3.1.a. Topics and Goals

The National Educational Technology Standards (NETS) (ISTE, 2002) provide an excellent starting place for defining requirements for elementary student preparedness in computer science.[3]

To live and work successfully in an increasingly information-rich society, K–8 students must learn to use computers effectively and incorporate the idea of algorithmic thinking into their daily problem-solving vocabulary. To ensure these outcomes, schools must provide computing tools that enable students to solve problems and communicate using a variety of media; to access and exchange information; compile, organize, analyze, and synthesize information; draw conclusions and make generalizations from information gathered; understand what they read and locate additional information as needed; become self-directed learners; collaborate and cooperate in team efforts; analyze a problem and develop an algorithmic solution; and interact with others using computers in ethical and appropriate ways.

Except in the context of mathematics education, this particular topic area is not a conventional part of the K–8 curriculum. That is, the concept of algorithm is used only to teach students the steps of arithmetic (addition, multiplication) and other basic mathematical ideas. However, the notion of algorithm affects students in a much richer array of problem-solving situations that they encounter in their lives.

In its simplest form, an algorithm is a method for solving a problem in a step-by-step manner. So children learn about algorithmic problem solving whenever they discover a collection of steps that can be carried out to accomplish a task. These steps should accommodate unusual contingencies (using conditional, or "if" statements) and repetitions (using loops, or "while" statements). Viewed in this way, algorithmic thinking is not simply a means to help children understand mathematical concepts—it has a much richer range of uses. Here are a few example problems that illustrate this point and would be appropriate at the K–8 level.

Give a complete algorithmic definition for:

1. finding your way out of a maze (Turtle graphics, robotics)
2. a dog retrieving a thrown ball
3. baking cookies
4. going home from school
5. making a sand castle
6. arranging a list of words in alphabetical order.

Thus, we agree with teachers who believe that students at this age ought to begin thinking algorithmically as a general problem-solving strategy. What children do, not what they see, may have the greatest impact on learning at the K–8 level. Thus, it makes sense to develop more teaching strategies that encourage students to engage in the process of visualizing an algorithm. Seymour Papert's pioneering experiments in the 1980s corroborate this belief, and his seminal work *Mindstorms* and related curricula (Papert, 1980) provide many more examples of how K–8 students can be engaged in algorithmic thinking. Additional examples of computer science topics appropriate for the K–8 level are included in the next section.

3.1.b. Grade-Level Breakdowns

To ensure that students achieve these goals, we paraphrase here the NETS model (ISTE, 2002), which identifies different sets of outcomes for three different groups of students: grades K–2, grades 3–5, and grades 6–8. We have augmented that model by adding outcomes that engage students with algorithmic thinking and other foundational elements of computer science.

[3] These standards were originally developed by the International Society for Technology in Education (ISTE) as part of an ongoing effort to enable stakeholders in Pre-K–12 education to develop national standards for educational uses of technology.

Grades K–2: Upon completion of grade 2, students will:

1. Use standard input and output devices to successfully operate computers and related technologies.
2. Use a computer for both directed and independent learning activities.
3. Communicate about technology using developmentally appropriate and accurate terminology.
4. Use developmentally appropriate multimedia resources (e.g., interactive books, educational software, elementary multimedia encyclopedias) to support learning.
5. Work cooperatively and collaboratively with peers, teachers, and others when using technology.
6. Demonstrate positive social and ethical behaviors when using technology.
7. Practice responsible use of technology systems and software.
8. Create developmentally appropriate multimedia products with support from teachers, family members, or student partners.
9. Use technology resources (e.g., puzzles, logical thinking programs, writing tools, digital cameras, drawing tools) for problem solving, communication, and illustration of thoughts, ideas, and stories.
10. Gather information and communicate with others using telecommunications, with support from teachers, family members, or student partners.
11. Understand how 0s and 1s can be used to represent information, such as digital images and numbers.
12. Understand how to arrange (sort) information into useful order, such as a telephone directory, without using a computer (see Appendix for examples).

Grades 3–5: Upon completion of grade 5, students will:

1. Be comfortable using keyboards and other input and output devices, and reach an appropriate level of proficiency using the keyboard with correct fingering.
2. Discuss common uses of technology in daily life and the advantages and disadvantages those uses provide.
3. Discuss basic issues related to responsible use of technology and information, and describe personal consequences of inappropriate use.
4. Use general-purpose productivity tools and peripherals to support personal productivity, remediate skill deficits, and facilitate learning throughout the curriculum.
5. Use technology tools (e.g., multimedia authoring, presentation, Web tools, digital cameras, scanners) for individual and collaborative writing, communication, and publishing activities to create presentations for audiences inside and outside the classroom.
6. Use telecommunications efficiently to access remote information, communicate with others in support of direct and independent learning, and pursue personal interests.
7. Use online resources (e.g., e-mail, online discussions, Web environments) to participate in collaborative problem-solving activities for the purpose of developing solutions or products for audiences inside and outside the classroom.
8. Use technology resources (e.g., calculators, data collection probes, videos, educational software) for problem-solving, self-directed learning, and extended learning activities.
9. Determine which technology is useful and select the appropriate tool(s) and technology resources to address a variety of tasks and problems.
10. Evaluate the accuracy, relevance, appropriateness, comprehensiveness, and bias that occur in electronic information sources.
11. Develop a simple understanding of an algorithm, such as text compression, search, or network routing, using computer-free exercises (see Appendix for examples).

Grades 6–8: Upon completion of grade 8, students will:

1. Apply strategies for identifying and solving routine hardware and software problems that occur during everyday use.
2. Demonstrate knowledge of current changes in information technologies and the effects those changes have on the workplace and society.
3. Exhibit legal and ethical behaviors when using information and technology and discuss consequences of misuse.
4. Use content-specific tools, software, and simulations (e.g., environmental probes, graphing calculators, exploratory environments, Web tools) to support learning and research.
5. Apply productivity/multimedia tools and peripherals to support personal productivity, group collaboration, and learning throughout the curriculum.

6. Design, develop, publish, and present products (e.g., Web pages, videotapes) using technology resources that demonstrate and communicate curriculum concepts to audiences inside and outside the classroom.
7. Collaborate with peers, experts, and others using telecommunications tools to investigate educational problems, issues, and information, and to develop solutions for audiences inside and outside the classroom.
8. Select appropriate tools and technology resources to accomplish a variety of tasks and solve problems.
9. Demonstrate an understanding of concepts underlying hardware, software, algorithms, and their practical applications.
10. Discover and evaluate the accuracy, relevance, appropriateness, comprehensiveness, and bias of electronic information sources concerning real-world problems.
11. Understand the graph as a tool for representing problem states and solutions to complex problems (see Appendix for examples).
12. Understand the fundamental ideas of logic and its usefulness for solving real-world problems (see Appendix for examples).

3.2 Level II—Computer Science in the Modern World

This is a one-year course (or the equivalent) that would be accessible to all students, whether they are college-bound or workplace-bound. The goal of this course is to provide all students with an introduction to the principles of computer science and its place in the modern world. This course should also help students to use computers effectively in their lives, thus providing a foundation for successfully integrating their own interests and careers with the resources of a technological society.

In this course, high school students can acquire a fundamental understanding of the operation of computers and computer networks and create useful programs implementing simple algorithms. By developing Web pages that include images, sound, and text, they can acquire a working understanding of the Internet, common formats for data transmission, and some insights into the design of the human-computer interface. Exposure to career possibilities and discussion of ethical issues relating to computers should also be important threads in this course.

Prior to this course, students should have gained experience using computers, as would normally occur at Level I. They should have used, modified, and created files for a variety of purposes, accessed the Internet and databases for both research and communication, and used other tools such as spreadsheets and graphics. Finally, they should have been introduced to the basic idea of algorithmic thinking and its uses in their daily lives.

3.2.a. Topics and Goals

A major outcome of this course (or its equivalent) is to provide students with general knowledge about computer hardware, software, languages, networks, and their impact in the modern world.[4] That is, since most students at Level II will eventually encounter computers and networks as users, the overarching aim here is to prepare students to master computer science concepts from the user's point of view rather than from the designer's. For instance, the idea that a robot needs a method of acquiring sensory data from its environment draws attention to the general notion of an "input device" beyond the standard keyboard and mouse. Teaching students about various input devices currently in use should help demystify the general idea of input, and prepare students to be comfortable using devices with which they are not yet familiar.

Students should gain a conceptual understanding of the following topics in computer science:

1. Principles of computer organization and the major components (input, output, memory, storage, processing, software, operating system, etc.)
2. The basic steps in algorithmic problem-solving (problem statement and exploration, examination of sample instances, design, program coding, testing and verification)

[4] Coincidentally, students will acquire proficiency with a current computer model and programming language, but that is not the main goal of this course.