example, physicists have used abstraction and modeling for centuries...Nevertheless, computer science provides a basis for a unified framework and language with which to discuss such notions explicitly, and these notions are the fundamental concepts of this discipline broadly construed [p 3]
- “...computational thinking is a set of skills that transfer across disciplinary boundaries.” [NRC 2011] [p 54]



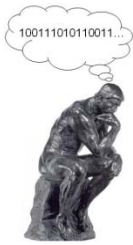
Two contrasting views

- Kolodner [NRC 2011] [p 53-56]
- “...thinking in terms of processes to be carried out, imagining the functional pieces of those processes, and identifying which of those pieces have been used in solving previous problems and which might be used in solving later ones.” (the Tinker-Edelson view)
 - A kind of problem-solving
 - Consistent with system-thinking and model-based reasoning
- “Computational thinking means expressing oneself... being able to create, build, and invent presentations and representations *using computation*. This requires fluency with computational media.” (the Resnick view)
- Individuals facile in one view might not be facile in the other view



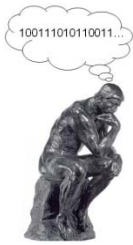
Other views

- Moursund: “...closely related to, if not the same as, the original notions of procedural thinking developed by Seymour Papert” [p 11]
- Lee: “...computational thinking is fundamentally about expanding human mental capabilities through abstract tools that help manage complexity and allow for automation of tasks.” [p 11]
- McGettrick: “computational ‘thinking’ had to involve actual capability and competency with technological artifacts in addition to thought processes.” [p 11]
- Wulf: “...computational thinking was primarily about process.” [p 11]
- Abrahamson: “...computational thinking as the use of computation-related symbol systems (semiotic systems) to articulate explicit knowledge and to objectify tacit knowledge, to manifest such knowledge in concrete computational forms, and to manage the products emerging from such intellectual efforts.” [p 11]



...more views

- Sussman: “...computational thinking as a way of formulating precise methods of doing things. Computational thinking is about rigorous analysis and procedures for accomplishing a defined task efficiently.” [p 11]
- Wing, Sussman: “a meta-science about studying ways or methods of thinking that are applicable across the different disciplines.” [p 12]
- Fox: “...handling and manipulating intangible abstractions for problem-solving purposes [are] at the core of computational thinking.” [p 12]
- Blake: “...computational thinking had to include representations, visualizations, modeling, or meta-modeling.” [p 12]
- Constable: “...an open-ended and growing list of concepts that reflects the dynamic nature of technology and human learning.” [p 12]
- Collins: “...one key feature of computational thinking is representational competence ... the effective application of computational means of representation of knowledge.” [p 25]



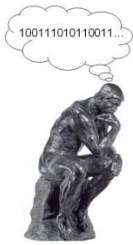
Ways of Understanding CT

- Wilensky [NRC 2011] [p 41]
 - Ways of seeing and knowing
 - Seeing the world as information and processes
 - Ways of doing and capacities
 - Building, designing, modeling
 - A method of inquiry
 - Creating simulated world for exploration
 - Way of collaborating
 - New opportunities for working in groups over time and across space



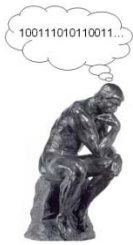
Elements

- “Reformulation of difficult problems by reduction and transformation; approximate solutions; parallel processing; type checking and model checking as generalizations of dimensional analysis; problem abstraction and decomposition; problem representation; modularization; error prevention, testing, debugging, recovery, and correction; damage containment; simulation; heuristic reasoning; planning, learning, and scheduling in the presence of uncertainty; search strategies; analysis of the computational complexity of algorithms and processes; and balancing computational costs against other design criteria,...algorithm, process, state machine, task specification, formal correctness of solutions, machine learning, recursion, pipelining, and optimization.” [p 3]



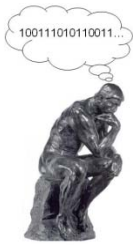
Elements

- Linn: problems in a wide range of courses require certain types of computational thinking ideas [NRC 2011] [p 47-48]
 - Human genome sequencing
 - algorithms; precisely formulated, unambiguous procedures; search, pattern matching, and iterative refinement; and randomization
 - Economics/sociology
 - aggregating multiple independently specified rule-based agents and sensitivity to initial conditions.
 - knowledge of community as a collection of independent decision makers



Language perspective

- “...computational thinking is another language (in addition to written and spoken language, science, and mathematics) that humans can use to talk about the universe and the complex processes within it.” [p 13]
- “... programming is a particularly important form of expression, and that “programming, like writing, is a means of expression and an entry point for developing new ways of thinking.” [p 13]
- Kay: “that a powerful aspect of computational thinking entails the ability to create a language well adapted to a personally relevant purpose—and indeed that this ability could be taught to students.” [p16]
- Sussman: “...computational thinking and mathematics both have an “underlying linguistic structure . . . [that is] language for precise descriptions and about how to do things and language describing the structure of things.” [p 33]



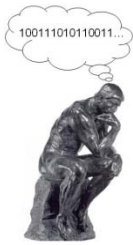
Abstraction perspective

- “...that computational thinking focuses on the process of creating and managing abstractions, and defining relationships between layers of abstraction. ... In this view, computational thinking is a tool for explaining and representing complexity through automation.” [p 16]
- Kahn: “that computational thinking provides a concretization—the creation of something concrete and tangible—of subjects that are typically dominated by abstract concepts. ...an example of such concretization is computer games—” [p 17]
- Wing: “...while similar to mathematical thinking in many respects, computational thinking does have to consider the physical constraints of the underlying computer.” [p 34]



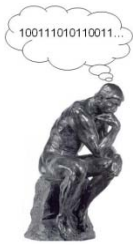
Cognitive perspective

- Moursund (referring to Perkins' Person Plus concept):
 - Three dimensions of team problem solving
 - Tools that expand or extend mental capabilities
 - Tools that extend physical capabilities
 - Education and training
 - “computational thinking and computers fit into both categories [of tools].” [p18]



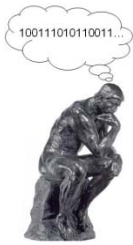
CT without programming

- Danish: an example of young students engaging in computational thinking concepts without using computers [p 20-22]
 - Individual creation of representations
 - Participatory modeling – collaborative demonstration
 - participatory simulation – instructing others
 - Technology use – simulation environment
- Bell: illustrations from Computer Science Unplugged
 - User interfaces – recognizing that the controls on a watch for a user interface
 - Routing – physical simulation
- Astrachan
 - Word puzzle: “white” → “house” by a sequence of single letter substitutions
 - Illustrates breadth-first search using graph structure



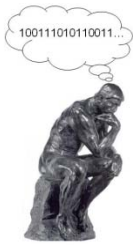
Role of Technology

- Is technology use necessary for computational thinkers?
 - “Many participants argued that the ability to develop facility with new technologies is a part of computational thinking. Computational thinking in this view involves finding the right technology for a problem and applying the technology to resolve the problem. ... computers and other computational devices enable computational thinking.” [p 26]
 - “...others ... argued strongly that because computers are not restricted to mechanical computers but instead can refer to human agents, computational thinking becomes relevant to individuals outside the context of mechanical computers.” [p 26]
 - “at its core, computational thinking was independent of technology—that being a competent computational thinker did not necessarily imply anything about one’s ability to use modern information technology. “ [p 61]
 - “Others believed that the connections between information technology and computational thinking were so deep that it effectively makes no sense to regard the two as separate.” [p 61]



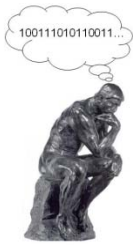
Concluding Questions

- What is the core of computational thinking?
- What are the elements of computational thinking?
- What is the sequence or trajectory of development of computational thinking?
- Does computational thinking vary by discipline?



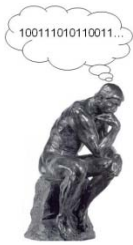
Tensions

- Between CT as a problem-solving skill or a means of creative expression
 - Affects definition of CT
 - Has implications for curriculum design
- Between CT being learned in context or as a general topic in its own right
 - Affects curriculum design
 - Guides development of assessment
- Between CT as a cognitive ability or also requiring competence in applying the ability using technology
 - Influences definition of CT
 - Has implications for assessment



Evolving definition

- Computational thinking is a cognitive ability characterized by creative work using information susceptible to automation.
 - Cognitive – a fundamental mental ability, not just skill in tool use
 - Information+automation –
 - what distinguishes computational thinking from other ways of thinking
 - Need not be automated, but must be automatable
 - Automation provided by traditional computing devices, biological systems, quantum computers, ...
- The ability is derived from sufficient mastery of a conceptual framework.
- A practicing computational thinker is an individual capable of using automation to realize their creative work in the world



References

- [NRC 2010] *Report of a Workshop on the Scope and Nature of Computational Thinking*. 2010, National Research Council.
- [NRC 2011] *Report of a Workshop on the Pedagogical Aspects of Computational Thinking*. 2011, National Research Council.