

National Assessment Governing Board

Assessment Development Committee

August 6-7, 2009

AGENDA

Thursday, August 6, 2009

Closed Session

8:30 a.m. – 2:00 p.m.

Review of NAEP U.S. History and Writing Items

Friday, August 7, 2009

Open Session

10:00 a.m. – 11:00 a.m.

1. Welcome, Introductions, and Agenda Overview

Kathi King, Chair

2. NAEP 2012 Technological Literacy Framework Project

Mary Crovo, Governing Board Staff

Alan Friedman, ADC Vice Chair

Senta Raizen, WestEd

Attachment A

3. NAEP Item Review Schedule

Mary Crovo

Attachment B

Closed Session

11:00 a.m. – 12:15 p.m.

4. Update on NAEP Assessment Development Activities

- a. Writing Assessment Development for 2011

Jay Campbell, ETS

Paul Harder, Fulcrum IT

- b. Accessible Booklet Study

Kim Gattis, NAEP Education Statistics

Services Institute

Attachment C

NAEP Technological Literacy Framework Project

Status

Information and discussion

Materials Provided

- Draft Framework Table of Contents
- Draft Framework Chapters 1 – 4

Background

The Governing Board's Assessment Development Committee (ADC) has been monitoring work on the 2012 NAEP Technological Literacy project since the contract award to WestEd in late September 2008.

At the May 2009 Board meeting, the ADC heard from co-chairs of the Framework Planning Committee—Edys Quellmalz of WestEd and Cary Sneider of Portland State University. The ADC had an opportunity to review and discuss draft portions of Chapter 2 related to areas of technological literacy. As part of the presentation, project staff provided several specific examples of assessment targets, which appear in the detailed matrices for grades 4, 8, and 12 to define the content to be measured on the technological literacy assessment.

Also in May 2009, ADC members discussed the public forum held in Seattle on May 13. The forum convened Seattle-area engineers, computer technology specialists, policymakers, and others to gather feedback on initial recommendations for the draft Framework. More than 20 individuals attended the forum to provide input on the Technological Literacy Framework project.

Since the May 2009 Board meeting, a number of additional forums have been convened involving a range of individuals with various perspectives on assessing Technological Literacy. At their August 2009 meeting, the ADC will receive feedback on the forums and learn how the project committees have worked to develop the initial draft Framework chapters that appear in the ADC tab. WestEd project staff will outline key issues raised during the forums and in the mid-July Steering Committee meeting. Most of the time on the Technological Literacy agenda topic will be spent discussing ADC comments and questions related to the draft Framework chapters.

Technological Literacy Framework for the 2012 National Assessment of Educational Progress

Discussion Draft – 7/24/09

Developed by WestEd
under contract to the National Assessment Governing Board
Contract # ED08CO0134



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CHAPTER ONE: OVERVIEW

Background of NAEP

For more than 35 years the National Assessment of Educational Progress (NAEP) has measured student achievement nationally, state by state, and, most recently, across selected urban districts. NAEP has been used as an independent monitor of what students know and can do in various subject areas, including reading, mathematics, science, U.S. history, and writing. For each subject area, a framework provides recommendations on the content to be assessed, the types of assessment questions, and the administration of the assessment. The framework is designed to guide the assessment for about a decade before it is updated.

Originally, NAEP assessments were carried out with age-based samples of 9-, 13-, and 17-year-old students. Beginning in 1983, the assessment has also included grade-based samples of students in grades 4, 8, and 12. Currently, the long-term trend NAEP continues to assess 9-, 13-, and 17-year-olds in mathematics and reading, while the main NAEP assesses students in grades 4, 8, and 12. More information about the differences between the long-term trend and the main NAEP can be found on the Internet at http://nces.ed.gov/nationsreportcard/about/Itt_main_diff.asp (NCES 2005b).

NAEP results, commonly referred to as “The Nation’s Report Card,” have become an important source of information on what U.S. students know and are able to do in a range of subject areas. One of NAEP’s most valuable features is that it provides information on how student performance has changed over time. Since the 1990s, in addition to the national-level assessments, state-level NAEP assessments have been conducted and reported at grades 4 and 8 in reading, mathematics, writing, and science. The resulting data on student knowledge and performance have been accompanied by background information that allows analyses of a number of student demographic and instructional factors related to achievement. The assessments have been designed to allow comparisons of student performance over time and among subgroups of students defined according to region, parental education, gender, and race/ethnicity.

Need for a Framework in Technological Literacy

One of the areas that NAEP has not assessed up to this point is technological literacy. Although it has been defined in a variety of ways, technological literacy can be thought of as general understanding of technology coupled with an capability to use, manage, and assess the technologies that are most relevant in one’s life, such as the information and communication technologies that are particularly salient in the world today.

Because technology is such a crucial component of modern society, it is important that students develop an understanding of its various aspects, from the design process that engineers use to develop new technological devices and the trade-offs that must be balanced in making decisions about the use of technology to the way that technology shapes society and society shapes technology. Indeed, some have argued that it is time for technological literacy to take its place

alongside the traditional literacies in reading, mathematics, and science as a set of competencies that students are expected to develop during their years in school.

A growing number of states are offering technology education as a separate subject, while others embed technology into other subject areas, such as science or social studies. According to the September 2007 issue of *The Technology Teacher*, 40 states included technology in their state curriculum framework as of that year, up from 38 in 2004. A dozen states required technology education for students in at least some grades, and a total of 22 offered technology education as an elective. The *Standards for Technological Literacy* developed by the International Technology Education Association were being used in 41 states at either the state level or in the school districts (Dugger 2007).

During the development of the *Science Framework for the 2009 NAEP*, members of the steering committee discussed whether technology and engineering principles should be included in that framework. Gerald Wheeler, who was chair of the steering committee and then also the executive director of the National Science Teachers Association, described the deliberations in later testimony before the National Assessment Governing Board. “After much consideration,” he said, “it was the consensus of the Steering Committee to keep the focus on science assessment within the Framework for 2009.” Nonetheless, there was a general sense that technological literacy and its assessment were subjects that the Governing Board should address.

In 2005, after considering input from a number of people with diverse perspectives, the Governing Board decided that it would sponsor development of a national assessment on technological literacy. In a press release dated October 6, 2008, announcing the plan to develop this framework, Alan Friedman, a physicist and member of the Governing Board’s executive committee, described the rationale for this effort as follows:

We all know that engineering and technologies in all forms—including computers, communications, energy usage, agriculture, medicine, and transportation—affect everything we hear, see, touch, and eat. With this new framework and the tests it will guide, we’ll discover how well students today are learning to understand and use these immensely powerful tools.

Context for Planning the Framework

Any NAEP framework must be guided by NAEP purposes as well as by the policies and procedures of the Governing Board, which oversees NAEP. For the NAEP Technological Literacy Assessment, the main purpose of the framework is to establish what students should know and be able to do in technology for the 2012 and future assessments and to set forth criteria for the design of the assessment. Meeting this purpose requires a framework built around what communities involved in technology, technology education, and technological literacy consider as a rigorous body of knowledge and skills that are most important for NAEP to assess.

In prioritizing the content, the Framework developers used the NAEP Technological Literacy steering committee guidelines (presented later in this chapter). These guidelines recommended drawing from the following sources:

- States that have well developed technology standards
- International technology standards (e.g. the United Kingdom)
- Research studies and reports (e.g. *Technically Speaking* and *Tech Tally: Approaches to Assessing Technological Literacy* from National Academy of Engineering (NAE) and the National Research Council (NRC))
- *National Education Technology Standards* by the International Society for Technology in Education (ISTE)
- *Standards for Technological Literacy: Content for the Study of Technology* by the International Technology Education Association's (ITEA)
- The *Science Framework for the 2009 National Assessment of Educational Progress*
- The Partnership for 21st Century Skills' *Framework for 21st Century Learning*
- *Benchmarks for Science Literacy* from the American Association for the Advancement of Science (AAAS)
- The *National Science Education Standards* from the National Research Council

These sources embody a wealth of information about technology, technology education, and technological literacy. All address similar issues of K-12 content and assessment, and in many ways they converge on a broad vision of technological literacy. However, the various documents do not always share common definitions of terms, and in many cases attach different meanings to phrases such as “educational technology” and “technology education” that a reader outside the field would find confusing. Consequently, it is important to establish clear definitions for the purpose of this Framework, and the work of NAEP that will follow.

Definition of Technological Literacy

The following discussion is intended to define the terms “technology” and “technological literacy” in a way that captures the knowledge and abilities that are essential for citizens in the 21st century and also in a way that can be assessed through an on-demand, large-scale assessment.

Technology

Research shows that most Americans have a limited view of what technology is and that they associate it most often with computers and related electronic devices (ITEA, 2004; Cunningham et al, 2005). However, while the computer is certainly an important example of technology—and one that plays an especially important role in this framework—the term “technology” has a broader and deeper meaning.

Broadly speaking, *technology* is any modification of the natural world done to fulfill human needs or desires. This definition sees technology as encompassing the entire human-made world, from the simplest artifacts, such as paper and pencil, to the most complex—buildings and cities, the electric power grid, satellites, and the Internet. Furthermore, technology is not just the things that people create. It includes the entire infrastructure needed to design, manufacture, operate,

and repair technological artifacts, from corporate headquarters and engineering schools to manufacturing plants and distribution networks (Shakrani and Pearson, 2008).

Throughout history technology has been one of the major factors shaping human life and human civilization, and, indeed, major periods of human development have typically been identified by the dominant technologies of the period: stone age, bronze age, iron age, industrial age, and, today, the information age. Technology itself is constantly changing and evolving, as are its effects on us and our way of life. Ten thousand years ago humans took the first steps toward agriculture with the purposeful planting of seeds; one hundred years ago farmers and plant scientists were regularly improving crops through hybridization; today, we have harnessed genetic engineering to create designer crops and farm animals. Perhaps the most dramatic example of technological evolution from today's perspective is the rapid development of communications technology from the invention of the telegraph and telephone in the 19th century, to the development of radio, television, and the Internet in the 20th century, to the past decade's explosion of e-mail, cell phones, and social networking. With each of these changes come new capabilities—and new challenges.

Technological Literacy

Having defined technology broadly in this way, we can define *technological literacy* in an equally broad fashion as the capability to use, understand, and evaluate technology as well as to apply technological concepts and processes to solve problems and reach one's goals.

Technological literacy is, like scientific, mathematical, or language literacy, a measure of how well individuals have mastered the tools they need to participate intelligently and thoughtfully in the world around them. As described in reports from the National Academy of Engineering (NRC 2002, 2006), the International Society for Technology in Engineering (ISTE 2007), and the International Technology Education Association (ITEA 2007), technological literacy includes knowledge, capabilities, and critical thinking and decision-making skills. From these documents we can extract lists of the various things that a technologically literate person should know and be able to do. These characteristics of a technologically literate person can be grouped into three categories:

Knowledge

- Understands the nature of technology in its broadest sense.
- Knows how technology is created and how it shapes society and in turn is shaped by society.
- Understands basic engineering concepts and terms, such as systems, constraints, and trade-offs.
- Is aware of the various digital tools and their appropriateness for different tasks.
- Understands cultural differences by engaging with learners of other cultures.

Capabilities

- Uses a wide range of technological tools and systems, ranging from kitchen appliances and alarm clocks to cars, computers, cell phones, and the Internet.

- Can apply technological concepts and abilities creatively, including those of engineering design and information technology, to solve problems and meet goals.
- Communicates information and ideas effectively to multiple audiences using a variety of media and formats.

Critical Thinking and Decision-Making

- Collects and analyzes data to develop a solution to complete a project.
- Uses multiple processes and diverse perspectives to explore alternative solutions.
- Can evaluate product claims and make intelligent buying decisions.
- Participates thoughtfully and productively in discussing critical societal issues involving technology, such as energy and power, climate change, and land use policy.

Three Areas of Technological Literacy

Technology education has a long and varied history, both globally and in the United States. In recent decades the meaning of technological literacy has taken on three quite different (though by no means inconsistent) forms in the United States. These are the science, technology, and society approach, the technology education approach, and the information and communications technology approach. In recognition of the importance, educational value, and interdependence of these three approaches, this framework includes all three under its broad definition of technological literacy. In recognition of the distinct goals and teaching methods involved in each, this framework also allows for assessment results to be disaggregated so as to monitor and analyze the results of each approach over time. In the next few paragraphs we offer a brief description of each of these approaches. A detailed description of the assessment targets in each area is provided in Chapter Two.

The science, technology, and society (STS) approach focuses on the ways that science and technology interact with society. In 1990 the board of directors of the National Science Teachers Association defined STS as the “teaching and learning of science and technology in the context of human experience” (NSTA 2006, pp. 229–230). In practice many STS programs use societal issues as course organizers. Such issues commonly include space travel, insecticide use, nutrition, disease, ozone, global warming, and other concerns reported in the popular press. Since technological advances and decisions lie at the core of such issues, the focus in discussing them is often on the technology involved (Yager and Akcay 2008, pp. 2-3). A survey of engineering and technology in state science standards found that a majority of state standards reflect the STS approach (Koehler et al. 2006). The STS approach is represented in this framework under the heading “Technology and Society.”

Technology education evolved from industrial arts (Dugger 2005), a school subject popular throughout most of the 20th century, which provided education in the use of hand and power tools for fabricating objects from wood, metal, or other materials, as well as teaching about industrial processes. As conceived today by the field’s professional organization, the International Technology Education Association (ITEA), technological literacy “... involves a vision where each citizen has a degree of knowledge about the nature, behavior, power, and consequences of technology from a broad perspective. Inherently, it involves educational

programs where learners become engaged in critical thinking as they design and develop products, systems, and environments to solve practical problems” (ITEA 1996, p. 1). Learning goals in technology education include creating a broad understanding of both technology and engineering as well as developing specific abilities in both areas (ITEA 2007). A survey of state science standards (Koehler et al. 2006) found that many states, especially those in the Northeast, include standards consistent with this approach, although not as many as the number whose standards relate to STS. The engineering design approach is represented in this framework under the heading “Design and Systems.”

Information and communications technology (ICT) is a third approach that has been growing in importance over the past three decades. The field’s major professional organization, the International Society for Technology in Education (ISTE), was formed in 1989 by the merger of two associations concerned primarily with the use of computers in education. Today, the vision of ICT is much broader than the use of computers alone. As expressed in the society’s National Educational Technology Standards (NETS 2009), ICT abilities include creativity and innovation, communication and collaboration, research and information fluency, and critical thinking, problem solving, and decision making. These abilities are applied specifically to the use of digital technologies and media, including the Internet and other networking applications. Although these information technologies make up just one corner of technology, broadly defined, they have been responsible for many of the most profound changes that have taken place in society over the past several decades, as pointed out in such works as *The World is Flat* (Friedman 2005) and the *New Division of Labor* (Murnane and Levy, 2004). And the variety, use, and power of such information tools is only expected to grow—and grow rapidly—over the next decade (The New Media Consortium 2009). The ICT approach to technological literacy is represented in this framework under the heading “Information and Communication Technologies.”

Although the results of the NAEP Technological Literacy Assessment will be disaggregated and reported separately, it cannot be stressed strongly enough that today’s youth are expected to acquire competency in all three areas of technological literacy and that these areas are neither learned separately nor applied separately. A technologically literate person understands and is able to analyze the relationship between technology and society, has a broad understanding of technology and can solve problems using the engineering design process, and is able to make fluent use of digital technologies and media in creative and innovative ways. Specific assessment targets related to the three areas are described at length in Chapter Two.

Educational Technology

Although it is not an assessment target for the purposes of NAEP, the field of educational technology provides another common use of the term “technology.” Broadly speaking, the field of educational technology is concerned with the use of various types of equipment as aides in teaching. Many of today’s teachers remember the replacement of chalkboards by whiteboards and the widespread use of overhead projectors. Advocacy for the use of computers in classrooms began more than twenty years ago, and the uses of computers have evolved rapidly from computers-as-teachers to computers-as-tools. Today a vast array of computer applications is available for use in all school subjects. Some new devices, such as “smart boards,” combine

technologies for entirely new purposes. The variety and use of such tools is expected to expand rapidly over the next decade, affecting the way people work, collaborate, and communicate (New Media Consortium 2009). The 2012 NAEP technological literacy assessment will take advantage of new developments in educational technology as the first NAEP assessment to be administered entirely by computer.

Technology Educators

Consistent with our broad definition of technological literacy, we recognize technology educators as all those who teach about the relationship between technology and society, or about the nature of technology and the methods used by engineers to improve and design new technologies, or who help students develop abilities to use computers, information networks, digital media, and other information technologies.

Technology educators have a number of challenges. Although technology has its own body of knowledge and processes, technological literacy also supports literacy in other content areas. So technology educators must think very broadly about their learning goals. Technology itself also changes rapidly, and technological advances often lead to advances in other fields. So it is essential for technology educators to continuously renew their own education.

The Relationship Among Science, Technology, and Engineering

Science, technology, and engineering are closely interlinked areas—so closely interlinked that it is often difficult to know exactly where one starts and the other stops. Students in sciences classes are often taught about technology and engineering, students in technology classes learn about science and engineering, and so forth. But for the purposes of designing a framework to assess technological literacy it is important to keep the distinctions among the three clear. The relationship between engineering, science and technology is explained this way in the National Academy of Engineering publication *Technically Speaking*:

Science and technology are tightly coupled. A scientific understanding of the natural world is the basis for much of technological development today. The design of computer chips, for instance, depends on a detailed understanding of the electrical properties of silicon and other materials. The design of a drug to fight a specific disease is made possible by knowledge of how proteins and other biological molecules are structured and how they interact.

Conversely, technology is the basis for a good part of scientific research. The climate models meteorologists use to study global warming require supercomputers to run the simulations. And like most of us, scientists in all fields depend on the telephone, the Internet, and jet travel.

It is difficult, if not impossible, to separate the achievements of technology from those of science. When the Apollo 11 spacecraft put Neil Armstrong and Buzz Aldrin on the moon, many people called it a victory of science. When a new type of material, such as lightweight, superstrong composites, emerges on the market,

newspapers often report it as a scientific advance. Genetic engineering of crops to resist insects is also usually attributed wholly to science. And although science is integral to all of these advances, they are also examples of technology, the application of unique skills, knowledge, and techniques, which is quite different from science. (NAE 2002, pp. 13-14)

One other distinction that is important to make is between technology and engineering. Again the explanation from *Technically Speaking* is helpful.

Technology is a product of engineering and science, the study of the natural world. Science has two parts: (1) a body of knowledge that has been accumulated over time and (2) a process—scientific inquiry—that generates knowledge about the natural world. Engineering, too, consists of a body of knowledge—in this case knowledge of the design and creation of human-made products—and a process for solving problems. (NAE 2002, p. 13)

Of the three terms—science, technology and engineering—the clearest parallel is between science and engineering, since both represent a body of work produced by a group of well-trained professionals. As explained in the *National Science Education Standards* (NRC 1996, p. 166) “*Scientists* propose explanations for questions about the natural world, and *engineers* propose solutions relating to human problems, needs, and aspirations.”

There is a fourth area that is often associated with these other three: mathematics. Although mathematics is a field in its own right, distinct from science and engineering, mathematical tools are essential to the work of both scientists and engineers. In fact, science, technology, engineering, and mathematics are so intimately connected that they are frequently referred to by the joint acronym STEM.

Before moving on to the next section, it is important to note that these definitions have been developed for the sole purpose of informing the National Assessment of Educational Progress about the field of technological literacy. No additional claim is made regarding the usefulness of these definitions for other purposes—and certainly not for the interpretation of assessments used at state and local levels, since these may be based on different definitions of technological literacy.

The Framework Development Process

In October 2008, the Governing Board awarded a contract to WestEd to develop a framework and specifications for assessing technological literacy. In carrying out its work, WestEd worked closely with the Council of Chief State School Officers (CCSSO), the International Technology Education Association (ITEA), the International Society for Technology in Education (ISTE), the State Educational Technology Directors Association (SETDA), and the Partnership for 21st Century Skills. In collaborating with these groups WestEd used a process for developing the framework and related products that was inclusive, deliberate, and designed to achieve as much broad-based input as possible.

A two-tiered committee structure with a technological literacy steering committee and a technological literacy planning committee provided the expertise to develop the framework as specified by the Governing Board. (See “NAEP Technological Literacy Project Staff and Committees” for lists of committee members.) The two committees were composed of members who were diverse in terms of role, gender, race or ethnicity, region of the country, perspective, and expertise regarding the content of the assessment to be developed.

The steering committee members included leaders in technology in schools, engineering, education, 21st century skills, the Internet, business, science education, general education, and assessment. The co-chairs were balanced, with one representing technology in schools and the other STEM and assessment. Functioning as a policy and oversight body, this group developed a charge that outlined the planning committee’s responsibilities in developing the framework. The committee reviewed and provided feedback on drafts of the framework and related materials. The interaction between the two committees was iterative over the course of the project.

The planning committee, supported by the project staff, was the development and production group responsible for drafting the framework, the specifications, recommendations for background variables, and preliminary technological literacy achievement level definitions. This committee was made up of business leaders, researchers, state and district technology coordinators, teachers, and representatives from educational organizations as well as experts in research, assessment, and evaluation. As with the steering committee, the planning committee co-chairs were balanced, with one being an expert in ICT-based learning and assessment and the other being an expert in K-12 science and engineering education.

The planning committee’s work was guided by policies, goals, and principles identified by the steering committee. In addition to the sources cited previously, the planning committee relied on guidance provided by *NAEP 2012 Technological Literacy Framework and Specifications Development: Issues and Recommendations*, a paper prepared by Sharif M. Shakrani and Greg Pearson for the National Assessment Governing Board.

The structure for conducting the work consisted of a series of meetings with numerous telephone calls and e-mail exchanges in between meetings. From December 2008 through September 2009, the steering committee met four times and the planning committee met six times. Three of the steering and planning committee meetings overlapped so that the two committees could share understandings and discuss critical issues. Governing Board staff supported and participated in all of the meetings. In addition, between formal work sessions, Governing Board members and staff provided ongoing feedback and guidance on project documents and processes.

After the development of initial drafts of the framework, WestEd led a series of outreach efforts to solicit feedback. Formal activities included, but were not limited to, presentations and sessions with industry representatives (e.g. IBM, CISCO), the International Technology Education Association, the Organisation for Economic Co-Operation and Development (OECD) International ICT Research Workshop, the Council of Chief State School Officers, the State Educational Technology Directors Association, the International Society for Technology in Education, and the Partnership for 21st Century Skills Webinar. The Governing Board engaged an external review panel to evaluate the draft framework and convened a public hearing to gather

additional input during the development process. (See “NAEP Technological Literacy Project Staff and Committees” for more complete lists of individuals and organizations that contributed to the development of this Framework.) The Planning Committee reviewed feedback from these groups as well as from the Steering Committee and made revisions as it deemed appropriate.

Challenges of Developing the Technological Literacy Framework

There were a number of challenges in developing the Technological Literacy Framework for the 2012 NAEP that were not encountered in developing other NAEP Frameworks: (1) the newness of the endeavor, (2) measurement constraints, (3) time and resource constraints, (4) designing an entirely computer-based assessment, and (5) predicting future changes in technology. Each of these challenges is discussed below.

Newness of the Endeavor

Technological literacy is a new and burgeoning area. Those in the field are still debating exactly what technological literacy is—so consensus on how to assess it remains out of reach. Unlike other NAEP subjects, such as reading or mathematics, there is no existing NAEP framework to draw on. Moreover, the existing item banks in the United States and other countries are very limited (NAE 2006). The technological literacy staff and committee members obtained only a limited number of sample items from outside sources, reflecting the current immature state of assessing technological literacy.

Measurement Constraints

NAEP, like any large-scale assessment in education, the workplace, or clinical practice, is constrained in what it can measure. This has implications for the proper interpretation of NAEP Technological Literacy Assessment results. The framework is an assessment framework, not a curriculum framework. Although the two are clearly related, each has a different purpose and a different set of underlying assumptions. A curriculum framework is designed to inform instruction, to guide what is taught, and, often, to guide how it is taught. It represents a very wide universe of learning outcomes from which educators pick and choose what and how they teach. An assessment framework is a subset of the achievement universe from which assessment developers must choose to develop sets of items that can be assessed within time and resource constraints. Hence, the technology content to be assessed by NAEP has been identified as that considered central to technological literacy.

As a result, some important outcomes of technology education (broadly defined) that are difficult and time-consuming to measure—such as habits of mind, sustained design projects, and collaboration—but that are valued by engineers, technology educators, and the business community will be only partially represented in the framework and on the NAEP Technological Literacy Assessment. Moreover, the wide range of technology standards in the guiding national documents that could be incorporated into the framework had to be reduced in number so as to allow some in-depth probing of fundamental knowledge and skills. As a result, the framework and the specifications represent a distillation rather than a complete representation of the original universe of achievement outcomes aimed at by technology education.

Time and Resource Constraints

Time and resources limit what NAEP can assess. Like most standardized assessments, NAEP is an “on demand” assessment. It ascertains what students know and can do in a limited amount of time—historically, 50 minutes for paper-and-pencil questions and, for a subset of students sampled, an additional 30 minutes for hands-on performance or interactive computer tasks, with limited access to resources (e.g., reference materials, feedback from peers and teachers, opportunities for reflection and revision). However, standards presented by professional associations and the states contain goals that require an extended time (days, weeks, or months) to assess. To assess the achievement of students in the kinds of extended activities that are a central feature of these other standards and of many technology curricula, it would be necessary to know a number of things about the students, including their

- Reasoning while framing their goals;
- Planning for design and the execution of that design;
- Abilities to meet unpredictable challenges that arise during actual, ongoing problem solving and achievement of goals;
- Lines of argument in deciding how to alter their approaches in the light of new evidence;
- Engagement with fellow students and the teacher in addressing goals and deciding how to achieve them; and
- Deliberations and reasoning when evaluating progress, trade-offs, and results.

NAEP, like other “on demand” assessments, then, cannot be used to draw conclusions about student achievement with respect to the full range of goals of technology education, broadly defined. States, districts, schools, and teachers can supplement NAEP and other standardized assessments to assess the full range of education standards that address technological literacy. In addition to describing the content and format of an examination, assessment frameworks, like this one, signal to the public and to teachers some core elements of a subject that are important.

Designing a Computer-Based Assessment

Although some NAEP assessments (the 2009 science assessment, for example) have called for interactive computer tasks, no NAEP assessment has yet been totally computer-based. The design challenges of creating such an assessment include:

- Developing the requisite number of tasks and items, especially since so few tasks and items currently exist that can serve as samples
- Constructing tasks and items that contain whatever prior knowledge is required to answer the question. Since so many contexts are available in which to set items, developers cannot assume that students will have prior knowledge of the specific technologies within the context (e.g., transportation, health, electronics, etc.). Items must not require students to have prior knowledge of specific technologies, and the knowledge required of particular technologies must be presented in the item.
- Determining the features and functions of complete tools students will use.

- Determining what aspects of an item need to be assessed. Is the time that a student takes to answer the question important to assess? What about the pathway the student follows? Perhaps the number of mistakes made prior to getting a correct answer? Rather than a single question and answer, an item might have several components that are being assessed.

In addition to the above there will also be administrative challenges, such as whose computers the students use to complete the assessment, handling students' different levels of access to computer technology, and contingencies in case equipment malfunctions. The framework designers were cognizant of these factors when developing the framework, but they focused on the design factors, leaving the challenge of determining how best to administer the Technological Literacy NAEP to the Governing Board and the National Center for Education Statistics (NCES).

Predicting Future Changes in Technology

The framework attempts to strike a balance between what can reasonably be predicted about future technology and technology education and what students are likely to encounter in their curriculum and instruction now and over the next decade. For example, specific communication technologies in use today (Internet-connected multimedia smartphones and PDAs) would not have been familiar to students a decade ago and may well be obsolete a decade from now.

The framework is intended to be both forward-looking (in terms of what technology content will be of central importance in the future) and reflective (in terms of current technology). Because it is impossible to predict with certainty the shape of educational technology and technology education beyond 2009, the choices made for 2012 should be revisited in response to future developments.

It is a significant challenge to write a framework for the future, and in no subject is that challenge greater than for technological literacy.

Steering Committee Guidelines Summary

To be developed.

Uses of NAEP Data

For more than four decades, NAEP has provided information integral to reporting on the condition and progress of education at grades 4, 8, and 12 for the nation and, more recently, for the states and for a set of large urban school districts. Legislation concerning NAEP states that its purpose is to provide, in a timely manner, a fair and accurate measurement of student academic achievement and reporting of trends in such achievement in reading, mathematics, and other subject matter (Public Law 107-279).

Because of their rigorous design and methodology, NAEP reports are increasingly used for monitoring the state of education in the subjects that are assessed, as models for designing other large-scale assessments, and for secondary research purposes.

Monitoring

As the nation's only ongoing survey of students' educational progress, NAEP has become an increasingly important resource for obtaining information on what students know and can do. Because the information it generates is available to policy makers, educators, and the public, NAEP can be used as a tool for monitoring student achievement in reading, mathematics, science, and other subjects at the national, state, and selected district levels. For example, NAEP reports, known as "The Nation's Report Card," compare student performance in a given subject across states, within the subject over time, or among groups of students within the same grade. NAEP also reports long-term achievement trends for 9-, 13-, and 17-year-olds in reading and mathematics (e.g., Perie, Moran, & Lutkus, 2005). To the extent that individual state standards reflect the common core of knowledge and skills specified in the Framework, state comparisons can legitimately be made. If a state has unique standards, any comparison is limited by the degree of mismatch between NAEP content and state content. Even with this caveat, however, NAEP still stands as a key indicator of students' knowledge and capabilities in a particular content area at grades 4, 8, and 12.

Model of Assessment Development and Methods

NAEP assessment frameworks and specifications documents are themselves used as resources for international, state, and local curriculum and assessment. The broad-based process used in the development of the frameworks and specifications means that current thinking and research is reflected in these descriptions of what students should know and be able to do in a given subject. In addition, NAEP uses a rigorous and carefully designed process in developing the assessment instruments themselves. Pilot tests and internal and external reviews ensure that NAEP assessments are reliable and valid with respect to what they attempt to accomplish. This sophisticated methodology serves as a model for other assessment developers.

Research and Policy

NAEP data include subject-matter achievement results (reported as both scale scores and achievement levels) for various subgroups; background information about schools, teachers and students at the subgroup level (e.g., course-taking patterns of Hispanic male 12th graders); state-level results; reports for a set of large urban districts; history of state and district participation; and publicly released assessment questions, student responses, and scoring guides. The NAEP website (<http://nces.ed.gov/nationsreportcard>) contains user-friendly data analysis software to enable policymakers, researchers, and others to examine all aspects of NAEP data, perform significance tests, and create customized graphic displays of NAEP results. These data and software tools can be used to inform policymaking and for secondary analyses and other research purposes.

Achievement Levels

Public Law 107-279 specifies the Governing Board's responsibilities regarding NAEP, including the identification of appropriate achievement goals for each age and grade in the subject areas assessed by NAEP.

To carry out its mandated responsibility to set appropriate achievement goals for NAEP, NAGB adopted an achievement levels policy in 1989 (modified in 1993). This policy establishes three levels of achievement—basic, proficient, and advanced. Basic denotes partial mastery of prerequisite knowledge and skills that are fundamental for proficient work at each grade. Proficient represents solid academic performance for each grade assessed. Students reaching this level have demonstrated competency over challenging subject matter, including subject-matter knowledge, application of such knowledge to real world situations, and analytical skills appropriate to the subject matter. Advanced signifies superior performance. These levels are the primary means of reporting NAEP results to the general public and policymakers regarding what students should know and be able to do on NAEP assessments. (See Appendix D for the NAEP Technological Literacy Preliminary Achievement Level Descriptions and additional information about their development and use.)

Overview of Framework Chapters

Chapter Two: Technological Content

Chapter Three: Technological Practices

Chapter Four: Overview of the Assessment Design

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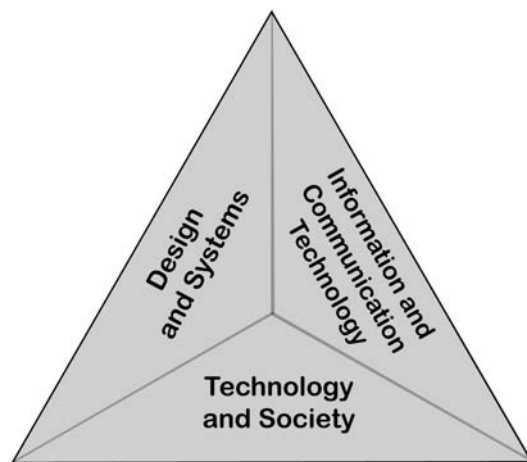
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CHAPTER TWO: AREAS OF TECHNOLOGICAL LITERACY

Introduction

This chapter describes the essential knowledge and abilities that will be assessed on the NAEP Technology Assessment, beginning in 2012. Although it is not possible to assess every aspect of technological literacy, this Framework identifies assessment targets related to the nature, processes, and uses of technology thought to be essential for *everyone* to participate fully and prosper in the 21st century. The assessment targets are organized into three *major areas* of technological literacy: Technology and Society, Design and Systems, and Information and Communication Technology.

These three areas of technological literacy are interconnected. For example, in order to address an issue related to technology and society, such as clean water, energy needs, or global climate change, a technologically literate person must understand technological systems and the design process and be able to utilize various information and communication technologies in order to research the problem and develop possible solutions. The relationship among these three major assessment areas can be illustrated as a three-sided pyramid (viewed from the top) in which each side supports the other two.



Chapter Two presents descriptions of each of the major areas of technological literacy, as well as sub-areas and tables of assessment targets that specify what technologically literate students in grades 4, 8, and 12 should know and be able to do. These assessment targets assume that learning is cumulative—that is, that the later grades build on what has been learned in earlier grades, so that students develop greater sophistication and depth of understanding as they advance in school. Some of the assessment targets foreshadow the *practices*—ways of thinking and reasoning—that will be described in Chapter Three.

Readers should not be surprised to see some overlap among the three major assessment areas. For example, there may be references to Information and Communication Technology (ICT) and to Design and Systems within the Technology and Society area. This is due in part to the mutual support that these technological principles and skills lend to each other, and to emphasize that a technologically literate person can bring any and all of these ways of thinking and acting to bear on any problem or goal they might encounter.

The three areas and sub-areas of technological literacy are briefly summarized below.

Technology and Society

A. Technology and Human Society concerns the ways in which society drives the improvement and creation of new technologies and how technologies serve society as well as change it.

B. Effects of Technology on the Natural World is about both the positive and negative ways that technologies affect the environment.

C. Effects of Technology on the World of Information and Knowledge focuses on the rapidly expanding and changing ways that information and communications technology enables data to be stored, organized and accessed, and how those changes bring about changes in society.

D. Ethics, Equity, and Responsibility recognizes that technologies have profound effects on people, that those effects can widen or narrow disparities, and that people are responsible for the consequences of their technological decisions.

Design and Systems

A. The Nature of Technology includes a broad definition of technology as consisting of all the products, processes, and systems created by people to meet human needs and desires.

B. Engineering Design is a systematic approach to creating solutions to technological problems and finding ways to meet people's needs and desires.

C. Maintenance and Troubleshooting is the set of methods we use to prevent technological devices from breaking down and to fix them when they fail.

D. Systems Thinking is a way of thinking about devices and situations so as to better understand interactions between parts, root causes of problems, and the consequences of various solutions.

Information and Communications Technology (ICT)

A. Construction and Exchange of Ideas and Solutions concerns an essential set of skills needed for using ICT and media to communicate ideas and collaborate with others to solve problems in core school subjects and practical situations.

B. Information Research includes the capability to employ technologies and media to easily find, evaluate, analyze, and synthesize information from different sources.

C. Investigation of Academic and Real-World Problems concerns the use of information and communication technologies to define and solve problems in core school subjects and in practical situations.

D. Acknowledgement of Ideas and Information involves respect for the intellectual properties of others and knowledge of how to credit others' contributions appropriately.

E. Selection and Use of Digital Tools includes both knowledge and skills for using a wide variety of electronic devices, including networked computing and communications technologies and media.

Development of the Assessment Targets

The process of developing the assessment targets has drawn heavily on prior documents that were created over the past two decades by national experts in a wide variety of fields. Primary source documents include:

- *Benchmarks for Science Literacy* (AAAS, 1993)
- *Framework for 21st Century Learning* (Partnership for 21st Century Skills, 2007)
- *National Educational Technology Standards* (ISTE, 2007)
- *National Science Education Standards* (1996)
- *Science for All Americans* (AAAS, 1989)
- *Standards for Technological Literacy* (ITEA, 2002).
- *Technologically Speaking: Why All Americans Need to Learn More About Technology* (NRC and NAE, 2001)

Other documents that focused on science but recognized the importance of knowledge and abilities in technology were valuable resources as well. These included:

- *Science Framework for the 2009 National Assessment of Educational Progress*
- Achieve International Benchmarking: Cashman, C. (2008, September 8). *NGA, CCSSO and Achieve Join Together to Promote International Benchmarking of U.S. Education Performance*. Washington, DC
- Best practices in various state frameworks on science and technology
- *Key Competencies for Lifelong Learning: European Reference Framework* (European Communities, 2007)
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- *Tech Tally: Approaches to Assessing Technological Literacy* (NRC 2006)
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The steering and planning committees recognize and appreciate efforts by Achieve, Inc., the American Academy for the Advancement of Science, the International Society for Technology Education, the International Technology Education Association, the National Academy of Engineering, the National Research Council, and the Partnership for 21st Century Skills for their efforts in developing these source materials, giving permission to quote the materials when desired, and for assisting in developing this *Framework*.

Technology and Society

From the beginning of human culture, technology and society have been closely intertwined. From stone tools to computers and the Internet, technologies have allowed people to shape the world to meet their needs and wants, to extend the reach of their bodies, hands, and minds, to span rivers, and to traverse continents. From Clovis points to laptops, technologies have always been an intrinsic part of civilization, and this is particularly true today, in the early part of the 21st century. It follows that awareness of the relationship between technology and society is an essential aspect of technological literacy.

Essential knowledge and skills for this facet of technological literacy are divided into four sub-areas:

- A. Technology and Human Society
- B. Effects of Technology on the Natural World
- C. Effects of Technology on the World of Information and Knowledge
- D. Ethics, Equity, and Responsibility

A fundamental principle in the area of Technology and Human Society is that societies shape the technologies that are developed and used and that those technologies in turn shape societies. Students are expected to demonstrate their understanding of the positive and negative effects that technologies may have on different segments of society as well as their capability to analyze historical and current examples of the technology-society relationship using concepts such as trade-offs, criteria, constraints, and consequences.

In solving problems related to technology and society students should weigh societal and behavioral changes along with purely technological solutions. For example, encouraging recycling and reuse of household materials may be more cost effective than building new waste facilities.

Technology and the Natural World takes a nuanced view of the relationship between technology and environmental change, recognizing both the negative impacts of technology on the environment and ways in which people have used technology to restore and protect natural environments. Students are expected to recognize that technological decisions involve competing priorities and also to consider the consequences of alternative decisions in developing sustainable solutions to environmental problems.

Technology and the World of Knowledge addresses the increasing access permitted by technology to expertise and information, the many powerful methods for storage and management of information, the expansion of the capability to express ideas, representations of dynamic phenomena, and the support of distributed teamwork.

The area of Ethics, Equity, and Responsibility addresses one of the most important aspects of technological literacy—the fact that technological decisions made by some people have significant impacts on others. Many of the thorniest technological issues of our age concern effects such as acid rain that cross borders, and some of them have global implications, such as

the effects of fossil fuel use on climate. A case in point is the ethical use of information and communications technologies that reach into nearly everyone's personal and professional lives. Although the *Framework* does not take positions on controversial issues, it does identify the knowledge and skills that students should have for analyzing and responding to technological issues that have ethical implications.

The following narrative provides an overview of each sub-area, followed by tables that detail the knowledge and skills that will be assessed by the 2012 NAEP Technological Literacy assessment in the area of Technology and Society.

A. Technology and Human Society

Many students are first exposed to the interaction between technology and human society through the study of history. They learn about the “ages of civilization,” starting with the Stone Age, the Bronze Age, the Iron Age, the Industrial Age, and, most recently, the Information Age. So these students have already been provided with a number of examples of how societies meet their needs by transforming the natural materials in the world around them to create new technologies, and they have seen how these technologies in turn shape the societies and their relationship to other societies through such mechanisms as trade, communication, war, and assimilation.

Students are also expected to learn from history and from their personal experiences that the relationship between technology and society is reciprocal. Society drives technological change, while technological change in turn shapes society.

Although the effects of technological change are more difficult to discern when the time period is a few years rather than a number of centuries, students are still capable of reflecting on the technological changes that have occurred during their lifetime. They should also be able to observe how the technological changes that are currently underway are driven by the needs of society, and they should be able to predict what some of the consequences of those new technologies might be. Examples of technological changes that nearly all students will have observed include the development of more fuel-efficient cars; the construction of new or improved buildings, roads, and bridges; new foods and types of clothing; and new kinds of media, computers, and communication systems.

Key principles in the area of Technology and Human Society that all students should learn at increasing levels of sophistication during their K-12 school experience are as follows:

- The relationship between technology and society is reciprocal. Society drives technological change, while technological change in turn shapes society.
- Technological decisions should take into account both costs and benefits.
- When considering technological decisions that involve competing priorities, it is helpful to consider the trade-offs among alternative solutions.
- Technologies may have unanticipated consequences.
- Technological solutions are guided and evaluated on the basis of criteria and constraints.

Fourth graders are expected to know that people's needs and desires determine the technologies that are developed or improved. For example, cell phones were invented, produced, and sold because people wanted to communicate with others wherever they were. The students should also learn that new products, tools, and machines in turn affect the lives of individuals, families, and whole communities, such as how transportation and communications systems enable people who live far apart to work together and interact with each other in new ways. Eighth graders are expected to understand how technologies and societies co-evolve over significant periods of time. For example, the need to move goods and people across distances prompted the development of a series of transportation systems from horses and wagons to cars and to airplanes. They should also recognize that the same technology may have different effects on different societies. Twelfth graders are expected to realize that the interplay between culture and technology is dynamic, with some changes happening slowly and others very rapidly. They should also be able to use various principles of technology—such as the concepts of trade-offs and unintended consequences—to analyze complex issues at the interface of technology and society and to consider the implications of alternative solutions.

Table 2.1 Technology and Human Society content statements for grades 4, 8, and 12

A. Technology and Human Society		
Fourth graders should be aware of how products, tools, and machines affect communities and make it possible for people to work together. Eighth graders should understand how society drives technological change and how new or improved technologies affect a society's economy, politics, and culture. Twelfth graders should have a heightened cultural sensitivity and attain a global view of the interplay between technology and culture.		
Grade 4	Grade 8	Grade 12
Students should know that: T.4.1: People's needs and desires determine which new tools, products, and machines are developed and made available.	Students know that: T.8.1: Society drives improvements in technological products, processes and systems.	Students know that: T.12.1: The decision to develop a new technology is influenced by societal opinions and demands. These driving forces differ from culture to culture.
T.4.2: New tools, products, and machines can change how people live and work.	T.8.2: Technology interacts with society, sometimes bringing about changes in a society's economy, politics, and culture and occasionally leading to the creation of new needs and wants.	T.12.2: Changes caused by the introduction and use of a new technology can range from gradual to rapid and from subtle to obvious. These changes may vary from society to society as a result of differences in a society's economy, politics, and culture.
Students should be able to: T.4.3: Identify potential positive and negative effects of the introduction of a new tool or machine into a community.	Students are able to: T.8.3: Describe and analyze positive and negative impacts on society from the introduction of a new or improved technology, including both expected and unanticipated effects.	Students are able to: T.12.3: Apply an appropriate technology to solve a given societal problem, and justify the selection based on an analysis of criteria and constraints, available resources, likely trade-offs, and relevant environmental and cultural concerns.
T.4.4: Compare the effects of two different technologies on their own lives by imagining what their lives would be without those technologies.	T.8.4: Compare the impacts of a given technology on different societies.	T.12.4: Analyze cultural, social, economic, and/or political changes that may be triggered by the transfer of a specific technology from one society to another. Include both anticipated and unanticipated effects.

B. Effects of Technology on the Natural World

As with technology's influences on culture and society, the effects of a technology on the environment can be either positive or negative. Since the Industrial Revolution and the rapid growth of human populations, the potential for technology to have a major impact on the environment has grown. Consequently, an essential aspect of technological literacy is an understanding of certain key principles about the effects of technology on the natural environment and of the many important efforts that people have made to preserve natural habitats, reduce air and water pollution, and maintain a healthful environment.

Technologically literate individuals should be aware of methods that have been developed to reduce the environmental impacts of technology. For example, an important step in designing a new product is to take the product's life cycle into account. Such an analysis may start with the raw materials that need to be mined or grown, the industrial processes and energy needed to manufacture the product, the transportation technologies required to get it to market, and its eventual disposal when the product is no longer needed.

Other ways to reduce environmental impact include the use of communication technologies to allow people to work at home rather than to physically commute, the use of computer models to optimize industrial processes to conserve energy and reduce waste, and the expansion of alternative energy sources such as wind power.

In the effort to find a balance between technological development and environmental protection, a key overarching principle is the concept of a sustainable solution. As defined by the Brundtland Commission in 1987, *sustainable solutions* are those that meet the needs of the present without compromising the ability of future generations to meet their own needs.

Key principles in the area of Effects of Technology on the Natural World that all students can be expected to learn at increasing levels of sophistication during their K-12 school experience are as follows:

- The use of technology may affect the environment positively or negatively.
- Technological decisions often involve trade-offs between human needs and environmental impacts.
- Waste management is a key component of any technological system.
- Reusing, recycling, and using fewer resources can reduce environmental impacts.
- Some technologies can reduce the negative impacts of other technologies.
- Sustainable solutions are those that meet the needs of the present without compromising the ability of future generations to meet their own needs.*
- Designers of new products can reduce environmental impacts by considering the life cycle of a product.

* *Report of the Brundtland Commission, Our Common Future*, London: Oxford University Press, 1987.

At the fourth grade level students are expected to learn that sometimes technology can cause environmental harm. For example, litter from food packages and plastic forks and spoons discarded on city streets can travel through storm drains to rivers and oceans where they can harm or kill wildlife. However, such negative effects can be lessened by reusing or recycling products as well as by reducing the amount of resources used. Eighth graders are expected to recognize that technological decisions often involve weighing competing priorities, so that there are no perfect solutions. For example, dams built to control floods and produce electricity have left wilderness areas under water and affected the ability of certain fish to spawn. Nonetheless, they should be able to analyze such conflicts and be able to recommend changes that would reduce environmental impacts. For example, students could study the trade-offs involved in using paper or plastic to carry groceries, or research the causes and effects of acid rain on forests and the costs of reducing those effects. They should understand that waste management is a key component of any technological system and that there are many things that individuals can do to reduce waste. Designers can also reduce waste by taking the entire life cycle of a product into account during design. In class, students might discuss what a community could do when its landfill is close to capacity or find ways that designers of new products could reduce waste by considering the life cycle of a product. By twelfth grade students should have had a variety of experiences in which technologies were used to reduce the environmental impacts of other technologies, such as the use of environmental monitoring equipment. For example, data on the environmental impacts of power plants that use different types of fuel can inform decisions on new power plants. They should also be able to analyze complex human activities, such as energy generation, and propose sustainable solutions. For example, students can research the environmental impacts of energy generation and create a presentation to a U.N. council on the trade-offs of various solutions.

**Table 2.2 Effects of Technology on the Natural World
content statements for grades 4, 8, and 12**

B. Effects of Technology on the Natural World		
<p>A critically important consideration when designing any tool, product, or process is its possible impact on the environment. Fourth graders should be aware that reducing litter and finding ways to recycle or reuse products could prevent harm to plants and animals. Eighth graders should be able to investigate the environmental effects of alternative decisions by tracing the life cycle of products and considering the trade-offs involved in different technologies. Twelfth graders should be aware that technologies used to monitor environmental change can help inform decision-making, and they should also be able to investigate complex global issues and generate innovative sustainable solutions.</p>		
Grade 4	Grade 8	Grade 12
<p>Students know that:</p> <p>T.4.5: The use of technology can affect plants and animals.</p>	<p>Students know that:</p> <p>T.8.5: Decisions to develop and use technologies often put environmental and economic concerns in direct competition with one another.</p>	<p>Students know that:</p> <p>T.12.5: The environmental impacts of new technologies can be reduced by using other technologies to monitor environmental change and by making decisions based on evidence.</p>
<p>T.4.6: Some materials can be reused or recycled rather than discarded.</p>	<p>T.8.6: People have devised physical, chemical and biological technologies to reduce problems associated with waste disposal.</p>	<p>T.12.6: An effective waste management plan to avoid environmental damage is essential in devising any technological system.</p>
<p>Students are able to:</p> <p>T.4.7: Identify the impact of a specific technology on the environment and determine what can be done to reduce negative effects.</p>	<p>Students are able to:</p> <p>T.8.7: Compare the environmental and economic effects of two alternative technologies devised to solve the same problem or accomplish the same goal and justify which choice is best.</p>	<p>Students are able to:</p> <p>T.12.7: Identify a complex global issue, develop a systematic plan of investigation, and present two or more innovative sustainable solutions.</p>

C. Effects of Technology on the World of Information and Knowledge

Human civilization owes its existence to a number of major revolutions in the ability to communicate information. The most fundamental of these may have been the advent of spoken language, which Charles Darwin (1871) and many others (Allott 1999) believe to have been the critical engine that has driven the development of human culture and civilization. The genesis of writing, which began at least as early as 3,000 years ago in ancient Mesopotamia led to a flowering of commerce, mathematics, science and learning (Neugebauer 1969, Van De Mieroop, 1999). Another milestone was the invention of the printing press by Johannes Gutenberg in the fifteenth century, which made it possible for ideas to be passed along to many people at widely distributed locations. These revolutions changed the world of information and knowledge with transformative effects on society.

Rapid advances in information and communication technologies (ICT) during the latter half of the 20th and early 21st centuries are creating another revolution, deeper and more profound than at any time in history. New information technologies have made possible the storage and organization of vast quantities of data, far beyond what was possible for a physical library, and greatly facilitated access to the information by anyone on the planet. Communications technologies are making it possible for people to communicate almost instantaneously across great distances, and to work together on collaborative projects as though they were in the same room. And unlike books that cannot be altered once printed, information stored electronically can be processed and displayed in various ways, such as data analysis, image enhancement, use in models and simulations, and development of expert systems and artificial intelligence entities. Together these technologies are modifying the world of information and knowledge itself, with implications for individuals, organizations, and entire societies.

Students whose knowledge and abilities are assessed by NAEP beginning in 2012 will have been born in the information age, and may not appreciate the extent to which their lives differ from the lives of their parents and grandparents. Nonetheless, it is important for all citizens to understand and be able to use current information and communications technologies, and understand how these technologies interact with society.

Key Principles in the area of Effects of Technology on the World of Information and Knowledge that all students can be expected to learn at increasing levels of sophistication during their K-12 school experience are as follows:

- Information technologies are evolving rapidly, enabling ever-greater amounts of data to be stored, managed, enhanced, analyzed and accessed through a wide array of devices in various media formats.
- Information and communications technologies (ICT) enable the creation and modification of information and knowledge products by remotely connected individuals and teams.
- The emergence of sophisticated information technologies such as artificial intelligence, image enhancement and analysis, and complex modeling and simulation systems are transforming the world of information and knowledge, with potentially profound effects on society.

Fourth grade students should know that information technology provides access to vast amounts of information, and can also be used to modify and display data, and that communication technologies make it possible to communicate across great distances using writing, voice and images. They are also able to use information and communications technologies (ICT) to access and interpret data and communicate with others. For example, students may search online for information on whales, and use communications technologies to prepare an illustrated message about whales to send to another student or grandparent. Eighth graders should be aware of the rapid progress in development of ICT, how information technologies can be used to analyze, display, and communicate data, and to collaborate with other students to develop and modify a knowledge product. For example, students may use a translation tool on a personal communication device to collaborate with students from other countries on a school project, such as digital storytelling. By twelfth grade students should have a full grasp of the data, expertise and knowledge available online, and be aware of the effect that sophisticated information technologies such as artificial intelligence, image enhancement, and computer modeling and simulation may have on society. They should be aware that the democratization of information communication and dissemination affects governments, news and other organizations as well as individuals, and can understand the extent to which ICT has enabled a revolution in the world of knowledge even more profound than the revolution enabled by invention and widespread use of the printing press.

Table 2.3 Effects of Technology on the World of Information and Knowledge content statements for grades 4, 8, and 12

C. Effects of Technology on the World of Information and Knowledge		
Fourth graders know that information, knowledge, and expertise can be accessed, collected, and shared by using information and communications technologies. Eighth grade students know that information and communication technologies are rapidly evolving and changing the ways people interact with information and each other. Twelfth graders know that sophisticated information and communication technologies have transformed the world of information and knowledge itself, with profound implications for society.		
Grade 4	Grade 8	Grade 12
Students know that: T.4.8: Information technology provides access to vast stores of knowledge and information.	Students know that: T.8.8: Information technologies are evolving rapidly, enabling ever-greater amounts of data to be stored and made accessible to others.	Students know that: T.12.8: Information technology allows access to vast quantities of data, expertise, and knowledge through a wide array of devices and formats to answer questions and inform the decision-making process.
T.4.9: Information technologies can be used to modify and display data in various ways.	T.8.9: Information technologies make it possible to analyze and interpret data, including text, images, and sound, in ways that are not possible with human senses alone.	T.12.9: Sophisticated information technologies such as artificial intelligence, image enhancement and analysis, and complex computer modeling and simulation create new types of information that may have profound effects on society.
T.4.10: Communications technologies make it possible for people to communicate across large distances in writing, voice, and images.	T.8.10: The large range of personal and professional information technologies and communication devices allows for remote collaboration and rapid sharing of ideas unrestricted by geographic location.	T.12.10: The democratization of information communication and dissemination channels has made it possible to publish and disseminate information globally, with implications for governments, news and other organizations, and individuals.
Students are able to: T.4.11: Use information and communications technologies to access and interpret data and communicate with others.	Students are able to: T.8.11: Use appropriate technologies to collaborate with others on the creation and modification of a knowledge product.	Students are able to: T.12.11: Compare the transformation of world knowledge that occurred when the printing press was invented with the transformation brought about by information and communications technologies, and discuss the implications for societal change.

D. Ethics, Equity, and Responsibility

Although technological advances have improved our quality of life, improved technologies have sometimes resulted in negative effects with ethical implications. Consequently, it is becoming increasingly important for every citizen to recognize ethical issues related to the introduction and use of various technologies. For example, factories and power plants that benefit the citizens of one country may produce gases that cause acid rain, damaging the forests in that country as well as neighboring countries. An ethical response to such a situation starts with recognition that such effects are occurring, followed by concrete steps to mitigate the problem.

An especially vulnerable sector of our technological infrastructure is the Internet and telecommunications. Access to the Internet offers unprecedented opportunities as well as challenges for students, since they have opportunities not only to access information but also to contribute and publish their own information for anyone in the world to read. But in order for students to use these tools and ones yet to be developed in a responsible manner, students need to understand fundamental rules of ethical behavior with regard to the exchange of information. They also need to know how to protect themselves.

Key principles in the area of Ethics, Equity, and Responsibility that all students can be expected to learn at increasing levels of sophistication during their K-12 school experience are as follows:

- Technology by itself is neither good nor bad, but its use may affect others.
- Not everyone has access to the same technologies.
- Differences in available technologies within the United States and in other countries have consequences for public health and prosperity.
- People living in one area need to be aware of how their use of technology impacts the lives of people in a different area.
- Storing information digitally requires a heightened attention to remote security threats.
- It is important for people to use technology responsibly.

Fourth graders should recognize that tools and machines can be helpful or harmful. For example, cars are very helpful for going from one place to another quickly, but can cause accidents in which people are seriously injured. They should also know that not everyone has access to tools and machines and that sharing is one way to reduce inequality. And they should recognize that technology can be used in ways that hurt others, such as when a false rumor is posted about someone online. Eighth graders should be able to recognize that the potential for misusing technologies always exists and that the possible consequences of such misuse must be taken into account when making decisions. They should have a grasp of the technological inequalities around the world, as illustrated by countries where few people can afford cars or refrigerators, and the economic and cultural reasons for these inequalities. They should know how to reduce the negative impacts that their use of technology may have on people in other countries and regions. For example, they might consider using fewer resources or conserving energy. They should also have a solid understanding of a range of unethical and criminal behaviors involving the use of Internet and communications technologies. Twelfth graders should take into account

both intended and unintended consequences in making technological decisions. They should understand the worldwide inequalities in technology access and know that it is not always easy to transplant a technology from one culture to another. They should be able to analyze the ethical responsibilities of various people in government and commercial enterprises and to demonstrate prudent and ethical use of communications technologies.

Table 2.4 Effects of Technology on the World of Information and Knowledge content statements for grades 4, 8, and 12

D. Ethics, Equity, and Responsibility		
Fourth graders should know that tools and machines used carelessly might harm others, take responsibility for the appropriate use of tools and machines, and recognize misuses of communications and other technologies. Eighth graders should recognize that technologies are not equally available to everyone and take responsibility to reduce the negative impacts of technologies. Twelfth graders should be able to take different viewpoints, recognize that transferring technologies from one society to another can be complex, and consider the consequences of unethical uses of technology.		
Grade 4	Grade 8	Grade 12
Students know that: T.4.12: When using tools and machines, the results can be helpful or harmful.	Students know that: T.8.12: Technology by itself is neither good nor bad, but its use may effect others. Therefore, decisions about products, processes, and systems must take possible consequences into account.	Students know that: T.12.12: Decisions made about the use of a technology may have both intended and unintended consequences, and these consequences may be different for different groups of people and may even change over time. Decisions about the use of a technology should consider different points of view.
T.4.13: Tools and machines can be very helpful, but not everyone has the same opportunity to use a given technology. Sharing is one way to reduce such differences in opportunities.	T.8.13: People who live in different parts of the world have different technological choices and opportunities. Differences may be economic, geographic, or cultural in nature.	T.12.13: Disparities in the technologies available to people in different locations have consequences for public health and prosperity. However, importing a new technology may not always be helpful without taking into account local resources and the role of culture in acceptance of the new technology.
Students are able to: T.4.14: Explain the safe use of a tool or machine by showing how it can and should be used as well as how it should not be used and the consequences that may result if it is used inappropriately.	Students are able to: T.8.14: Describe the responsibility that citizens have to reduce the impacts of their technologies on the lives of people in another area or on future generations.	Students are able to: T.12.14: Analyze responsibilities of different individuals and groups, ranging from citizens and entrepreneurs to political and government officials, with respect to a controversial technological issue.
T.4.15: Demonstrate the ethical use of information technologies by recognizing ways that someone might injure someone else through the use of communications technologies.	T.8.15: Explain why it is unethical to infect or damage other people's computers with viruses or to "hack" into other computer systems to gather or change information.	T.12.15: Demonstrate the responsible use of information and communication technologies by describing the consequences of unethical practices.

Design and Systems

We live in a global society that is increasingly dependent on technology. In the drive to satisfy human needs and wants, people have developed and improved ways to communicate, move people and goods, build structures, make products, enhance ideas, cure diseases, use energy, and provide nutritious and safe food and water as well as numerous other innovations. Technological development has resulted in a complex world of products and systems—often called “the designed world”—that is constantly changing. The study of technological design and systems is the study of the world in which we all live and which our students will shape by the decisions they make as workers, consumers, and citizens.

Because students live in a complex technological world, they face decisions every day that involve technology. Some of these are simple choices, such as deciding whether to use paper or plastic bags for groceries or choosing which form of entertainment to enjoy, while others are more far-reaching and complex, such as which type of job to choose or what sort of medical treatment to select. How well students are prepared to make those choices depends in part on their understanding of technology. Essential knowledge and skills in this area of technological literacy are divided into four sub-areas:

- A. Nature of Technology
- B. Engineering Design
- C. Maintenance and Troubleshooting
- D. Systems Thinking

Understanding the Nature of Technology requires that one take a broad view. Simply put, technology satisfies the basic human needs for food and water, protection from the elements, health, energy, improved transportation, better and cheaper products, and improved communication. Students are expected to understand that the laws of nature provide limits on the types of technologies that can be developed. For example, no one can create a perpetual motion machine since the laws of nature forbid it.

Students are also expected to distinguish between science and technology and to recognize that science enables improvements in technology, while improvements in technology often lead to advances in science. Students should also recognize that some problems are better solved through behavioral rather than physical changes, for example, encouraging the use of carpools to relieve traffic congestion rather than constructing additional highway lanes.

Engineering Design is an iterative and systematic approach to creating solutions to a broad variety of problems in order to meet people’s needs and desires. The process of design includes defining problems in terms of criteria and constraints; researching and generating ideas; selecting between alternatives; making drawings, models and prototypes; optimizing, testing, and evaluating the design; and, eventually, communicating the results.

Maintenance and Troubleshooting are how most people encounter technology on a daily basis—by troubleshooting technologies that malfunction and by maintaining tools and systems so they

do not break down. The better a person understands the way that something works, the easier it is to maintain that thing and to track down problems when they arise.

Systems Thinking concerns the capability to identify the components, goals, and processes of systems. It also includes an understanding of such systems principles as feedback and control and the capability to use simulations or other tools to predict the behavior of systems.

A. Nature of Technology

Two out of every three people in the United States think of “technology” as meaning just computers and the Internet. (Rose and Dugger, 2001 & Rose, Gallup, Dugger, and Starkweather, 2004) Some people conceptualize technology somewhat more broadly to include cell phones and other electronics, but that does not go nearly far enough. Technology includes every way in which people manipulate the natural environment to satisfy their needs and wants. So frozen foods, paper cups, and clothing are examples of technology, as are dams, motorcycles, windmills, water-treatment plants, flu shots, and grandfather clocks. Technology includes all the various devices and systems that people make to fulfill some function.

In addition to understanding the scope of technology, students are expected to understand how technology evolved and why the pace of technological change is so much faster today than in the past. For much of human history technological knowledge was held by small groups of individuals who did not spread it widely but rather passed it guardedly from one generation to the next, sometimes from parent to child or master to apprentice. Today, by contrast, know-how is communicated to anyone who wants to learn through a wide variety of educational institutions, both physically and online. Engineers and designers improve existing technologies, invent new devices and systems, and make technological breakthroughs that can be widely communicated in a short period of time, resulting in changes that can revolutionize entire industries. This is part of the reason that the rate of technological development is now increasing at unprecedented speed.

Another part of the reason can be found in today’s rapid advances in science. In many cutting-edge fields, such as bioengineering and nanotechnology, scientists and engineers work hand-in-hand, and sometimes the roles of scientist and engineer are both played by one person. For example, breakthroughs in genetics have made possible new crops with higher yields that are resistant to disease. Conversely, new technologies help science advance by providing more precise instruments, better collaboration tools, and ever more powerful computers.

Tools and materials have also advanced. From hand tools and power tools to computer probes and simulations, tools extend human capabilities, allowing people to see further or in greater detail, to accomplish tasks more efficiently, and to accomplish things that might otherwise be impossible. At the same time, new ways are constantly being developed to process raw materials in order to create products with properties unlike any in nature—self-cleaning clothing and paint, nano-fiber clothing that sheds water and never wrinkles, and composite materials for airplanes that are lighter and stronger than metal alloys, to name only a few.

Key principles in the area of Nature of Technology that all students can be expected to learn at increasing levels of sophistication during their K-12 school experience are as follows:

- Technology is constrained by laws of nature, such as gravity.
- Scientists are concerned with what exists in nature; engineers modify natural materials to meet human needs and wants.
- Technological development involves creative thinking.
- Technologies developed for one purpose are sometimes adapted to serve other purposes.
- Technology, science, mathematics, and other disciplines are mutually supportive.
- The pace of technological change has been increasing.
- Tools help people do things more efficiently, accurately, and safely.

Fourth grade students are expected to distinguish natural and human made materials, to become familiar with simple tools, and to recognize the vast array of technologies around them. Eighth graders should know how technologies are created through invention and innovation, that sometimes a technology developed for one purpose is later adapted to other purposes, and that technologies are constrained by natural laws. They should also learn that other resources besides tools and materials—energy, people, capital, and time—are generally needed to solve problems and meet design challenges. Twelfth graders should develop an in-depth understanding of the ways in which technology co-evolves with science, mathematics, and other fields; should be able to apply the concept of trade-offs to resolve competing values; and should be able to identify the most important resources needed to carry out a task.

Table 2.5 Nature of Technology content statements for grades 4, 8, and 12

A. Nature of Technology		
Fourth graders should know that technology involves tools, materials, and creative thinking used to meet human needs and wants. Eighth graders should know that technology advances through invention and innovation and requires a variety of resources. Twelfth graders should know how technology co-evolves with science and other fields to allow people to accomplish challenging tasks.		
Grade 4	Grade 8	Grade 12
Students know that: D.4.1: Technology is all around us and is defined as the ways we modify natural materials to meet human needs and wants.	Students know that: D.8.1: Technology is the modification of natural materials to satisfy people’s needs and wants and is constrained by physical laws, such as gravity.	Students know that: D.12.1: Science is concerned with what exists in nature; technology and engineering are concerned with modifying nature to meet human needs and wants.
D.4.2: The improvement of existing technologies and the development of new technologies involve creative thinking.	D.8.2: Technology advances through the processes of innovation and invention. Sometimes a technology developed for one purpose is adapted to serve other purposes.	D.12.2: Science, mathematics, and other disciplines are used to improve technology, while technologies are used to advance these disciplines. Over the past century this interaction between technology and other disciplines has deepened, and the rate of technological development has increased.
D.4.3: Tools are simple objects that help people do things better or more easily, such as preparing food, making clothing, and protecting themselves by cutting, shaping and putting materials together and moving things from one place to another.	D.8.3: Tools have been improved over time to do more difficult tasks and to do simple tasks more efficiently, accurately, or safely by furthering the reach of hands, voices, memory, and the five human senses.	D.12.3: The evolution of tools and materials has played an essential role in the development and advancement of civilization, from the establishment of the first cities and industrial societies to the global trade and commerce networks of today.
D.4.4: Different materials have different properties that determine their suitability for a given application or product.	D.8.4: Resources, such as tools and machines, materials, information, energy, people, capital, and time, are needed to accomplish a task.	D.12.4: Raw materials are processed in numerous ways to produce forms that do not exist in nature, such as bronze and iron, ceramics, and glass.
Students are able to: D.4.5: Distinguish natural objects from products that are made or modified by people.	Students are able to: D.8.5: Given a need, choose the resources required to meet or satisfy that need.	Students are able to: D.12.5: Given a need or task, choose the best resources to use by considering trade-offs between competing values.

B. Engineering Design

Engineering design (sometimes called technological design) is an iterative, systematic process for solving problems that involves creativity, experience, and accumulated disciplinary knowledge. As used in this *Framework*, engineering design is a broad term, including such specific processes as architectural design, manufacturing design, and industrial design.

Much like scientific inquiry, engineering design is a dynamic approach to solving problems and achieving goals, not a rigid method. The process usually begins by stating a need or want as a clearly defined challenge in the form of a statement with criteria and constraints. *Criteria* are characteristics of a successful solution, such as functionality or efficiency. *Constraints* are limitations, such as available funds, resources, or time. Together, the criteria and constraints are the *requirements* for a successful solution.

Once the challenge is defined, the next steps are often to investigate relevant scientific information and the way that similar challenges have been solved in the past, and then to generate various possible solutions. This generation of potential solutions is the most creative part of the design process and is often aided by sketching and discussion. Using a process of informed decision-making, the designer or design team compares different solutions to the requirements of the problem and either chooses the most promising solution or synthesizes several ideas into an even more promising potential solution. The next step is usually to try out the solution by constructing a model, prototype (first of its kind), or simulation and then testing it to see how well it meets the criteria and falls within the constraints. An additional characteristic of engineering design is that ideas are tested before investing too much time, money, or effort.

A person does not have to be an engineer to employ an engineering design process. Children can use this process to create a new toy, teachers can use it to plan a semester of lessons, and anyone can use it to or address a need or desire encountered in everyday life.

The result of an engineering design process is not always a product. In some cases the result may be a process (such as a chemical process for producing an improved paint) or a system (such as an airline control system or a railway schedule).

When designing, it is important to take into account the entire life cycle of the product or process, including maintenance, troubleshooting, fallibility, effects on the environment, and impacts on society. Designing usually concludes with a presentation to clients or other interested parties (often classmates) on the preferred solution.

Optimization, which is sometimes part of designing, means finding the best possible solution when some criterion or constraint is identified as the most important and others are minimized. For example, optimizing the design of a pen might mean designing for lowest cost, best ink flow, or best grip, but not all three. Optimizing the design of an airplane engine usually means maximizing safety. In some engineering disciplines the entire engineering process is referred to as “optimization under constraint.”

It bears emphasizing that these steps need not be followed in order. An experienced engineer might skip ahead a step or two or go back one or two steps. Or after generating solutions it may become clear that the problem was poorly defined, so it is necessary to restart the process from the beginning.

Key principles in the area of Engineering Design that all students can be expected to learn at increasing levels of sophistication during their K-12 school experience are as follows:

- Engineering design is a systematic, creative, and iterative process for addressing challenges.
- Designing includes identifying and stating the problem, need, or desire; generating ideas; evaluating ideas; selecting a solution; making and testing models or prototypes; redesigning; and communicating results.
- Requirements for a design challenge include the criteria for success, or goals to be achieved, and the constraints or limits that cannot be violated in a solution. Types of criteria and constraints include materials, cost, safety, reliability, performance, maintenance, ease of use, and policies.
- Often there are several possible ways of addressing a design challenge.
- Evaluation means determining how well a solution meets requirements.
- Optimization involves finding the best possible solution when some criterion or constraint is identified as the most important and others are minimized.
- Engineering design usually requires one to develop and manipulate representations and models (e.g., prototypes, drawings, charts, graphs).

Fourth graders should know that engineering design is a purposeful method of solving problems and achieving results. They should be able to state a simple design challenge in their own words, test a solution, and communicate the findings with drawings and models. Eighth graders should be able to carry out a full engineering design process to solve a problem of moderate difficulty. They should be able to define the challenge in terms of criteria and constraints, research the problem, generate alternative solutions, build and test a model or prototype, and communicate the findings. Twelfth graders should be able to meet a complex challenge, weigh alternative solutions, and use the concept of trade-off to balance competing values. They should be able to redesign so as to arrive at an optimal solution.

Table 2.6 Engineering Design content statements for grades 4, 8, and 12

B. Engineering Design		
Fourth graders should start to answer the question “How are technologies created?” by learning to deal with simple design challenges. Eighth graders should be able to use a more elaborate engineering design process, including problem definition and the use of prototypes and trade-offs. Twelfth graders should have a deep understanding and a broad array of design skills, including optimization.		
Grade 4	Grade 8	Grade 12
Students know that: D.4.6: Engineering design is a systematic and creative process for meeting challenges. Often there are several solutions to a design challenge. Each one might be better in some way than the others. For example, one solution might be safer, while another might cost less.	Students know that: D.8.6: Engineering design is a systematic, creative, and iterative process for meeting human needs and wants. It includes stating the challenge, generating ideas, choosing the best solution, making and testing models and prototypes, and redesigning. Often, there are several possible solutions.	Students know that: D.12.6: Engineering design is a complex process in which creative steps are embedded in content knowledge and research on the challenge. Decisions on trade-offs involve systematic comparisons of all costs and benefits, and final steps may involve redesigning for optimization.
D.4.7: Requirements for a design include the desired features of a product or system as well as the limits placed on the design, such as which materials are available.	D.8.7: Requirements for a design are made up of the criteria for success and the constraints, or limits, which may include time, money, and materials. Designing often involves trade-offs between competing values.	D.12.7: Specifications involve criteria, which may be weighted in various ways, and constraints, which can include natural laws and available technologies. Evaluation is a process for determining how well a solution meets the requirements.
Students are able to: D.4.8: Use a systematic process to propose and test a solution to achieve a simple design goal.	Students are able to: D.8.8: Carry out an iterative design process to solve a problem of moderate difficulty by identifying criteria and constraints, determining how these will affect the solution, researching and generating ideas, and using trade-offs to choose between alternative solutions.	Students are able to: D.12.8: Meet a sophisticated design challenge by identifying criteria and constraints, determining how these will affect the solution, researching and generating ideas, and using trade-offs to balance competing values in selecting the best solution.
D.4.9: Construct and test a simple model to test a design idea.	D.8.9: Construct and test a model or prototype to see if it meets the requirements of a problem.	D.12.9: Construct and test a model or prototype. Graph results to determine how to improve it.
D.4.10: Communicate design ideas using drawings and models.	D.8.10: Communicate the results of a design process and articulate the reasoning behind design decisions by using verbal and visual means. Identify the benefits of a design as well as the possible unintended consequences.	D.12.10: Communicate the entire design process from problem definition to evaluation of the final design, taking into account all relevant criteria and constraints, including aesthetic and ethical considerations as well as purely logical decisions.

C. Maintenance and Troubleshooting

The statement that “anything that can go wrong will go wrong,” known as Murphy’s Law, has been attributed to aerospace engineer Edward Murphy, who first used the expression (or something like it) in 1949 to explain the failure of measurement equipment for a high-speed rocket sled (Spark, 2006). Murphy’s Law has come to characterize everyday life, not only for engineers but also for everyone in modern society. Today we are surrounded by and dependent upon complex devices that seem to go wrong at critical times. It is not uncommon to experience more than one technological failure in a single day, whether it’s a car that fails to start, a cell phone without “bars,” or something as simple as an eyeglass frame with a lens that repeatedly pops out.

A technologically literate person is aware that all systems fail at one time or another and is therefore equipped with a foundation of concepts and abilities that can be applied either to correct failed devices and systems or to prevent the failure from occurring in the first place. The most important of these concepts and abilities are maintenance and troubleshooting.

In the *Technological Literacy Framework for the 2012 NAEP* the term maintenance has a very specific meaning: It refers to keeping technological devices and systems in good condition so as to extend their useful life and reduce the number of breakdowns. For example maintenance can refer to the regular upkeep of technologies so that they are less likely to fail, such as replacing the oil in a car engine, cleaning the lint filter of a clothes dryer, or running regular software updates on a computer operating system.

Troubleshooting, by contrast, refers to a systematic method of dealing with failures once they have occurred. It is common to begin troubleshooting by ascertaining the nature of the problem. For example, in the case of a television that has failed, it is important to determine if some parts of the device are still working. Is the power light on? Is sound missing, or a picture, or both? If the power light is not on, it may be unplugged. If that is not the problem, a second step may be to isolate the problem to one part of the system. For instance, the problem may not be the TV at all but rather a faulty DVD, which can be tested by inserting a different DVD. A third step might be to learn as much as possible about how the system functions, either from an owner’s manual or from someone who is familiar with such systems.

Perhaps the most distinctive feature of troubleshooting is coming up with a number of different ideas about what may have caused the failure and then using a logical method for narrowing down the possible causes with a series of either-or tests, sometimes called a *fault tree*, until the source of the problem is discovered.

Additionally, when designing new products and systems it is important for engineers to consider maintenance costs, since people may wish to pay a little more for a product that is less expensive to maintain. Similarly it is important for engineers to anticipate ways that complex products and systems are likely to break down, and to build into the design simple ways to troubleshoot and fix the most common causes of failure. Factors to consider may include maintenance costs, available technologies, time until obsolescence, and environmental impacts.

Key principles in the area of Maintenance and Troubleshooting that all students can be expected to learn at increasing levels of sophistication during their K-12 school experience are as follows:

- Tools and machines must undergo regular maintenance to ensure their proper functioning.
- Troubleshooting is a systematic approach to diagnosing a technological failure.
- Taking into account the entire lifecycle of a product is an important part of designing.

At the fourth level students should know that it is important to care for tools and machines so they can be used when they are needed. For example, tools should not be left out in the rain, and electronic equipment should be handled with care. Students should also learn that if something does not work as expected, it is possible to find out what the problem is so that they can decide if the item should be replaced or determine, if possible, how to fix it. They should know that some items, such as ballpoint pens, are designed to be disposable, and they should be able to discuss the disposal or recycling of such items. Eighth graders should be familiar with the concept of maintenance and should understand that failure to maintain a device can lead to a malfunction. They should also be able to carry out troubleshooting, at least in simple situations. For example, they should be able to safely use tools and instruments to diagnose a problem in a device, and they should be able to consult manuals or talk to experienced individuals to learn how the device works. They should also be able to test various ideas for fixing the device. And they should be able to analyze an item's life cycle and discuss the impact of disposing of an item that has reached the end of its life cycle. By twelfth grade students should know that many devices are designed to operate with high efficiency only if they are checked periodically and properly maintained. They should also have developed the capability to troubleshoot devices and systems, including those that they may have little experience with. Students at this level should also be able to think ahead and to identify and document new maintenance procedures so that the malfunction does not occur again. They should be able to weigh the costs and benefits of maintaining an existing item versus disposing of it and obtaining a newer replacement, with particular attention paid to lessening the environmental impact of disposing of obsolescent or non-functioning products.

Table 2.7 Maintenance and Troubleshooting content statements for grades 4, 8, and 12

C. Maintenance and Troubleshooting		
Fourth graders should recognize that tools and machines need to be cared for and that devices that fail can be fixed or replaced. Eighth graders should know that tools and machines must be maintained and be able to use a troubleshooting process to diagnose problems in technological systems. Twelfth graders should understand the importance of maintenance, be able to analyze malfunctions, and be able to devise ways to reduce future failures.		
Grade 4	Grade 8	Grade 12
Students know that: D.4.11: It is important to care for tools and machines so that they are available to be used when needed.	Students know that: D.8.11: Tools and machines must undergo regular maintenance, including lubrication of joints and replacement of parts before they fail to ensure proper functioning.	Students know that: D.12.11: Tools, machines, and structures of various kinds can be redesigned to eliminate frequent malfunctions and reduce the need for regular maintenance.
Students are able to: D.4.12: Find out why something does not work in order to know how to go about fixing it.	Students are able to: D.8.12: Safely use tools and instruments and a logical process of troubleshooting to diagnose a problem in a device. Consult manuals and experienced individuals to learn how the device works and to develop and test different ideas for fixing it.	Students are able to: D.12.12: Analyze a system malfunction using logical reasoning (such as a fault tree) and appropriate diagnostic tools and instruments to probe the system. Devise a strategy to fix the problem, and document a procedure for maintaining the system.
D.4.13: Trace the life cycle of a disposable product from inception to disposal or recycling.	D.8.13: Trace the life cycle of a repairable product from inception to disposal or recycling. Determine the environmental impact of the product in light of local rules for disposal and recycling.	D.12.13: Taking into account costs and current trends in technology, identify how long a product should be maintained and repaired and how close it is to obsolescence. Consider how the product might be redesigned to lessen environmental impacts.

D. Systems Thinking

A system is any collection of interacting parts that make up a whole. In a sense, all technologies can be thought of as systems. Furthermore, the ways in which objects are produced and used can also be thought of as systems. Even simple objects are made from raw materials and are eventually discarded, at which point they may be recycled or added to landfills.

Systems thinking is the capability to investigate—or think about—a system using certain principles, and it enables people to understand complex situations that involve many interactions. For example, consider these principles: Systems include sub-systems; any given system is typically part of one or more larger systems; and systems interact with other systems. These principles are important in thinking about, for instance, our nation’s transportation system. The transportation system consists of a vast network of roads and rails and millions of vehicles. It is dependent on another system that transports oil from wells halfway around the world, which is carried in thousands of supertankers to huge refineries and from there to distribution points and gas stations. Since the combustion of fuels produces carbon dioxide, these systems are connected as well to the global climate system. Citizens who understand the effects of different fuels on the environment will be able to make decisions about what kind of automobile to purchase based on both these interconnected technological systems and the price of gas.

Beyond understanding that systems exist, technologically literate citizens should also be comfortable with the broader skill of systems thinking, a set of mental tools that increases in sophistication and power over time. These mental tools help people to analyze various problems that they encounter and to propose solutions or determine reasonable courses of action. Simply put, systems thinking helps people understand how things are put together, how they function, and how they connect with other aspects of the world, and it assists people in making informed decisions.

Key principles in the area of Systems Thinking that all students can be expected to learn at increasing levels of sophistication during their K-12 school experience are as follows:

- All systems require energy and have parts that work together to accomplish a goal.
- Technological systems are designed to achieve goals. They incorporate various processes that transform inputs into outputs. Two important features of technological systems are feedback and control.
- Systems may include subsystems. Conversely, systems may be embedded within larger systems.

Fourth graders should know that a system is a collection of interacting parts that make up a whole, that systems require energy, and that systems can be either living or non-living. They should also be able to look at a simple system, identify its various parts, and recognize the functions of these parts within the larger system. Eighth graders should be able to analyze a system in terms of goals, inputs, processes, outputs, feedback, and control. They should be aware that systems can interact with each other and be able to use reverse engineering to identify the subsystems and components of a device. They should also be able to trace the life cycle of a product from raw materials to eventual disposal. Twelfth graders should be aware that

technological systems result from goal-directed designs and that the building blocks of any technology consist of systems that are embedded within larger technological, social, and environmental systems. They should also be aware that the stability of a system is influenced by all of its components, especially those in a feedback loop. Students should be able to use various techniques to forecast what will happen if a component or process is changed.

Table 2.8 Systems Thinking content statements for grades 4, 8, and 12

D. Systems Thinking		
Fourth graders should be able to identify systems in their everyday world and to construct simple systems. Eighth graders should be able to describe goals, inputs, outputs, and processes of systems, and use reverse engineering and life cycles to analyze systems. Twelfth graders should understand that systems are embedded in larger systems, recognize factors that stabilize systems, use systems for forecasting, and clearly describe systems.		
Grade 4	Grade 8	Grade 12
Students know that: D.4.14: All systems require energy and have parts (natural and technological) that work together to accomplish a goal.	Students know that: D.8.14: Technological systems are designed to achieve goals. They incorporate various processes that transform inputs into outputs. These processes may include feedback and control.	Students know that: D.12.14: Technological systems and processes are the result of specific, goal-directed designs. The stability of a system is influenced by all of its components, especially those in a feedback loop.
D.4.15: Many systems have subsystems within them. Many systems are parts of larger systems.	D.8.15: Technological systems can interact with one another to perform more complex functions and tasks than any individual system can do by itself.	D.12.15: Technological systems are embedded within larger technological, social, natural, and environmental systems.
Students are able to: D.4.16: Given a product, identify its systems, subsystems, and components by taking it apart either physical or virtually.	Students are able to: D.8.16: Examine a product or process through reverse engineering by taking it apart step by step to identify its systems, subsystems, and components, and describing their interactions.	Students are able to: D.12.16: Examine a system to predict how it will perform with a given set of inputs in a given situation. Determine the consequences of making a particular change in the system.
D.4.17: Construct a simple system to accomplish a goal, based on knowledge of the function of individual components.	D.8.17: Construct and use a moderately complex system, given a goal for the system and a collection of parts, including those that may or may not be useful in the system.	D.12.17: Critique and redesign a complex system so that it is better able to achieve a given goal.

Information and Communication Technology (ICT)

The integration of Information and Communications Technologies (ICT) into every sphere of contemporary life has had profound implications for learning in school, for solving practical problems, and for functioning in the workplace. Networked computing and communications technologies and media have become essential tools of practically every profession and trade, including lawyers, doctors, artists, historians, electricians, mechanics, and salespersons. These devices make it possible to redistribute learning and work experiences over time and space. Tools employed by various professions and trades such as word processors, spreadsheets, audio/video/photo editing tools, models, visualizations, and mobile wireless devices are, in turn, being put to work in the study of core school subjects. Students are able to connect, access, and communicate with the wider world in ways that were unimaginable just a few years ago and that are continually changing. Particularly relevant for this *Framework* is the fact that virtually all efforts to improve or create new technologies involve the use of ICT tools. And for many years to come, such novel technologies, digital and otherwise, will continue to bring about new approaches to education, work, entertainment, and daily life.

As the term is used in this *Framework*, Information and Communication Technologies (ICT) includes a wide variety of technologies, including computers and software learning tools, networking systems and protocols, hand-held digital devices, digital cameras and camcorders, and other technologies, including those not yet developed, for accessing, creating, and communicating information.

Although ICT is one among several types of technologies, it has achieved a special prominence in technological literacy because familiarity and facility with it is essential in virtually every profession in modern society, and its importance is expected to grow over the coming decades. A wide variety of ICT tools are routinely used in schools, the workplace, and homes. Rapidly evolving learning tools such as computers, online media, telecommunications, and networked technologies are becoming powerful supports for communities of learning and practice. Moving far beyond traditional text-based communication methods, the common language of global information sources and communication has broadened to include endless sources of images, music, video, and other media. Computers, networks, telecommunications, and media support collaboration, expression, and dissemination ranging from data organization and analysis, research, scholarship, and the arts to peer interactions. Ever-shrinking computer chips are put to work in a collection of devices that seems to be growing exponentially and that, at present, includes cell phones, digital assistants, media players, and geographical information systems, among a host of other devices.

Although not everyone is expected to understand the inner workings of these devices, a technologically literate person must know that they exist and how they are used, must have mastered a wide range of ICT tools in common use, and must have the confidence and capability to learn to use new ICT technologies as they become available. Five sub-areas of ICT literacy have been identified for assessment:

- A. Construction and Exchange of Ideas and Solutions
- B. Information Research

- C. Investigation of Academic and Real-world Problems
- D. Acknowledgement of Ideas and Information
- E. Selection and Use of Digital Tools

Each of the above sub-areas relates to one of the broad categories included in the National *Educational Technology Standards for Students* (NETS•S), the Partnership for 21st Century Skills, the American Association of School Librarians, and the International Technology Education Association. The link between these sub-areas and the NETS•S Framework is outlined in Appendix C.

A. Construction and Exchange of Ideas and Solutions

Year after year, information and communication technologies challenge people to think, learn, and work, in ways that were unimaginable only a short time ago and, as a result, enhance communication and collaboration among individuals, groups, and organizations. For schools, this continuing evolution translates into an ever-increasing need to provide students with opportunities to develop digital and media communication skills and to collaborate in non-traditional learning environments. Several recent sets of national standards and many state standards cite effective communication skills and the capability to work collaboratively as essential for student success in the 21st century. In addition to mastering a set of computer-based skills, students should be able to employ a variety of media and technologies in order to communicate ideas, interact with others, and present information to multiple audiences. As effective collaborators, students should be able to negotiate team roles and resources, draw upon the expertise and strengths of other team members and remote experts, monitor progress toward goals, and reflect on and refine team processes for achieving goals.

Key principles in the area of Construction and Exchange of Ideas and Solutions that all students can be expected to learn at increasing levels of sophistication during their K-12 school experience are as follows:

- Communication and collaboration are affected (in terms of quantity, quality, and results) by the choice of digital tools used.
- Digital tools can be used for achieving expressive goals.
- Teams need people with a variety of skills.

Fourth grade students should feel comfortable working as members of a team and should realize that teams are usually better at solving problems than individuals. They should be able to gather information from various sources and share ideas with a specified audience. Eighth grade students should know that communicating always involves understanding the audience—the people for whom the message is intended. They should also be able to use feedback from others, and provide constructive criticism. Twelfth grade students are expected to have developed a number of effective strategies for collaborating with others. They should be able to synthesize information from different sources and communicate with multiple audiences.

Table 2.9 Construction and Exchange of Ideas and Solutions
content statements for grades 4, 8, and 12

A. Construction and Exchange of Ideas and Solutions		
<p>Fourth grade students should be able to collaborate and communicate by working with other members of a team to make decisions and develop presentations using a variety of formats. Eighth grade students should be able to take into account the perspective of different audiences, use a variety of media to create effective messages, and modify presentations based on feedback. Twelfth grade students should have developed strategies to be effective collaborators, should be able to take into account multiple viewpoints, and should be able to synthesize information from a variety of sources.</p>		
Grade 4	Grade 8	Grade 12
<p>Students know that:</p> <p>I.4.1: Collaborating with other people as a team can often produce a better product than a person working alone. There are common digital tools that can be used to facilitate virtual or face-to-face collaboration.</p>	<p>Students know that:</p> <p>I.8.1: Collaboration can take many forms. Pairs or teams can work together in the same space or at a distance, at the same time or at different times, and on creative projects or technical tasks. Different communications technologies are used to support these different forms of collaboration.</p>	<p>Students know that:</p> <p>I.12.1: Effective collaboration requires mutual respect, careful listening, and strategies for reaching agreement when there are opposing points of view.</p>
<p>Students are able to:</p> <p>I.4.2: Utilize input from (virtual) collaborators and experts or sources in the decision-making process to design a product or presentation.</p>	<p>Students are able to:</p> <p>I.8.2: Provide feedback to a (virtual) collaborator on a product or presentation, taking into account the other person's goals and their sensitivity to constructive criticism.</p>	<p>Students are able to:</p> <p>I.12.2: Work through a simulation of opposing viewpoints in a collaborative process to a solution based on a predetermined set of operating guidelines.</p>
<p>I.4.3: Communicate information and ideas effectively to an audience in order to accomplish a specified purpose.</p>	<p>I.8.3: Communicate information and ideas effectively using a variety of media, genres, and formats for multiple purposes and a variety of audiences.</p>	<p>I.12.3: Synthesize input from multiple sources to communicate ideas to a variety of audiences using various media, genres, and formats.</p>

B. Information Research

Research and information competency is a central ICT skill. In using digital and networking tools to find relevant and useful information, students must first be able to formulate a set of questions that will guide them in their search, and they must be capable of synthesizing data from multiple sources. Students must be able to formulate efficient search strategies and to evaluate the credibility of information and data sources. They must extract and save information and data that they judge to be relevant to the question at hand. Students also need to be able to use multiple ICT tools to organize, synthesize, and display information and data.

Key principles in the area of Information Research that all students can be expected to learn at increasing levels of sophistication during their K-12 school experience are as follows:

- Increases in the quantity of information available through electronic means and the ease by which knowledge can be published have heightened the need for the verification of sources of expertise.
- Information can be distorted, exaggerated, or otherwise misrepresented.
- Important strategies for insuring quality of information include 1) assessing the source of information and 2) using multiple sources to verify the information in question.
- Search strategies and skills are important capabilities in performing effective information research.

Fourth grade students should be aware of a number of digital and network tools that can be used for finding information, and they should be able to use these tools to collect, organize, and display data in response to specific questions. Eighth grade students should also be aware of digital and network tools and be able to use them efficiently. Additionally, they should be aware that some of the information they retrieve may be distorted, exaggerated, or otherwise misrepresented, and they should be able to identify cases where the information is suspect. Twelfth grade students should be able to use advanced search methods and select the best digital tools and resources for various purposes. They should also be able to evaluate information that they find for timeliness and accuracy, and they should have developed strategies to check the credibility of sources.

Table 2.10 Information Research content statements for grades 4, 8, and 12

B. Information Research		
Fourth grade students can use digital and network tools to find information and identify sources that may be biased. Eighth grade students are able to use digital resources to find information and to recognize when information may be distorted, exaggerated, or otherwise misrepresented. Twelfth grade students can use advanced search methods and select the best digital tools and resources for various purposes, can evaluate information for timeliness and accuracy, and can check the credibility of sources.		
Grade 4	Grade 8	Grade 12
Students know that: I.4.5: Digital and network tools and media resources are helpful for answering questions, but they can sometimes be biased.	Students know that: I.8.5: Increases in the quantity of information available through electronic means and the ease by which knowledge can be published have heightened the need to check sources for possible distortion, exaggeration, or misrepresentation.	Students know that: I.12.5: Advanced search techniques can be used with digital and network tools and media resources to locate information, and to check the credibility and expertise of sources.
Students are able to: I.4.6: Use digital and network tools and media resources to collect, organize, and display data in order to answer questions.	Students are able to: I.8.6: Select and use appropriate digital and network tools and media resources to collect, organize, and display data to answer questions and test hypotheses.	Students are able to: I.12.6: Select digital and network tools and media resources to gather information and data on a real-world task, and justify choices based on the tools' efficiency and effectiveness for a given purpose.
I.4.7: Search media and digital sources on a community or world issue and identify sources that may be biased.	I.8.7: Search media and digital resources on a community or world issue and identify possible examples of distortion, exaggeration, or misrepresentation of information.	I.12.7: Search media and digital resources on a community or world issue and evaluate the timeliness and accuracy of the information as well as the credibility of the source.

C. Investigation of Academic and Real-World Problems

Digital tools are widely used in core school subjects to support students' critical thinking, problem solving, and decision-making. For example, in language arts courses students use online graphic organizers, word processors, and media as they read, analyze, and draw conclusions about various texts. They launch discussions on wikis to stimulate a rich consideration of topics prior to class time and to give students who are less aggressive in face-to-face situations the opportunity to be major contributors. In social science courses students use databases and spreadsheets to create tables and graphs as they analyze and compare population densities in different historical periods. In science and mathematics, students use spreadsheets, visualization and modeling tools, digital probeware, and presentation tools to gather and interpret data on science and health issues.

Since schools are society's means of preparing students for the real world, many of the ways that students use digital tools reflect the way that similar tools are used by professionals to solve real-world issues such as environmental problems, political conflicts, or economic challenges. In these cases, digital tools may be used to present the challenge scenario; guide students in formulating the requirements of the challenge to be addressed; and enable students to ask and answer significant questions, exchange views with other students, sometimes in other cities or countries, collect and analyze data, and then develop and test various solutions through simulations. Other uses of digital tools in schools involve practical applications designed to prepare students for the myriad responsibilities of adulthood.

Key principles in the area of Investigation of Academic and Real-World Problems that all students can be expected to learn at increasing levels of sophistication during their K-12 school experience are as follows:

- Digital tools can be very helpful in academic subjects and in researching real-world problems.
- Information technology offers countless options for formal and non-formal expression in virtually every academic and professional discipline.
- Digital tools can be used to investigate academic and real-world problems through experiments and simulations.

Fourth grade students should be able to use a variety of information and communication technologies to investigate a local or otherwise familiar issue and to generate, present, and advocate for possible solutions. They should also be able to use digital tools to test hypotheses in various subject areas and to build models of simple systems. Eighth grade students should be able to use digital tools to identify and research a global issue and to identify and compare different possible solutions. They should also be able to use digital tools in testing hypotheses of moderate complexity in various subject areas in which they gather, analyze, and display data and draw conclusions. They should also be able to explore real-world issues by building models and conducting simulations in which they vary certain quantities to test "what if" scenarios. Twelfth students should be able to use digital tools to investigate global issues and to fully investigate the pros and cons of different approaches. They should be able to design and conduct complex investigations in various subject areas using a variety of digital tools to collect, analyze, and

display information and be able to explain the rationale for the approach they used in designing the investigation as well as the implications of the results. High school students should also be able to conduct simulations, draw conclusions based on the results, and critique the conclusions based on adequacy of the model to represent the actual problem situation.

**Table 2.11 Investigation of Academic and Real-World Problems
content statements for grades 4, 8, and 12**

C. Investigation of Academic and Real-World Problems		
<p>Fourth grade students are able to use digital tools to investigate local issues, test hypotheses, and build models. Eighth grade students are able to use digital tools to investigate alternative solutions to global issues, test moderately complex hypotheses, build models, and conduct simulations. Twelfth grade students can conduct more sophisticated investigations and simulations as well as recognize their limitations. For all levels the focus is on types of hardware and software rather than on use of particular products.</p>		
Grade 4	Grade 8	Grade 12
<p>Students are able to:</p> <p>I.4.7: Identify and investigate a local issue and generate possible solutions using digital tools and resources.</p>	<p>Students are able to:</p> <p>I.8.7: Identify a global issue using digital tools to investigate possible solutions. Select and present the most promising sustainable solution.</p>	<p>Students are able to:</p> <p>I.12.7: Identify a complex global issue and develop a systematic plan of investigation using digital tools and resources. Present findings in terms of pros and cons of two or more innovative sustainable solutions.</p>
<p>I.4.8: Test hypotheses in various subject areas using digital tools.</p>	<p>I.8.8: Test hypotheses of moderate complexity in various subject areas using digital tools to gather and display data. Draw and report conclusions consistent with observations.</p>	<p>I.12.8: Design and conduct complex investigations in various subject areas using digital tools to collect, analyze, and display data. Explain rationale for the design and justify conclusions based on observed patterns in the data.</p>
<p>I.4.9: Use digital models to describe how parts of a whole interact with each other in a model of a system.</p>	<p>I.8.9: Conduct a simulation using a digital model of a system. Explain how changes in the model result in different outcomes.</p>	<p>I.12.9: Having conducted a simulation of a system using a digital model, draw conclusions about the system based on outcomes of the simulation. Critique the conclusions based on the adequacy of the model.</p>

D. Acknowledgement of Ideas and Information

Digital citizenship is an essential element of technological literacy. As rapid technological advances have increased people's abilities to access and share information anytime and anywhere around the globe, there is increasing concern about the misuse and abuse of information. Some of the ethical and legal concerns were described under "Technology and Society" and include worries about such issues as providing false information, invading people's privacy, "hacking" into secure networks, and using ICT tools for industrial espionage. This sub-area concerns an especially important category: the appropriate use of intellectual property in the context of digital media.

For many students the first opportunity to learn about the ethical implications of intellectual property appears in discussions about classroom cheating, in which a student looks at someone else's test paper and writes down answers and ideas as his or her own. At the highest levels of academia, this practice is known as "plagiarism," and allegations of plagiarism can lead to criminal as well as ethical sanctions. On the other hand, it is not cheating to incorporate other people's ideas as long as credit for the source of the ideas is given at the time they are used. It is therefore essential that students know the conventional methods for appropriately crediting others' ideas, words, and images, both verbally and in the form of writing and other media.

A closely related issue is the use and misuse of copyrighted material. Even at the elementary level it has become so easy to copy and share digital information that children need to learn about the importance of respecting copyrighted materials. If students learn these lessons in school they will be more likely to continue to honor intellectual property rights as adults by respecting the laws protecting patents, trademarks, music, and video. Although technological safeguards may be developed in future years, individual respect for the intellectual property of others will continue to be an important ethical imperative.

Key principles in the area of Acknowledgement of Ideas and Information that all students can be expected to learn at increasing levels of sophistication during their K-12 school experience are as follows:

- Copyright laws and policies are designed to protect intellectual property.
- Fair use guidelines are designed to support academic use of copyrighted materials.
- There are multiple guiding principles (laws, policies, and guidelines) interacting that govern the use of ideas and information.

Fourth grade students should understand that it is permissible to use others' ideas as long as appropriate credit is given. This ethical guideline that one should give credit where it is due holds just true for tests and homework, but even in everyday conversation. They should also know that copyrighted materials cannot be shared freely. Eighth grade students should be aware both of school rules and of laws concerning the use of other people's ideas. They should know about the limits of fair use of verbatim quotes and how to cite sources in papers or other media productions. They should also be guided in developing an ethical rudder in the giving of appropriate credit for others' ideas and contributions. Twelfth grade students should understand

the fundamental reasons for intellectual property laws and should know acceptable practices for citing sources when incorporating ideas, quotes, and images into their own work.

**Table 2.12 Acknowledgement of Ideas and Information
content statements for grades 4, 8, and 12**

D. Acknowledgement of Ideas and Information		
<p>Fourth grade students exhibit digital citizenship by understanding that it is permissible to use others' ideas as long as appropriate credit is given and that copyrighted materials cannot be shared freely. Eighth grade students should be aware of and comply with laws and ethical guidelines for incorporating ideas, text, and images into their own work. Twelfth grade students should understand the reasons for protecting intellectual property and demonstrate responsible and ethical behaviors when using ideas, quotes, and images from others.</p>		
Grade 4	Grade 8	Grade 12
<p>Students know that:</p> <p>I.4.10: It is allowable to use other people's ideas in one's own work provided that proper credit is given to the original source, whether information is shared in person or through ICT media.</p>	<p>Students know that:</p> <p>I.8.10: Style guides provide detailed examples for how to give appropriate credit to others when incorporating their ideas, text, or images in one's own work.</p>	<p>Students know that:</p> <p>I.12.10: Legal requirements governing the use of copyrighted information and ethical guidelines for appropriate citations are intended to protect intellectual property.</p>
<p>Students are able to:</p> <p>I.4.11: Demonstrate respect for copyrighted material, such as resisting the request from a friend to copy a song from a CD or placing copyrighted material online.</p>	<p>Students are able to:</p> <p>I.8.11: Demonstrate compliance with fair use practices and appropriate citation of sources when using information from books or digital resources.</p>	<p>Students are able to:</p> <p>I.12.11: Demonstrate responsible and ethical behavior by following the letter and spirit of current laws concerning personal and commercial uses of copyrighted material as well as accepted ethical practices when using verbatim quotes, images, or ideas generated by others.</p>

E. Selection and Use of Digital Tools

Clearly, students must be fluent with technological operations and concepts. Until recently, classroom uses of technology tended to focus almost exclusively on helping students become competent users of the technology itself. Although no one would argue that basic technology skills are no longer necessary, educators now recognize that *how technology is used as a tool* for learning is at least as important—if not more so—than simply *how to use* technology. That said, there are basic operational skills and concepts that enable students to be more effective users of technology for learning. These skills include the abilities to select and use the appropriate tools, to use those tools to complete tasks effectively and productively, and to apply current knowledge about technology to learn how to use new technologies as they become available.

Key principles in the area of Selection and Use of Digital Tools that all students can be expected to learn at increasing levels of sophistication during their K-12 school experience are as follows:

- Knowledge about the common uses of readily available digital tools supports effective tool selection.
- A fundamental aspect of technological literacy is the possession of foundational ICT skills in the use of common productivity tools.

Fourth grade students should know that different digital tools have different purposes. They should also be able to use a variety of digital tools that are appropriate for their age level. For example, they should be reasonably competent in using digital tools for creating documents and images, for solving problems, and for collecting and organizing information. Eighth grade students should be familiar with different types of digital tools and be able to move easily from one type of tool to another—for example, creating a document or image with one tool and then using a second tool to communicate the result to someone at a distant location. They should be able to select and use effectively a number of tools for different purposes. Twelfth grade students should be competent in the use of a broad variety of digital tools and be able to explain why some tools are more effective than others that were designed to serve the same purpose, based on the features of the individual tools.

Table 2.13 Selection and Use of Digital Tools content statements for grades 4, 8, and 12

E. Selection and Use of Digital Tools		
Fourth grade students know that different digital tools have different purposes and are able to use a number of different tools. Eighth grade students can categorize digital tools by function and can select appropriate tools and demonstrate effective use of the tools for different purposes. Twelfth grade students are competent in the use of a broad variety of digital tools and can justify why certain tools are chosen over others that might accomplish the same task, by referencing specific features.		
Grade 4	Grade 8	Grade 12
Students know that: I.4.13 Different digital tools have different purposes.	Students know that: I.8.13 Some kinds of digital tools are appropriate for gathering, organizing, analyzing, and presenting information, while other kinds of tools are appropriate for creating text, visualizations, and models and for communicating with others.	Students know that: I.12.13 A variety of digital tools exist for a given purpose. The tools differ in features, capacities, operating modes, and style. Knowledge about many different ICT tools is helpful in selecting the best tool for a given task.
Students are able to: I.4.14 Use digital tools (appropriate for fourth grade students) effectively for different purposes, such as searching, organizing, and presenting information.	Students are able to: I.8.14 Select the appropriate digital tools to accomplish a variety of tasks, including gathering, analyzing, and presenting information as well as creating text, visualizations, and models and communicating with others.	Students are able to: I.12.14 Demonstrate the capability to use a variety of digital tools to accomplish a task or develop a solution for a real-world problem. Justify the choice of tools, explain why other tools were not used, based on specific features of the tools, and summarize the results.

Conclusion

This chapter has described in detail what all students are expected to know and be able to do in order to be technologically literate. Although a few examples have been provided, for the most part this body of knowledge and skills has been described abstractly. The next chapter will describe the technological context for assessment items and provide examples of what assessment items will look like.

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CHAPTER THREE: TECHNOLOGICAL LITERACY PRACTICES AND CONTEXTS

Introduction

Chapter Two described the assessment targets for Technological Literacy, both knowledge and abilities, which NAEP will assess. This chapter describes the *contexts*, or situations, for the assessment tasks and items as well as three *practices* that specify the general, crosscutting kinds of thinking and reasoning that will be expected of students. Together, the assessment targets, contexts, and practices will support the generation of tasks and items. This chapter describes the contexts and practices in some detail and provides examples of tasks and items that result when these three elements are combined.

Contexts

Technological literacy requires not just that students know *about* technology but also that they are able to recognize the technologies around them, understand the complex relationship between technology and society, and use technological principles and tools to solve problems and meet their goals. Consequently, NAEP Technological Literacy assessment items will measure students' technological literacy in the context of relevant societal issues, actual problems that people are commonly called upon to solve, and situations in which competency with technology determines a person's capability to succeed in reaching his or her goals. Since the three areas of technological literacy to be measured by NAEP tend to focus on somewhat different types of problems and goals, the contexts and situations that will frame the technology assessment items in these areas will differ as well.

Technology and Society

The complex and multi-faceted interactions between technology and society often manifest themselves in unexpected and unpredictable ways as new technologies are used in particular contexts or situations. A new technology may succeed in meeting the need that it was intended to meet and bring about far-reaching benefits, but it may also have negative, unintended consequences. For example, mobile communication devices have transformed business and personal interactions, yet a large number of traffic accidents have been blamed on drivers using cell phones while operating their vehicles. Similarly, farming practices have increased crop production, but they have also depleted non-renewable sources of groundwater. Such issues can clearly be used as contexts for NAEP Technological Literacy assessment items (as illustrated in ISTE's NETS, Partnership for 21st Century Skills' Framework, and ITEA's Standards for Technology Literacy). Contexts for tasks and items in the area of Technology and Society may also present non-controversial ways that technology improves people's lives, such as water purification, sewage treatment, and medicine, or the various ways that people regularly interact with technology, from brushing teeth in the morning to crawling into a warm, comfortable bed at night. The following are examples of topics in the contexts of health, energy, and electronic communications that could be used to generate assessment tasks and items for sample targets in the three sub-areas of Technology and Society for grade 8:

- Agriculture and health contexts: water as a scarce resource
- Energy context: wind turbines for homes
- Electronic communications context: personal communication devices

Table 3.1 Examples of how different contexts may be used to generate tasks and items at grade 8 for Technology and Society

	A. Technology and Human Society	B. Effects of Technology on the Natural World	C. Effects of Technology on the World of Information and Knowledge	D. Ethics, Equity, and Responsibility
Grade 8 Assessment Targets	Society drives improvements in technology.	Decisions to develop and use technologies often put environmental and economic concerns in direct competition with one another.	Technology provides instant access to information, expertise, and knowledge through a wide array of devices and in a variety of media formats	Technology by itself is neither good nor bad, but its use may affect others.
Context: Water as a Resource	What societal needs drove the changes made to a river's natural flow?	What issues need to be addressed to ensure that the water system stays healthy?	Find two reports describing alternative water purification methods.	How might the decision to divert water from the rivers affect farmers and small towns downstream?
Context: Wind Turbine	Describe the positive and negative impacts that residential wind turbines might have on society.	Compare and contrast the environmental and economic impacts of wind turbines with other potential sources of energy.	Compare the persuasiveness of two multimedia presentations on alternative wind turbine designs.	Describe a process for citizens to evaluate the impact that wind turbines might have on others in the community.
Context: Electronic Communication	What are the positive and negative impacts that personal communication devices may have on traditional human communication?	Describe the impact of video evidence of environmental destruction on society's awareness of the global impact of pollution.	Describe ways that personal communication devices provide access to information and expertise.	What might the impact be of allowing cell phones to be used in school?

Design and Systems

Nearly all of the products and processes that surround us result from the development of one or more kinds of technology. Homes, factories, and farmhouses are built with construction technologies. Fruits and vegetables are grown and processed using agricultural technologies and brought to market and to the dinner table with transportation technologies. Methods of extracting and using fuels to power civilizations involve energy and power technologies, and the tools and processes used by doctors, nurses, and pharmacists are a part of medical technologies. Although these technologies can be classified in various ways, in order to provide guidance to item writers this *Framework* identifies the following types of technologies (drawn primarily from ITEA 2007) that can be used as contexts to measure students' understanding of design and systems:

- Medical technologies
- Agricultural and related biotechnologies
- Energy and power technologies
- Transportation technologies
- Materials and manufacturing
- Construction technologies
- Information and communication technologies

The section below presents potential scenario topics placed in contexts from the above types of technologies. The table illustrates how the topics in these contexts can be used to generate tasks and items in the four sub-areas of Design and Systems for grade 8.

Table 3.2 Examples of how different contexts may be used to generate tasks and items at grade 8 for Design and Systems

	A. Nature of Technology	B. Engineering Design	C. Maintenance and Troubleshooting	D. Systems Thinking
Grade 8 Assessment Targets	Technology advances through the processes of innovation and invention.	Requirements for a design are made up of criteria for success and constraints, or limits, which may include aesthetic and ethical considerations.	Tools and machines must undergo regular maintenance to ensure their proper functioning.	Technological systems can interact with one another to perform more complex functions and tasks than any individual system can do by itself.
Context: Transportation	How have transportation methods changed over time?	Propose two different ways to modify an intersection to make it safer.	What problems might occur if engines are not oiled periodically?	What are the advantages of container cargo ships over other ways to transport goods to market?
Context: Medical Technology	What were the needs that led medical researchers to develop vaccines?	Identify the requirements for a prosthetic arm that will enable a person to play tennis.	How should medical instruments be maintained between surgeries?	Name several elements of our nation's medical system and describe how they are related.
Context: Wind Turbine	What natural constraints exist in San Francisco that might cause a homeowner to choose wind power over other "green" energy alternatives?	Compare the aesthetic qualities of the two types of wind turbines (vertical or horizontal).	Using the simulation model of a residential wind turbine, describe which parts of the machine would require the most maintenance.	Using the simulation model of a residential wind turbine, identify the goals, inputs, processes, outputs, and feedback and control features.
Context: Information Communication Technologies	Trace the evolution of features on early cell phones compared to current smart phones.	Compare the trade-offs of functions available in two specific devices designed for a workplace or personal use.	Describe a set of troubleshooting steps that would be appropriate for analyzing a problem with a printer.	Explain two ways in which personal computing devices can work together for a team to achieve its project goal.

It is important to note that students are not expected to be familiar with the specific components and working details of any specific technology. For example, they will not be tested on their knowledge of genetic engineering, an important biotechnology, nor on their understanding of energy and power or networking technologies. While these topics will form the context of test items, the information required for students to respond to the test questions will be provided in the scenario or background of the question. Students will be tested on the broad set of principles concerning design and systems and capabilities described in Chapter Two. However, one of the technologies from the list in the previous section has been chosen for more emphasis in the *2012 NAEP Technology Framework*, and that is Information and Communication Technology (ICT).

Information and Communication Technology (ICT)

In contrast to other types of technologies, students will be expected to be fluent in the use of information and communication technologies, as described in the tables of Chapter Two. The reason for this additional attention to ICT is that it is pervasive in our society, and some level of technological literacy is required for virtually every profession, in every school subject, and in all walks of life. Furthermore, it is likely that literacy with information and communication technologies will become even more important in the decades ahead.

Because of the ubiquity of ICT, it is difficult to describe the particular contexts for items that NAEP will design to assess students' knowledge and abilities of its use. ICT competency can be applied in the context of developing and using any of the technologies listed in Table 3.2 under Design and Systems, and it can be applied to any of the ways that technology interacts with society. ICT principles and tools should be a part of every person's set of capabilities for solving a problem or working to meet a goal. Technologically literate people should be able to select and use technological tools to research a period in history, compare cultures, collect and display data in a science investigation, develop a story or presentation, or produce a work of art. The types of scenarios used to assess students' knowledge and abilities in this area will require that the item provide an opportunity for students to demonstrate their understanding of and abilities to use ICT to address goals and problems in Technology and Society, in Design and Systems, and in the use of ICT in all disciplines, school subjects, or practical applications. The following table illustrates how topics set in different contexts can be used to generate tasks and items for targets in the five subareas of ICT.

Table 3.3 Examples of how different contexts may be used to generate tasks and items at grade 8 for Information and Communication Technology (ICT)

	A. Construction and Exchange of Ideas and Solutions	B. Information Research	C. Investigation of Academic and Real-World Problems	D. Acknowledgment of Ideas and Information	E. Selection and Use of Digital Tools
Grade 8 Assessment Targets	When communicating a message it is important to take into account the audience—the people for whom the message is intended.	Digital and network tools and media resources are helpful for answering questions and testing hypotheses. However, it is important to watch for the possibility that information has been distorted, exaggerated, or otherwise misrepresented.	Identify an academic, social, political, or community issue using ICT tools to investigate possible solutions. Select and present the most promising sustainable solution.	School rules and laws provide detailed guidelines for how to give appropriate credit to others when incorporating their ideas, text, or images in one's own work.	Select and demonstrate effective use of digital tools to accomplish a variety of tasks, including gathering, analyzing, and presenting information, as well as creating text, visualizations and models, and communicating with others.
Context: Local Community Action	Web pages have been created to convince people to move to your community. Use a rubric to evaluate mock-up samples of Web pages, including appropriate use of media to provide information to appropriate audience and appropriate citation of sources.	Synthesize data from a variety of sources (census, local economy, demographics, industry, history) to show that the availability of jobs in your town.	Watch an example video of a successful local campaign to declare a local building as a historic landmark. Answer a series of questions about the effectiveness of the video.	Review examples of media that could be used for a presentation and make decisions as to appropriateness and legality of using them.	Using articles and simulated Web sites, create a media-rich presentation designed to convince people to move to your city.
Context: Wind Turbine	Using information from the text and the provided slide-making tools, design a presentation that presents the positive and negative impacts of residential wind turbines to a group of homeowners.	Using the provided Internet search and slide-making tools, research and create a presentation comparing and contrasting the benefits of residential wind turbines with other "green" energy alternatives.	Using the simulation model and the available city data, determine which cities in the United States would be most appropriate for installing residential wind turbines. Be sure to use data from the simulation to support your conclusions.	Examine a set of slides and the associated resources and determine how best to give appropriate credit for the information and images used in the presentation.	Using the information provided in the text, choose from the available digital tools and create a multimedia information packet to promote residential wind turbines.

Practices

Practices contribute to the *Framework* by articulating the kinds of thinking and reasoning that students are expected to demonstrate when responding to an assessment item. The *Framework* specifies three kinds of practices: (1) identifying and applying technological principles; (2) using technological processes and tools to solve problems and achieve goals; and (3) communicating and collaborating.

The *Science Framework for the 2009 National Assessment of Educational Progress* served as the primary source of the technological literacy practices. Developers of the science framework had examined the sections on Science and Technology and the Designed World of the *National Science Education Standards, Benchmarks for Scientific Literacy*, and cognitive research on science learning. For the Technological Literacy Framework, the cross-cutting practices from the *Science Framework for the 2009 NAEP* were adapted to apply to processes relevant for the technological literacy areas. In addition, the national, international, and state technological literacy frameworks cited in Chapter Two were used as reference points.

Although the practices are related and not independent of each other, classifying the assessment targets in Chapter Two, according to the three crosscutting practices, will support the development of a range of rich and challenging assessment tasks and items. Following is a brief description of each of these three practices.

Identifying and Applying Technological Literacy Principles focuses on students' capability to make use of their knowledge about technology from discrete declarative facts and concepts to higher-level reasoning of how facts, concepts, and principles are organized into structures and relationships that students can call upon to explain how things fit together and in order to use the knowledge to make predictions, comparisons, and evaluations. The targets that reflect this practice call upon students to recognize, recall, describe, define, analyze, compare, relate, and represent technological principles. In addition, this practice includes knowledge of the relationships among components of systems and processes.

Using Processes to Solve Problems and Achieve Goals refers to students' systematic use of technological knowledge, tools, and skills to solve problems and achieve goals presented in realistic contexts. This practice includes both procedural and strategic competencies—knowing how to apply simple steps and use technological tools to address real situations as well as when and where to apply the tools and processes. This practice draws upon the previous practice—to identify and apply technological literacy principles—and adds the dimension of using the knowledge to solve a problem or achieve a goal. This practice involves applying fundamental problem-solving processes. It may engage students in analyzing goals, planning, designing, and implementing as well as iteratively revising and evaluating possible solutions to meet the requirements of a problem or to achieve a goal. For *NAEP Technological Literacy*, a distinguishing feature of this practice is that the students respond to questions and tasks within the process of solving a problem or determining how best to achieve a goal.

Communicating and Collaborating centers on students' capability to use contemporary technologies to communicate for a variety of purposes and in a variety of ways, working

individually or in teams. In the three major assessment areas, in order to address societal issues, solve problems, achieve goals, and design processes and products, students must develop representations and share ideas, designs, data, explanations, arguments, and presentations. Effective teamwork and collaboration support achievement of goals.

Table 3.4 presents examples of how these three practices can be used to classify targets in the three major assessment areas. It should again be noted that the boundaries between the practices are not entirely distinct, but thinking in terms of these three practices can be helpful in developing items and interpreting student performance.

Table 3.4 Classification of assessment targets in the three major technological literacy assessment areas according to the technological literacy practices

	Technology and Society	Design and Systems	Information and Communication Technology
Identifying and Applying Principles	Analyze advantages and disadvantages Explain costs and benefits Compare effects of two technologies on individuals’ Propose solutions and alternatives Predict consequences Select among alternatives	Describe features of a system or process Identify examples of a system or process Explain the properties of different materials that determine which is suitable to use for a given application or product Analyze a need Classify the elements of a system	Describe features and functions of ICT tools Explain how parts of a whole interact Analyze relevant features Compare outcomes Critique a process or outcome Propose solutions Evaluate examples of effective resolution of opposing points of view Justify tool choice
Using Processes to Solve Problems and Achieve Goals	Select appropriate technology to solve a societal problem Develop a plan to investigate an issue Investigate environmental and economic impacts Evaluate tradeoffs and impacts	Design a product, process, or investigation Develop forecasting techniques Construct and test a model or prototype Produce an alternative Evaluate trade offs Determine how to meet a need by choosing resources required to meet or satisfy that need	Select and Use appropriate tools Search media and digital resources Forecast consequences Propose solutions Predict outcomes Implement a solution Plan research and presentations Publish findings and expressions Construct communications and presentations Evaluate credibility Organize data and information Transform from one representational form to another Conduct experiments using digital tools and simulations
Communicating and Collaborating	Present innovative, sustainable solutions Compose a multimedia presentation	Communicate design ideas using models and blueprints Use a variety of media and formats to communicate information and ideas effectively Produce an historically accurate timeline Display design of a prototype Organize and Represent data in graphs, tables, and models Provide and Integrate feedback	Provide and Integrate feedback to make changes in a presentation Incorporate feedback Critique presentations Express historical issues in a multimedia presentation Argue from an opposing point of view Inform a specified audience how something works Address multiple audiences Synthesize data and points of view

Examples of Practices Applied in each of the Assessment Areas

The following sections describe how the three practices of Identifying and Applying Principles, Using Technological Processes to Solve Problems and Achieve Goals, and Communicating and Collaborating can be used to classify these general types of thinking and reasoning across assessment targets in the three major assessment areas of Technology and Society, Design and Systems, and Information and Communication Technology (ICT).

Technology and Society

Assessment targets in the area of technology and society are concerned with the effects of technology on human society, the natural world, and the world of information and knowledge as well as with issues of ethics, equity, and responsibility.

Identifying and Using Principles

To identify and use principles in these three sub-areas, students could be asked to recognize examples of the effects of technologies; identify examples of ethical and equity issues; describe local and global effects of technologies; explain effects of rapidly changing technologies on knowledge creation, access, and management; analyze beneficial and negative impacts; recognize examples of responsible, ethical uses of technologies; compare costs and benefits of technologies; predict potential impacts on society and the environment; and explain the relationships among technologies.

Using Technological Processes and Tools to Solve Problems and Achieve Goals

To demonstrate their abilities to address the types of issues and problems in the assessment area of Technology and Society, students could be asked to develop alternative proposals for a new technology based on an analysis of potential positive and negative impacts. The problem-solving practices could be demonstrated in a series of tasks and items for analyzing the uses of the new technology, gathering data and information on its impacts, analyzing the data, interpreting results, and evaluating alternatives.

Communicating and Collaborating

To address issues in Technology and Society, students can use a variety of modalities to represent and exchange data, ideas, and arguments about the advantages and disadvantages of technologies. Students can collaborate (virtually) to form teams that will gather and integrate information about the potential impacts of a technology on human society or the natural world. Tasks can ask students to demonstrate their capability to interact, collaborate, and contribute to work as a team. Table 3.5 illustrates how the three practices can be applied to assessment targets at the middle school level to generate tasks and items.

Table 3.5 Examples of tasks representing practices in each sub-area of Technology and Society

	A. Technology and Human Society	B. Effects of Technology on the Natural World	C. Impacts on the World of Information and Knowledge	D. Ethics, Equity, and Responsibility
Selected Principles	The relationship between technology and society is reciprocal. Society drives technological change, while technological change in turn shapes society.	Waste management is a key component of any technological system.	Technology enables presentation, observation, and participation in temporal, causal, spatial, and dynamic phenomena.	Technology by itself is neither good nor bad, but its use may affect others.
Practices				
Identifying and Applying Technological Principles	Explain what factors need to go into a decision to change the use of a river and identify possible consequences of doing so.	Identify and provide a rationale for appropriate and inappropriate procedures for disposing of electronic devices.	Compare the impact of geographical information systems and 14th-century maps on people's capability to explore new territory.	What are the positive and negative consequences of the predicted change from print to digital news?
Using Processes to Solve Problems and Achieve Goals	The community has decided to implement a new wind turbine system. Design an investigation into the impact on the community of a wind turbine system.	Given a specific consumer electronics product such as a cellular telephone, design a new way to increase its appropriate disposal.	Use a simulation to test the adequacy of exit routes for evacuating residents of a mountain town during a wildfire.	What processes and digital tools might the city council put into place in order to make sure all citizens have a say?
Communicating and Collaborating	Collaborate with engineers and urban planners through a Web site to collect and communicate data about the effects of a wind turbine system on the community.	Organize a campaign with a virtual team to inform the public of the dangers of improper disposal of consumer electronic products.	Select a set of images from aerial maps and geographical visualizations for a presentation on the effects over the last century of urban development in your state on forests.	Using information from the text, describe a process that has been put in place that allows for citizens to evaluate the impact that wind turbines might have on all segments of the community.

Illustrative Tasks and Items

Scenario-Based Assessment Sets

These items will present students with a problem or goal set within a broader context. The example below gives students the task of using technological tools to analyze the impacts of various factors on the natural world. While this example has some student responses on paper, the NAEP Technological Literacy tasks will be completely administered and completed on the computer.

Context: Natural world

Topic: Declining bird population

In this simulation, students are given the scenario of a population of small birds—chortlers—whose population is declining. The students use various tools to analyze data and determine some possible causes for the decrease in order to present their findings on the impacts on the chortlers.

Chortlers

Page1Page 2

The chortler is a small woodland bird which has been declining in numbers recently. Here are some ideas why chortlers are becoming less common:


- More air pollution
- High summer rainfall
- Increasing numbers of hawks

120 woodland sites are surveyed.

The number of chortlers and hawks are recorded as a percentage of the numbers found 5 years ago.

The average summer rainfall and air pollution levels have been recorded for the last 5 years.

Go to page 2 and explore the survey data.



Chartlers

Page1 Page 2

Click on the buttons below to present the data in different ways.

Browse & Sort Data **Draw Graphs** **Group Data**

Drag these labels to the graph axes to choose what to plot.

Hawk Numbers (%)

Pollution Index

2. Use these tools to investigate possible causes of the fall in chortler numbers.

Write your conclusions on paper.
Say how you would present the data to clearly support your conclusions.

(Source: Martin Ripley's presentation at the Assessment & Teaching of 21st Century Skills meeting, April 2009)

Discrete Item Sets

These types of items will ask for students to select or construct their answers. The examples below represent familiar multiple choice and constructed response formats.

Constructed Response

Context: Natural world

Topic: Climate change

Climate Change Text 1

Read the following information and answer the questions which follow.

WHAT HUMAN ACTIVITIES CONTRIBUTE TO CLIMATE CHANGE?

The burning of coal, oil and natural gas, as well as deforestation and various agricultural and industrial practices, are altering the composition of the atmosphere and contributing to climate change. These human activities have led to increased concentrations of particles and greenhouse gases in the atmosphere. The relative importance of the main contributors to temperature change is shown in Figure 1. Increased concentrations of carbon dioxide and methane have a heating effect. Increased concentrations of particles have a cooling effect in two ways, labelled 'Particles' and 'Particle effects on clouds'.

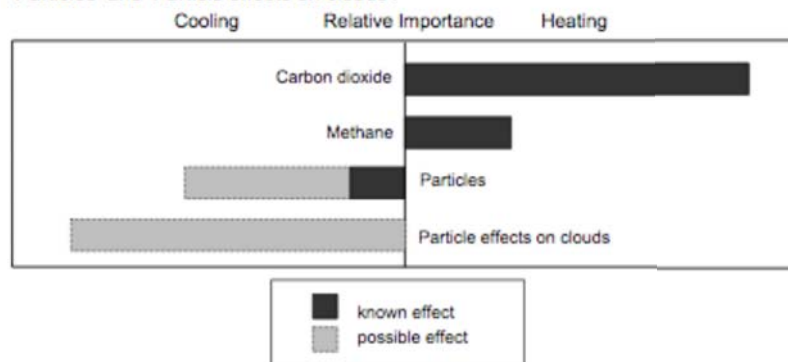


Figure 1: Relative importance of the main contributors to change in temperature of the atmosphere.

Bars extending to the right of the centre line indicate a heating effect. Bars extending to the left of the centre line indicate a cooling effect. The relative effect of 'Particles' and 'Particle effects on clouds' are quite uncertain: in each case the possible effect is somewhere in the range shown by the light grey bar.

Source: adapted from <http://www.gcric.org/ipcc/qa/04.html>

Question 1: CLIMATE CHANGE

S210Q01- 0 1 2 8 9

Use the information in Figure 1 to develop an argument in support of reducing the emission of carbon dioxide from the human activities mentioned.

.....

.....

.....

(Source: PISA 2003)

Selected Response - Multiple Choice

Context: Natural world

Topic: Climate Change

The burning of fossil fuels has increased the carbon dioxide content of the atmosphere. What is a possible effect that the increased amount of carbon dioxide is likely to have on our planet?

- Ⓐ A warmer climate
- Ⓑ A cooler climate
- Ⓒ Lower relative humidity
- Ⓓ More ozone in the atmosphere

(Source: TIMSS 2003)

Design and Systems

Assessment targets in the area of Design and Systems relate to the nature of technology, the engineering design process, maintenance and troubleshooting, and systems thinking. The sections below describe how the three cross-cutting practices apply to targets in the area of Design and Systems.

Identifying and Using Principles

Technological principles for Design and Systems identify the core understandings students should have about the types of technologies, processes for designing technologies, approaches for preventing failures, and how components of technological systems interrelate. The practices for Identifying and Using Principles in these areas could ask students to draw upon their knowledge to identify examples of technologies, components of design processes, components of a system, or maintenance and troubleshooting methods. Students could be asked to explain the relationship among technologies in a system, analyze the components of a system, recognize design constraints, or evaluate alternative representations of a system.

Solving Problems and Achieving Goals

Problem solving is a major part of the engineering design process. Thus there are many opportunities for students to demonstrate their problem-solving abilities in assessment tasks for this area. Such tasks could require them to develop designs, propose or critique solutions to problems given criteria and constraints, select appropriate resources by considering tradeoffs, construct and test a model or prototype, troubleshoot systems and applications, and determine the consequences of making a change in a system.

Communicating and Collaborating

Communication and collaboration practices are integral to achieving the goals of technological design and systems. Students can demonstrate teamwork in tasks in which design assignments are distributed among team members, progress and results are integrated and shared, and products presented jointly. Designs and the design process can be represented in visual and verbal forms. Students can create instructions for system assembly and prepare documentation of a procedure for maintaining a system.

Table 3.6 Examples of tasks representing practices in each sub area of Design and Systems

	A. Nature of Technology	B. Engineering Design	C. Maintenance and Troubleshooting	D. Systems Thinking
Selected Principles	Technologies developed for one purpose are sometimes adapted to serve another purpose. Technological development involves creative thinking.	Requirements for a design challenge include criteria for success and constraints (limits) that cannot be violated in the solution.	Tools and machines must undergo regular maintenance to ensure proper functioning.	All systems have parts that work together to accomplish a goal.
Practices				
Identifying and Applying Technological Principles	Describe the properties of a spring that inspired the invention of the Slinky. (animation)	List three important criteria for a device that will toast bread, and justify each one.	Why do Bill and Sally oil their bike chains and axles and check the brakes each month? What may happen if they do not?	What are the systems a bathroom shower needs in order to function properly? (animation)
Problem Solving and Achieving Goals	Given a collection of objects, design a new toy (e.g., for a baby, young child). What are the criteria for a toy, and how does your design meet them?	Design a process to serve 50 slices of warm toast in 5 minutes given specific equipment and resources.	Bill's bike tire is scraping the fender, and it's hard to steer. What should he do?	Design modifications to a shower for people with a particular physical disability (e.g., blind, wheelchair bound). (animation)
Communicating and Collaborating	Select a team of people who could design and build a new toy for a 5 year old, and justify the choices. Work individually, or collaborate with a virtual person to make your selections.	How would an industrial toaster salesperson develop talking points for selling a particular toaster to a given restaurant?	Bill, Sally, and many other students would like to ride their bikes to school. What steps should they take to design a bike parking lot at the school?	Collaborate with a group of (virtual) people to design shower rooms for the girls' and boys' locker rooms of a school gym.

Illustrative Tasks and Items

Scenario-Based Item Set

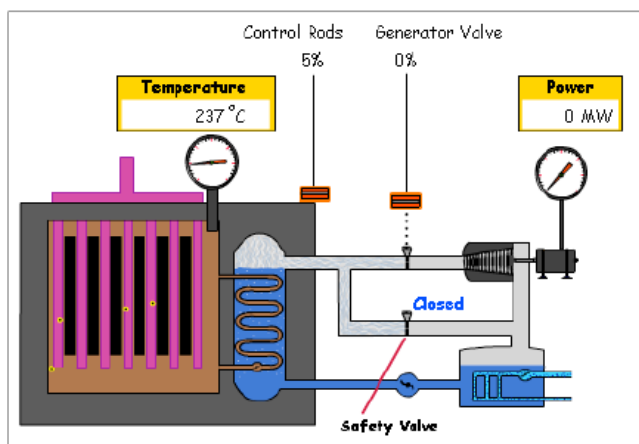
Context: Energy

Topic: Nuclear reactor

In this example, students are asked a series of questions related to a simulation. In the NAEP Technological Literacy, the questions might relate to aspects of the design of the reactor, results of investigations based on manipulating the simulation, and reports of findings.

Question 13: Nuclear Power Plant

In the nuclear power plant simulation below, the number of nuclear interactions produced by the reactor is regulated by the **Control Rods**. The power output is regulated by the **Generator Valve**. The **Control Rods** and the **Generator Valve** can be controlled by dragging the sliders up and down.



Set the generator valve at 80%. How far (%) should the control rods be lifted for the power plant to supply a continuous output of 800 Megawatts (MW) without the safety valve opening?

- ☐ 55%.
- ☐ 70%.
- ☐ 85%.
- ☐ 100%.

(Source: PISA)

Discrete Item Sets

Selected Response - Multiple Choice

Context: Construction

Topic: Cabinet design

2003, Science and Technology/Engineering - Grade 5

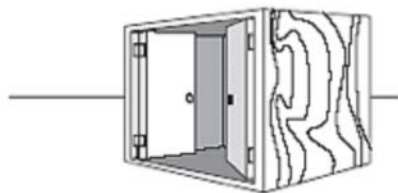
Question 34: Multiple-Choice

Reporting Category: Technology/Engineering

Standard: Engineering Design - 2.3

Standard: Materials and Tools - 1.2

A student has designed a cabinet that he can use to store his books, as shown below.



To give him more storage space, what can he **most easily** change in his design?

- A. use a different type of wood
- ✓ B. move the hinges so the doors open to the outside
- C. put doors on the top and the bottom of the cabinet as well as the front
- D. use wood glue instead of mechanical fasteners to attach the different pieces

State Average = 87%

(Source: Massachusetts Comprehensive Assessment System (MCAS))

Constructed Response

Context: Construction

Topic: Developing a design pilot study

2005, Technology/Engineering - High School

Question 18: Open-Response

Reporting Category: Technology/Engineering

A group of students is doing a semester project to determine the best material for textbook covers. During the project, they will conduct a one-month pilot study in which a class of students will try out different types of textbook covers.

- a. Identify **one** step in the engineering design process that the students should do before starting the pilot study.
- b. Explain in detail **one** step that the students should do after the pilot study.
- c. Explain in detail why **both** of these steps are important.

NOTE: A NEW SELECTED RESPONSE ITEM MAY BE ADDED
(Source: MCAS)

Information and Communication Technology (ICT)

ICT literacy involves the capability to communicate ideas and solutions, to conduct research, to investigate solutions to academic and real-world problems, to find ways to meet the ever-changing needs of society, to properly acknowledge the source of ideas and information, and to select and use appropriate digital tools. The sections below describe how the three practices apply to the ICT assessment targets.

Identifying and Applying Principles

The principles in the ICT assessment area relate to understanding the variety of ICT tools and how and when they can be used. Students will need to recognize the general features and functions of ICT tools, to know which are appropriate for particular purposes, and understand criteria for determining if the tools were used appropriately and well.

Using Technological Processes to Solve Problems and Achieve Goals

Information communication technology tools can be employed to support problem solving in all three of the technological literacy areas. The types of problems addressed in the ICT assessment area relate to the selection and use of appropriate tools to achieve goals related to information research, solving academic and real world problems, meeting the needs of society, constructing and exchanging information and ideas, and the acknowledgement of ideas and information. ICT problem-solving practices could be elicited by tasks and items asking students to select and use applications effectively and productively; to access and use information and data to solve a problem or achieve a goal; to use technical tools to solve a problem or achieve a goal; or to use ICT tools to plan, represent data, analyze, and summarize results.

Communicating and Collaborating

ICT relies heavily on students' command of communication and collaboration practices. Students can be asked to demonstrate the capability to contribute effectively to a body of knowledge or to take part in group deliberation through social media and through the use of other contemporary communication tools and structures. Students can be asked to investigate a problem or pursue a goal with a group (virtually), to integrate input from multiple collaborators, and to reach consensus. Students can integrate feedback from others, provide constructive criticism, and communicate to multiple audiences using a variety of media and genres. Findings can be represented in a variety of ways, such as diagrams, tables, graphs, and digital media.

Table 3.7 Examples of tasks representing practices that apply to each sub-area of Information and Communication Technologies (ICT)

	A. Construction and Exchange of Ideas and Solutions	B. Information Research	C. Investigation of Academic and Real-World Problems	D. Acknowledgment of Ideas and Information	E. Selection and Use of Digital Tools
Selected Principles	Digital tools can be used for achieving expressive goals.	Important strategies for insuring quality of information include 1) assessing the source of information and 2) using multiple sources to verify the information in question. Information can be distorted, exaggerated, or otherwise misrepresented.	Digital tools can be used to investigate academic and real world problems through experiments and simulations.	There are multiple guiding principles (laws, policies, and guidelines) interacting to govern the use of ideas and information.	A knowledge base of common uses of readily available digital tools supports effective tool selection.
Practices					
Identifying and Applying Technological Principles	Describe how graphics, text, and tables convey a message.	Select the particular Web page from among a group provided that contains an example of exaggeration.	Identify the combination of data tools that will best present a particular set of data.	Select the example that shows the appropriate way to give credit to another student's graphic.	Critique a digital tool suggested for designing an online story.
Using Processes to Solve Problems and Achieve Goals	Develop an online survey for elementary level students on the design of a new playground.	Create a digital story about an historical period by choosing images of art from the period.	Use simulations and visualizations to describe the rate of deforestation in Brazil.	Identify which online images can legally be used in a student presentation.	Predict trends in rates of software piracy based on provided data.
Communicating and Collaborating	Respond to suggestions from two virtual collaborators explaining why only the search results of one of the collaborators has sufficient information for the report.	Ask a virtual collaborator for help on developing a digital presentation.	Enter costs from several sources and communicate to the principal the most economical printer for school play posters.	Post a copyright free image to a web site and communicate to friends that it is available.	Use two digital tools to create a public service announcement on software piracy.

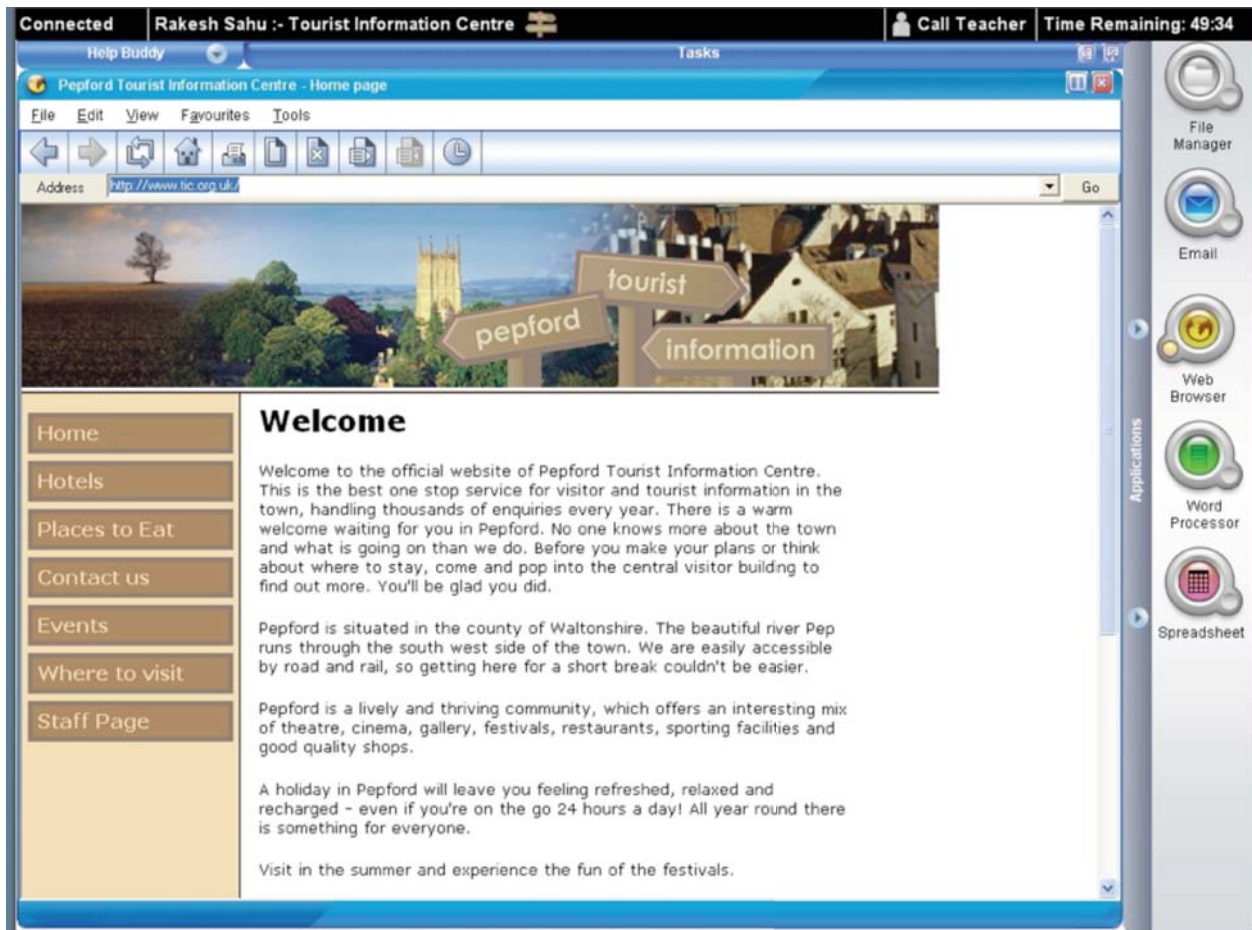
Illustrative Tasks and Items

Scenario-Based Item Sets

Context: ICT

Topic: Promotional brochure

In this simulation, students navigate among a file manager, an e-mail client, a Web browser, a word processor, and a spreadsheet to make a travel brochure for a fictional town, Pepford. They are assessed on how they accomplish the task, not on the quality of the brochure. The process is more important than the outcome.



(Source: Martin Ripley's presentation of the UK ICT-Literacy Assessment at the Assessment & Teaching of 21st-Century Skills meeting, April 2009.)

Context: ICT

Topic: Business decisions

It is your assignment to justify the decisions about which flowers to stock for the upcoming Mother's Day rush of purchases in order to be able to serve your customers. You will review last year's spreadsheet to analyze the types, numbers, and costs of flowers, then create a graphic to justify your decision. Your decision will be based on the different types of flowers purchased for Mother's Day, the number of orders placed, your company cost of each order, the selling price of each, and the requests for orders that could not be filled. Create the appropriate graphic to support your decisions.

- Task one: Review the spreadsheet data from last year of the Mother's Day purchases.
- Task two: Use the spreadsheet tools to arrange the purchase prices of the different flowers from high to low price.
- Task three: Create a chart showing the purchase price information.
- Task four: Use the tools to arrange the number of orders for each flower WITH the requests that could not be filled in a descending order to determine the most popular flower requested.
- Task five: Create a chart to show this information about the most popular orders/requests.
- Task six: Based on this information, create a presentation slide with a picture of the most popular flower, the number of orders expected for the upcoming year, the selling price from last year and an expected selling price for this year which includes a 10% increase over the cost for last year.

(Source: ICT Working Group)

Discrete Item Sets

Constructed and Selected Response

Context: ICT

Topic: Web search

Section 2 PISA-ICT Literacy Assessment Time: 29:02

DIRECTIONS:

You have searched the Internet for general information about treating bee stings and found the sites shown.

Pick one site that you think has reliable information about treating bee stings. Type the letter of that site (A-J) in the box below.

Explain why you chose this site.
Type your answer below.

WebSearch [Advance Tools](#) [Preferences](#) [Language Tools](#)

A. [Bee Venom Therapy \(Bee Stings\) | AHealthyMe.com](#)
Find out whether subjecting yourself to **bee stings** can help ease the pain...
bee venom to successfully **treat** rheumatoid arthritis
[www.ahealthy.me.com/topic/bee venom](#) - 49k - [Cached](#) - [Similar pages](#)

B. [Families for Natural Living](#)
... Have treatment brought to them. ... When I was a child, my mother always ...
bee stings and other venomous. ...
[familiesfornaturaliving.org/herbs/summerrem.htm](#) - 16k - [Cached](#) - [Similar pages](#)

C. [Great for Bee Stings ...](#)
Nova Skin Rash Complex is Great for Poison Ivy, Poison Oak, Hives, **Bee Stings**, and Insect Bites. ... diagnosing or **treating** a health problem or disease
[www.painpharm.com/mall/n_prod_skinrash.asp](#) - 41k - [Cached](#) - [Similar pages](#)

D. [MEDLINEplus Medical Encyclopedia: Insect bites or stings](#)
... develop severe allergic reactions (anaphylaxis) to insect **stings**. ... the **sting** is from a honey **bee**, remove the stinger ... **treat** the victim...
[www.nlm.nih.gov/medlineplus/ency/article/000033.htm](#) - 43k - [Cached](#) - [Similar pages](#)

E. [Treating Bee Stings - DrGreene.com - caring for the next...](#)
... was swollen. Is this serious? How do you **treat bee stings**? What insect repellents work the best at preventing them? California. **Bee** ...
[www.drgreene.com/21_202.html](#) - 49k - [Cached](#) - [Similar pages](#)

(Source: Feasibility Study for the PISA ICT Literacy Assessment)

CHAPTER FOUR: OVERVIEW OF THE ASSESSMENT DESIGN

Introduction

This chapter provides an overview of the major components of the assessment design. It begins with a brief description of the 2012 NAEP Technological Literacy assessment and a discussion of the types of assessment tasks and items, how they can be used to reveal student understanding and skills, how students will respond to these tasks, and how their responses will be monitored and measured. In addition, this chapter describes how the assessment should be balanced across the major assessment areas in technological literacy and across technological practices. The types of items to be included in the assessment are described and examples are provided. Consideration is given to Universal Design for assessment and for English language learners and students with disabilities.

Overview of the Technological Literacy Assessment

In 2012, a probe will be conducted at one or more grade levels for NAEP Technological Literacy. The assessment will include tasks and items sampled from the domain of technological literacy achievement identified by the intersection of the three major areas of technological literacy and the technological practices at grades 4, 8, and 12. The assessment will be administered by computer and will be composed of sets of long scenarios, short scenarios, and discrete items. Students will be asked to respond to selected-response items and to short and extended constructed-response items. Student responses will be measured both directly and through their interactions with simulated tools and their manipulation of components of systems in the scenario-based tasks.

Types of Tasks and Items

Allowing students to demonstrate the wide range of knowledge and abilities expressed in the technological literacy assessment targets requires a departure from the typical assessment designs used in other NAEP content areas. To show those competencies, students will need to perform a variety of actions using diverse tools to solve problems and meet goals within rich, complex scenarios that reflect realistic situations. Consequently, this assessment will rely primarily on scenario-based assessment sets that test students through their interaction with multimedia tasks that not only present conventional item types such as selected response items but also monitor student actions as they manipulate components of the systems and models that are presented to them. The following sections describe in detail the scenario-based assessment sets and the sets of discrete, conventional items that will be developed for the technological literacy assessment.

The assessment will be administered to a nationally representative sample of students to allow inferences about the level of performance at the group level. The assessment is not designed to provide reliable estimates of performance for any individual student or school. To obtain reliable estimates across the population that is tested, a large pool of assessment items will be developed. That pool of items will be too large to give to every individual student, so sets of items will be

grouped together to administer to individual students. Testing of an individual will occur in two 25-minute blocks. The assessment sets that will be developed for the technological literacy assessment are described below.

Scenario-Based Assessment Sets

There will be two types of scenario-based assessment sets, one long and one short. The long scenarios will take students 25 minutes, the length of one test block. The short scenarios will take students about 12-15 minutes to respond, or about half the length of a test block. The two types of scenarios have common characteristics, but they differ in the complexity of the scenario and the number of assessment tasks and items to which a student is asked to respond. Long scenarios will allow for about 10-15 measures of performance, while short scenarios will capture approximately 5-10 measures as students work through them.

Discrete Item Sets

One of the challenges for the assessment is that the use of scenario-based assessment sets reduces the number of independent measures in the assessment as a whole. By representing complex, real-world tasks, the scenarios bring greater validity to the assessment as a whole because of their complexity and the longer time that students spend on the tasks, but at the same time the use of these complex tasks reduces the number of measures that can be included in any one test and also causes many of the measures to be interdependent because they are related to the same scenario. To counteract this and maintain a balance of measures that produce acceptable levels of reliability, the assessment of technological literacy will also include sets of discrete items that produce independent measures. Discrete item sets will include conventional selected-response items and short constructed-response items.

Definitions of the Scenario-Based and Discrete Item Assessment Sets

Scenario-Based Assessment Sets

At the time of writing the Framework, the use of computer-based scenarios for assessment purposes is an emerging, but growing area. The 2009 NAEP Science Framework called for the use of interactive computer tasks as part of that assessment, and in 2009 three long and six short interactive tasks were administered to national samples of students in grades 4, 8 and 12. The results have been encouraging. Another set of interactive assessment tasks has been used in the Minnesota state tests of science achievement, and a large scale pilot test will be conducted in three states, Nevada, Utah, and North Carolina, in an Enhanced Assessment Grant project funded by the U.S. Department of Education to determine how simulation-based scenarios in science might form part of district and state accountability systems. As assessment developers gain more experience in this emerging field, they will develop a better sense of how to create the tasks efficiently and how to ensure that the tests produce valid and reliable measures. Following is a descriptive outline of the main features of the scenarios that will be developed for the technological literacy assessment. Examples are described, and an accompanying DVD contains narrated movie files that demonstrate the main features of the scenario-based tasks that are required for this assessment. [NOTE: We will select an appropriate scenario-based assessment

and will record a typical student interaction in the key tasks in that assessment. Then we will edit those segments in a movie file with a voice-over that explains the actions that are seen on-screen. WestEd has successfully used this approach to demonstrate features of its own simulation-based assessments for middle school science.]

At the beginning of the scenario, it is important to set the context for the activities in which the student will be involved. This introduction provides a setting for the assessment tasks that, as far as possible, should mimic tasks that might be performed in the real-world, either within an academic setting or outside of school. Also, near the start of the scenario, a motivating need will be introduced. This need is the driving rationale for the tasks that the student will perform, and it provides a storyline that helps define the relevance and coherence of the tasks and that offers a motivation for the student to undertake them. The motivating need might be to solve a particular problem or to achieve a certain goal within the scenario.

A characteristic of these scenarios is that they use appropriate multimedia to form the settings for the assessment tasks. This can include video segments or animations to be observed, and it will generally also use text, numbers, and graphics to convey information necessary for the tasks to be accomplished. All the representations are carefully chosen to serve a purpose in the assessment tasks, and none is present simply for visual interest.

A central part of many assessment scenarios will be the representation of a system. Depending on the context for the particular scenario, this might be an engineering system such as [NOTE: include an example from something developed by the committee], or a [NOTE: include another example]. Whatever the system, it will have components that are dynamically related, so that a student can observe the role of a particular component (e.g., watch what happens when a valve is opened in an irrigation system) or interact with a component (e.g., by setting a value for a parameter or moving an object to a particular part of the system) and see a resulting change of state in the system (e.g., a rise in temperature or a movement of a robot). A second type of scenario will lay out an overarching goal or problem which students will reach or solve by conducting various interrelated tasks. [NOTE: include ICT example]

Within a scenario, a student may be asked to select tools from a toolkit and use them within the system. They might be asked, for example, to select a [NOTE: insert example] or to use a [NOTE: insert example] to [NOTE: insert example]. A range of tools might be made available depending on the scenario. For example, word-processing, texting, or presentation tools might be available for communication tasks. Web design or page layout tools might be used for the presentation of large amounts of information. For some scenarios it might be appropriate to provide more specialized tools, such as computer-aided design, geographical information systems, or video editing tools.

By interacting with the components of the system or task that are key elements for achieving the goal, students may respond to tasks that ask them to explore alternative outcomes, control certain variables, and observe the resulting changes in the system. Then students can observe and describe the patterns or characteristics of the outcomes and can interpret the feedback from the system. They can then evaluate the outcomes of the choices they made in manipulating the components of the system or using particular tools, and, finally, they can form conclusions. It

might be necessary to simulate virtual versions of real-world equipment that can be used within the scenario. For example, an anemometer might be used to measure wind speed in a scenario about wind turbines, or a temperature probe might be used in an agricultural scenario requiring the measurement of temperature in a compost bin. Alternatively, graphics or images might be constructed or selected to communicate a design or idea. In providing tools in a scenario, it is necessary to determine which elements of a tool are necessary for the activities in the scenario and which features of the tool will be used by students. It is not necessary to provide or simulate a fully featured version of a tool. For example, only certain functions of a spreadsheet tool might be provided so that a student could take a table of data resulting from actions in the system and transform it into a graphical representation of his or her choice (a line graph, say, or a bar graph or pie chart). It would not be necessary to provide all the other features of the spreadsheet tool, and, in fact, it would be distracting to students and produce measurement “noise.”

Throughout their interaction with a system, students may be asked to use tools to find relevant resources; communicate to others about their actions, decisions, or results (e.g., texting a virtual team member); or, at the end, convey their conclusions (e.g., creating a slideshow presentation).

Discrete Item Sets

The discrete item sets will comprise approximately 10-15 standalone items for 25-minute blocks. These items would not be part of a complex scenario or related to one another. Each discrete item provides a stimulus that presents enough information to answer the particular question posed in the stem of the item. Items in discrete sets will be selected-response items (e.g., multiple-choice) or short constructed-response items in which a student writes a text-based response.

Descriptions of the Response Types Used in the Assessment Sets

In conventional items on previous NAEP assessments, students have responded either by selecting the correct response from among a number of choices or else by writing a short or long text-based response to the questions posed. In the technological literacy computer-based assessment that includes scenario-based assessment sets, there are opportunities to greatly extend the ways in which a student can respond during an assessment task. As a result, the old ways of describing response types as, for example, multiple-choice or written-response, is too limiting, and new ways of thinking about response types need to be defined. In this assessment, three response types are used: selected-response, short constructed-response, and long constructed-response. Although the names of the response types are commonly used in other NAEP assessment frameworks, in the context of the Technological Literacy assessment they have a more expanded meaning. These meanings are defined in the following sections.

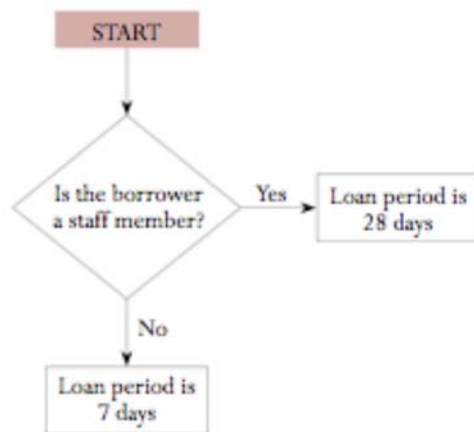
Constructed Response

Constructed responses are ones in which the student “constructs” the response rather than choosing a response from a limited choice of alternatives, as is the case with selected-response items. Constructed responses in the Technological Literacy assessment will include short constructed-response tasks and items as well as extended constructed-response tasks and items. These are described in detail in the following sections.

Short Constructed Response

Short constructed responses might be used in either the discrete-item assessment sets or in the short scenario-based assessment sets. They generally require students to do such things as supply the correct word, phrase, or quantitative relationship in response to the question given in the item, to identify components or draw an arrow showing causal relationships, to illustrate with a brief example, or to write a concise explanation for a given situation or result. Thus, students must generate the relevant information rather than simply recognizing the correct answer from a set of given choices, as in selected-response items. When used as part of a discrete item set, all of the background information needed to respond is contained within the stimulus material. The following is an example of a short constructed-response item that might be used in a discrete item set.

The John Hobson High School library has a simple system for lending books: for staff members the loan period is 28 days and for students the loan period is 7 days. The following is a decision tree diagram showing this simple system:



The **Greenwood High School** library has a similar, but more complicated, lending system:

- All publications classified as “Reserved” have a loan period of 2 days.
- For books (not including magazines) that are **not** on the reserved list, the loan period is 28 days for staff, and 14 days for students.
- For magazines that are **not** on the reserved list, the loan period is 7 days for everyone.
- Persons with any overdue items are not allowed to borrow anything.

LIBRARY SYSTEM – Question 2

Develop a decision tree diagram for the **Greenwood High School Library** system so that an automated checking system can be designed to deal with book and magazine loans at the library. Your checking system should be as efficient as possible (i.e. it should have the least number of checking steps). Note that each checking step should have only **two** outcomes and the outcomes should be labelled appropriately (e.g. “Yes” and “No”).



(Source: PISA 2003, Note: Alternative task may be used.)

Extended Constructed Response

Extended constructed responses will be used in the long scenario-based assessment sets. In a scenario-based assessment set, the real-world scenario is built upon as the student moves through the assessment set. As previously described, opening screens for the scenario will provide context and motivation for the tasks in the assessment set. As the scenario builds, the student will undertake tasks that might involve constructing a response using several methods. For example, a student might be asked to enter a search term to gather information about a historical period and to request information from virtual team members. Students could vary the size of populations to test a model of a city’s transportation system. A student might be asked to construct a wind turbine from a set of virtual components in which there are several combinations of turbine blades and generators. Additional measures of the student’s response can be made by capturing data about which combinations of components they selected, whether they covered all possible combinations, and what data they chose to record from their tests of the components. A follow-on task might ask the student to then select different types of graphic representations for the tabulated data they captured, and their selection of an appropriate type of graph would be informative about how they use data analysis tools. Finally, they could be asked to interpret their data, make a recommendation for the best combination of turbine blade and generator, and justify their choice in a short written (typed) response. In this way, both the task and the response are extended. Thus, unlike short constructed-response items in which all the information to answer a particular task is contained in a single stimulus, the information necessary to answer an extended constructed response is contained in several parts of the overall task. In this example, it would not be possible for a student to make recommendations about

which combination of blades and generators is best without having done all parts of the previous tasks.

Designing extended constructed-response tasks presents certain challenges. Enough information must be provided in the scenario to allow for the student to perform well-defined, meaningful tasks that yield measurable evidence that the student possesses the knowledge and skills defined in the assessment targets. Another challenge is to ensure that the dependencies among the tasks that a student performs within an extended response are minimized. For example, in the wind turbine example described above, a student could run tests of combinations of certain turbine blades and generators, and the responses could be assessed. Then, the student could be given data from another set of tests of different blades and generators that someone else did and asked to interpret those data. In this way the dependency between the student's own data gathering and the data analysis stage is minimized. Thus mistakes or deficiencies in the first part of the task are not carried forward into the second task, thereby giving all students the same opportunity to show their data analysis skills, regardless of how well they did on the first task.

Scenario: Creating a Slide

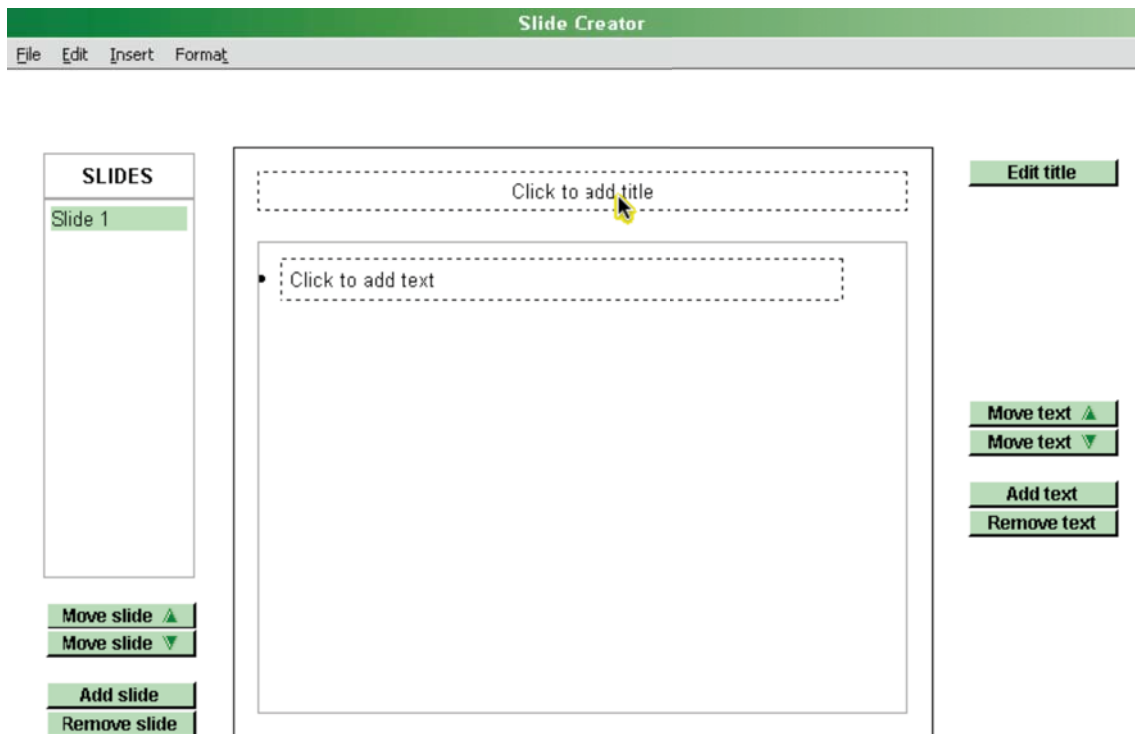
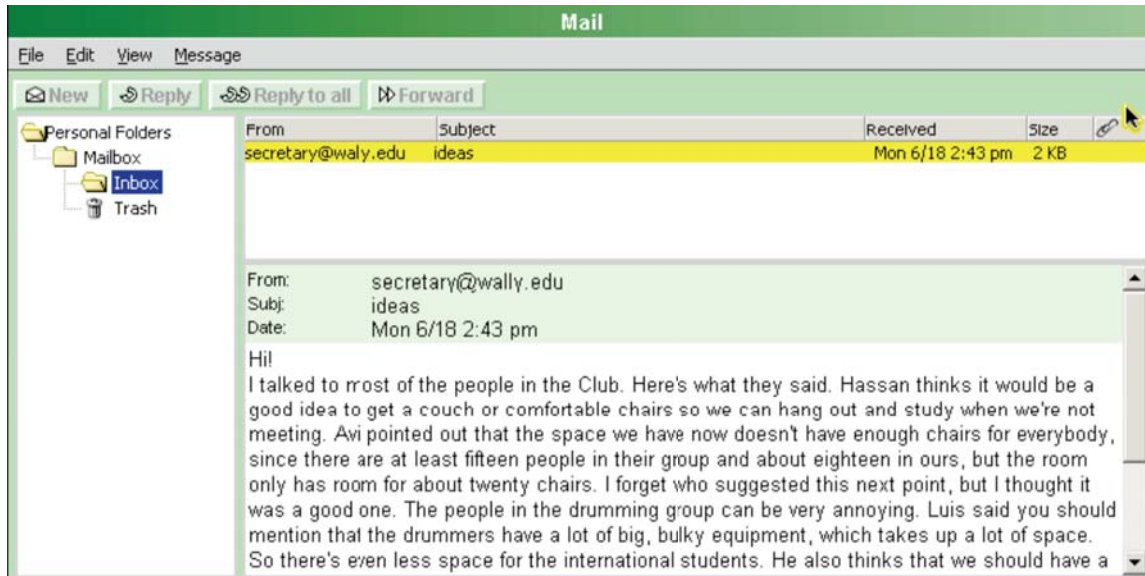
International Student Club



You are president of the International Student Club, which shares meeting space with the Drummers' Club. Because both clubs have good reasons for using the space on Monday, Tuesday and Thursday afternoons, your club meetings have become crowded and noisy. Your club has asked you to talk with the faculty advisor about getting a new room for your meetings. The club secretary has sent you an email containing suggestions from different club members, and now you need to prepare a slide that makes your case for a new meeting room in a clear and persuasive set of bullets.

Task:

- Using the email as the source for your points, create a single persuasive slide to use in your discussion with the faculty advisor.
- Format your slide appropriately, using the fonts and text styles provided in the slide creator.
- To sequence bulleted text in a slide, select the bulleted text that you want to reorder and use the up or down buttons to move it. To delete a bullet point, select the bulleted text that you want to delete and click on "Remove text."





(Source: ETS iSkills)

Extended responses can provide particularly useful insight into students' levels of conceptual understanding and reasoning. They can also be used to probe a student's capability to analyze a situation and choose and carry out a plan to address that situation, and to interpret the student's response. Students may also be given an opportunity to explain their responses, their reasoning processes, or their approaches to the problem situation. They can also be asked to communicate about the outcomes of their approach to the situation. Care must be taken, however, particularly with fourth graders and English language learners, that language capability is not confounded with technological literacy.

Selected Response

As the name implies, selected-response items are ones in which students read a question and are presented with a set of responses from which they choose the best answer. In other NAEP assessments, selected-response items most often take a multiple-choice format. In multiple-choice items, students select an answer from, say, four options provided. The choices include the most applicable response—the "answer"—as well as three "distractors." The distractors should appear plausible to students but should not be justifiable as a correct response; and, when feasible, the distractors should also draw from current understanding about students' mental models in the content area. The Technological Literacy assessment will include such multiple-choice items both within the scenario-based and the discrete-item assessment sets. An example of a selected-response item that might form part of a discrete assessment set is shown below.

2006, Science and Technology/Engineering - Grade 8

Question 17: Multiple-Choice

Reporting Category: Technology/Engineering

Standard: Engineering Design - 2.6

The picture below shows an iron.



When considering an iron as an example of a system, what is the input?

- ✓ A. electricity
- B. temperature
- C. motion on clothes
- D. steam from the plate

State Average = 78%

(Source: MCAS)

In addition to the conventional multiple-choice selected items, the scenario-based sets in the Technological Literacy assessment will include a broad range of selected-response items. The computer-based nature of the scenarios will allow other types of student selections to be measured. For example, a student might be given a task to perform and asked to select an individual tool from a set of virtual tools. When a student selects a tool by clicking on it, it is a measurable response that is, in essence, a selected response. A selected response in such a scenario might have fewer choices than in a conventional multiple-choice item. For example, a student might select between two alternatives, such as deciding whether a switch in a circuit should be open or closed to produce a particular outcome, but the student would also have to justify the selection. The first part of this example response is a selected-response, although it might be necessary to score the two parts of the item together so that the selection and justification together is what determines the score. In complex, real-world scenarios, it might be that there is not a “correct” selection, and in that case what matters is that the selection is

justified adequately. An example of a selected response item that might form part of a scenario-based assessment set is shown below.

Park rangers noticed the problem because they've been estimating the number of hares in the area for the last four years. Here's what they found. Last year, 2002, there were about 95,000 hares. The year before that, 2001, there were about 80,000. In 2000, there were 25,000. And in 1999, there were only about 1,000 hares.

Your task is to organize the data to see if there is a trend.

Pick a tool to use:

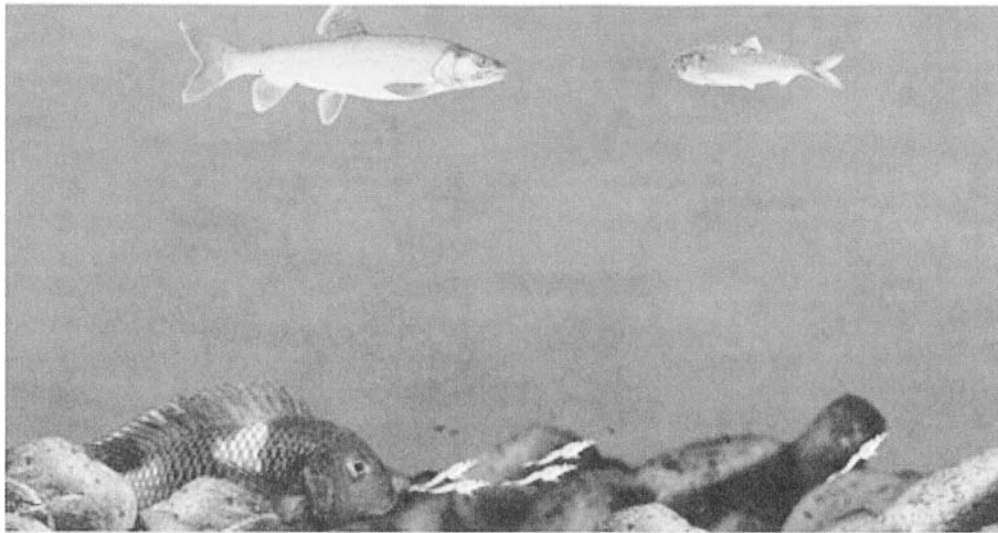
Word processor

Spreadsheet

Presentation

(Source: Quellmalz, E.S. & Kozma, R. (2004). Coordinated, Innovative Designs for International Information Communication Technology Assessment in Science and Mathematics Education: Final Report. Menlo Park, CA: SRI International, Center for Technology in Learning)

Other selected-response types within a scenario-based assessment set might include a task in which a student selects all options that apply from a set of choices. Again, in a real-world situation there might be one 'best' combination of choices but also one or more other combinations that are partially correct. In such a situation, it makes sense to use a scoring rubric that rewards different combinations of selected-response items with different scores.

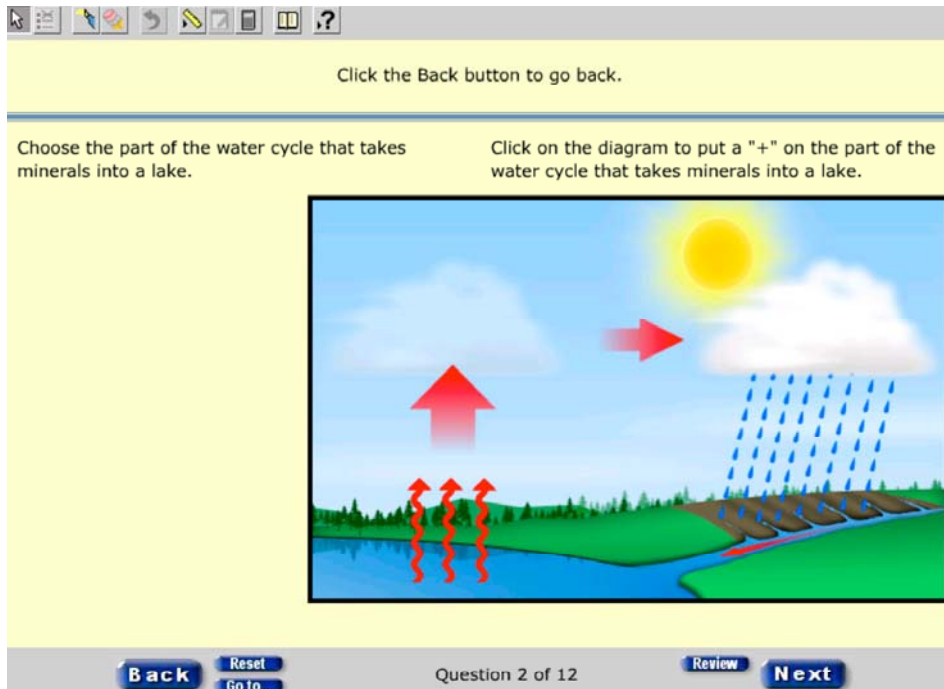


Select the organisms that are consumers.



(Source: *Using Science Simulations to Support Powerful Formative Assessments of Complex Science Learning*. Quellmalz, Timms, & Buckley, 2009 AERA presentation)

Another form of selected response is a “hot spot” whereby a student can click on a spot on an image such as a map, picture, or diagram.



This item asks students to identify the part of the water cycle that takes minerals into a lake. A similar item on the NAEP Technological Literacy assessment might ask students to identify a source of pollution in a water supply system.

(Source: Minnesota Comprehensive Assessment - II)

Ways of Measuring Student Responses

The computer-based administration of the scenario-based assessments combined with the broad range of selected and constructed responses possible with this approach will provide many opportunities to measure students' abilities as defined in the assessment targets. The range of measures will be greater than those generated in a typical NAEP assessment in other subjects, and so it is necessary to describe how these measures might be handled. It is helpful to think of the measures as falling into two categories: student direct responses and pattern-tracking measures that are based on student interactions with the tools and systems portrayed in the scenarios.

Conventional items always involve the student in a *direct response*. For example, after being presented with information in a diagram, a text-based question is posed to the student, and then the student selects the best answer from a limited set of choices. Student direct responses can also be used in scenarios. For example, an assessment task in the scenario may have asked the student to set two different values for a component of the system and observe what happens. The student direct response comes when, after the interaction with the system, the student is asked, for example, to compare and contrast the two outcomes and explain in a short written response

why they happened as they did. What makes this a student direct response is that, although the student interacted with the system, none of that interaction was captured for measurement purposes. Only the written observation and explanation are to be assessed. One type of student direct response is selection from a set of choices—e.g., multiple-choice, check the boxes for all that apply, or, in a scenario-based assessment, select an object or choose a tool for the task. Other types of direct response include providing a written analysis of a set of results and writing a short explanation of why a selection was made in a scenario.

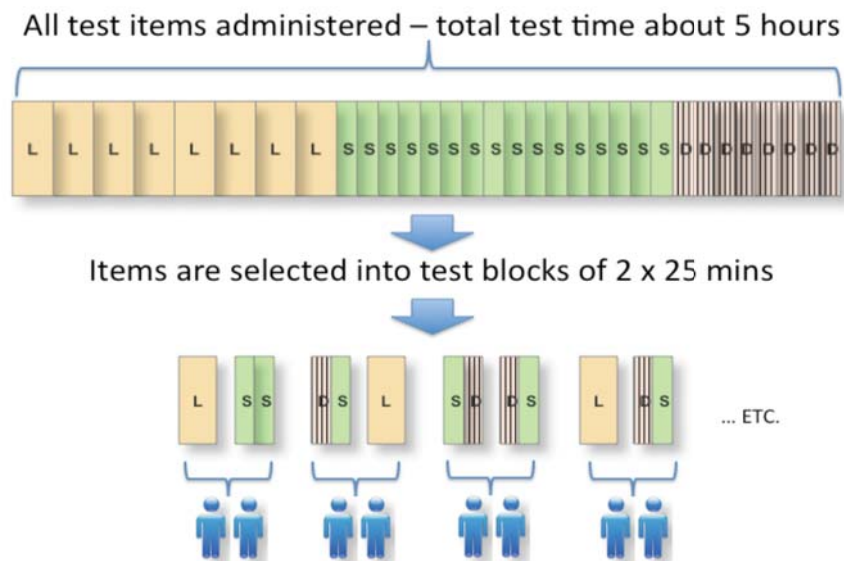
By contrast, in *pattern-tracking measures* the interactions that the student engaged in may provide relevant evidence that the student possesses a skill that is an assessment target and should, therefore, be captured, measured, and interpreted. For example, a student may have been asked to determine [insert example here]. In responding to that task, the student’s manipulation of the components of the system shows [insert example here]. So the things that the student chose to manipulate, how the student manipulated them, and how long it took might all be measured and interpreted in combination in order to provide a judgment that indicates if the student possesses a particular skill that is important in the assessment target. One type of pattern-tracking measure is the observation of patterns of action—for example, capturing a sequence of actions taken to determine if the correct set of actions was taken and if the actions were executed in the optimal order. Another pattern-tracking measure is tracking the manipulations that the student performs in a scenario. How, for instance, how did the student change the properties of an object (e.g., enlarging a font size to make a clearer presentation in a slideshow) or vary the parameters that control a component of a system (e.g., changing the speed of rotation in a model of a wind turbine) or transform an object from one form into another (e.g., transforming search results into a presentation slide)? Pattern-tracking measures might be used to assess certain aspects of communication or collaboration skills. For example, measuring the number of times a student communicates with virtual team members in a team task and the length of those communications can provide a measure of how collaborative the student is.

Balance of the Assessment

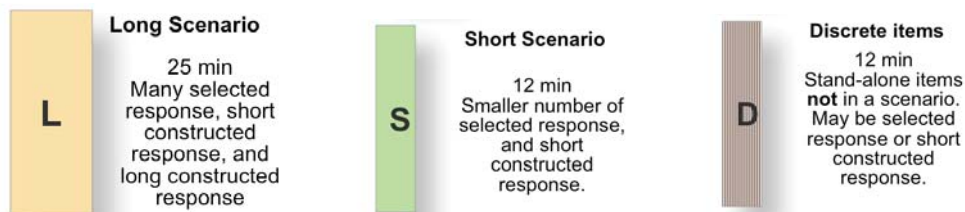
To ensure an appropriate distribution of the test time, it is important to balance the different components of the assessment. This section discusses how this can be done. Note that “total test time” refers to the length of time spent administering all available assessment blocks (see figure 4.1), which is the equivalent of about 5 hours of test time. Many students will be in the sample population during each administration, but each of these students will spend only 50 minutes on the assessment tasks, so there must be a plan for distributing each assessment block to many students. Figure 4.1 also shows a simple example of how assessment types might be grouped together.

Figure 4.1 Diagram of how the total test time might be balanced.

[NOTE: The artwork is not final art]



Legend:



This section discusses four separate types of assessment balance that should be considered in determining an overall balance:

- Balance by Technological Practice
 - Identifying and Applying Technological Principles
 - Using Technological Processes and Tools to Solve Problems
 - Communicating and Collaborating
- Balance by Major Assessment Area
 - Technology and Society
 - Design and Systems
 - Information and Communication Technology

- Balance by Assessment Set Type
 - Long scenarios
 - Short scenarios
 - Discrete items sets
- Balance by Response Type
 - Selected response
 - Short constructed response
 - Extended constructed response

The balance required at each grade level is specified in the following sections as a percentage of the total test time. In other words, the percentage expresses what proportion of the total amount of testing time—as represented in the total item pool shown at the top of the diagram in Figure 4.1—is to be included. Since a student is assigned a group of item sets as shown in Figure 4.1, the percentages do not necessarily represent the balance in any one student’s test session.

Assessment Balance by Technological Practice

The balance of the assessment by technological practices across the three grades levels is shown in Table 4.1. At all grades the balance of total test time is as follows:

- Identifying and applying technological principles – 30%
- Using technological processes and tools to solve problems – 40%
- Communicating and collaborating and about technological issues – 30%

The rationale for a slight emphasis on the practice of using technological processes and tools to solve problems is that it is important for students to be able to use their knowledge of technological principles in solving problems.

Table 4.1 Assessment Balance by Technological Practices and Grades

Technological Practices	Grade 4 (% total test time)	Grade 8 (% total test time)	Grade 12 (% total test time)
Identifying and applying technological principles	30	30	30
Using technological processes and tools to solve problems	40	40	40
Collaborating and communicating about technological issues	30	30	30

Assessment Balance by Major Assessment Area

Table 4.2 shows the balance by major assessment area at each of the three grade levels. At fourth grade there is an emphasis on ICTs because the focus of technological literacy instruction at that grade is on using common information and communication technologies. At eighth grade the balance is weighted to design and systems because in middle school there is more emphasis on systems, and there is slightly less time spent on ICTs than in the early grades. At twelfth grade the balance is slightly weighted to design and systems and to the ICT.

Table 4.2 Assessment Balance by Major Assessment Areas and Grades

Major Assessment Areas	Grade 4 (% total test time)	Grade 8 (% total test time)	Grade 12 (% total test time)
Technology and Society	25	25	30
Design and Systems	30	40	35
Information and Communication Technology (ICT)	45	35	35

Assessment Balance by Set Type

In addition to ensuring a balance across the content of the assessment, Table 4.3 specifies how the total amount of testing time should be balanced across the three types of assessment set—long scenario, short scenario, and discrete item sets.

Table 4.3 Assessment Balance by Set Types and Grades

Set Type	Grade 4 (% total test time)	Grade 8 (% total test time)	Grade 12 (% total test time)
Long Scenarios (25 mins)	40	40	40
Short Scenarios (12-15 mins)	40	40	40
Discrete items	20	20	20

Assessment Balance by Response Type

Table 4.4 specifies the balance of assessment response types across the total testing time. [NOTE: The following table is included for illustration of how the table would appear, but there are no percentages specified. The members of the planning committee asked for additional information to be provided about the different assessment response types before they could make a decision]

Table 4.4 Assessment Balance by Response Types and Grades

Response Types	Grade 4 (% total test time)	Grade 8 (% total test time)	Grade 12 (% total test time)
Selected response	—	—	—
Short constructed response	—	—	—
Extended constructed response	—	—	—

Universal Design for Assessment

[Section to be developed]

Students with Disabilities and English Language Learners

[NOTE: the following text is taken from the NAEP 2009 Science Assessment Framework and is included here to illustrate the content that will be developed that is similar, but specific to the Technological Literacy domain]

As national and state testing increases, so does the demand that assessment systems include all students—for example, those with disabilities and those learning English—many of whom have not been included in these systems in the past. As NAEP looks to measure the educational progress of students in the nation’s classrooms, assessment developers will encounter challenges that require giving deeper thought and consideration to the development of items providing as fair a context as possible for all students.

NAEP should strive to develop Technological Literacy assessments that allow for the participation of the widest possible range of students, so that interpretation of scores of all who participate leads to valid inferences about the levels of their performance, as well as valid comparisons across states and with state assessments. Students should have the opportunity to

demonstrate their knowledge of the concepts and ideas that the NAEP Technological Literacy assessment is intended to measure.

According to the National Research Council:

Fairness, like validity, cannot be properly addressed as an afterthought once the test has been developed, administered, and used. It must be confronted throughout the interconnected phases of the testing process, from test design and development to administration, scoring, interpretation, and use (1999b, pp. 80-81).

When assessments are first conceptualized, they need to be thought of in the context of the entire population that will be assessed (American Educational Research Association, American Psychological Association, & National Council on Measurement in Education, 1999; NRC, 1999a; Thompson, Johnstone, & Thurlow, 2002). NAEP assessments, as well as all large-scale assessments today, need to be responsive to growing demands: increased diversity, increased inclusion of all types of students in the general curriculum, and increased emphasis and commitment to serve and be accountable for *all* students. Assessments need to measure the performance of students with a wide range of abilities and skill repertoires, ensuring that students with diverse learning needs receive opportunities to demonstrate competence on the same content.

Students with disabilities and English language learners each present challenges in how their knowledge and skills can be assessed validly. Nevertheless, there are some commonalities, not the least of which is considerable heterogeneity within each of these groups as to assessment needs. In addition:

- Conceptual frameworks based on appropriate theories of language development and proficiency and of various forms of disabilities will be needed to build inclusive assessments.
- Financial and human resources will be needed over what is usually allocated in order to develop, administer, and interpret performance on relevant tasks.

Two general recommendations address both groups in the context of good assessment design for all students: readability of written text and alignment to content statements.

Students' capability to read and respond to written text often determines successful performance on assessments. Assessment items may pose an unfair disadvantage for some students if there is a heavy burden on reading skills when reading is not the target of the assessment. Language that is both straightforward and concise and that uses everyday words to convey meaning is needed. The goal of ensuring that language has these characteristics is to improve the comprehensibility of written text while preserving the essence of its meaning. The use of language that reduces the linguistic demands placed on students reduces the effect of reading skills and language proficiency on students' science performance and assessment scores. More information on reading level is provided in the *Specifications*.

Items on the NAEP Technological Literacy assessment must be aligned to the technological

practices and areas of technological literacy with the same depth and breadth of coverage and the same cognitive demands as specified in the *Framework*. The emphasis in assessment design should be on accessibility using different formats, technologies, designs, and accommodations to include as many students as possible. It must be clear from the beginning that, to be equitable, assessments need to measure the achievement of all students on the same content and achievement standards.

To these ends, field tests should sample every type of student expected to participate in the final assessment administration, including students with a wide range of disabilities, English language learners, and students across racial, ethnic, and socio-economic lines. Field-testing NAEP items with a broad range of students will not only help determine whether items are unclear, misleading, or inaccessible for certain groups of students, but will also help ensure that assessment procedures are accessible to students when the NAEP Technological Literacy assessment is fully implemented. Further detail on both recommendations can be found in the *Specifications*.

NAEP strives to assess all students selected by its sampling process. Rigorous criteria are applied to minimize the number of English language learners and students with disabilities excluded from NAEP assessments. Participating students with special needs are permitted to use accommodations, as stated in current NAEP policy:

All special-needs students may use the same accommodations in NAEP assessments that they use in their usual classroom testing unless the accommodation would make it impossible to measure the ability, skill, or proficiency being assessed, or the accommodation is not possible for the NAEP program to administer (NCES, 2005a, Current Policy section, ¶ 4).

For more detail on NAEP's inclusion policy and permitted accommodations, see the *Specifications*.

CHAPTER FIVE: REPORTING THE RESULTS OF THE ASSESSMENT

To be developed.

APPENDICES

Appendix A: Steering Committee Guidelines

To be developed.

Appendix B: Alignment Table – Comparing the Framework to Source Documents

To be developed.

Appendix C: Alignment Table – Comparing ICT Sub-Areas to ISTE NETS

To be developed.

Appendix D: NAEP Technological Literacy Preliminary Achievement Level Descriptions

To be developed.

Appendix E: Sample Items and Scoring Guides

To be developed.

Appendix F: Public Forums and Outreach Events

To be developed.

Appendix G: Bibliography

To be developed.

Appendix H: Glossary

To be developed.

Assessment Development Committee

Tentative Item Review Schedule

May – November 2009

(Updated 7/27/09)

Review Package to Board	Board Comments to NCES	Background/ Cognitive	Review Task	Approx Number Items	Status
February 25	March 13	Background	2011 Pilot Student, Teacher and School Questionnaire Components for Writing, (4,8,12)	180	√
May 1	May 22	Background	2010 Operational Student, Teacher and School Questionnaire Components for U.S. History, (4,8,12)	170	√
May 6	May 22	Background	2010 Operational Student, Teacher and School Questionnaire Components for Civics (4,8,12)	170	√
May 6	May 22	Background	2010 Operational Student, Teacher and School Questionnaire Components for Geography (4,8,12)	170	√
May 6	May 22	Cognitive	2011 Pilot Writing (8,12) (prompts presented on paper)	70 prompts	√
July 7	July 22	Cognitive	2011 Pilot Writing (4)	46 Prompts	√
July 16	August 14	Cognitive	2010 Operational Geography (4,8,12)	112 items (7 blocks)	√
July 16	August 11	Cognitive	2010 Operational U.S. History (4,8,12)	119 items (7 blocks)	Review at Aug. 6 ADC Meeting
July 30	August 10	Cognitive	2011 Pilot Writing (8,12) (fully-programmed prompts in delivery system)	70 prompts	Review at Aug. 6 ADC Meeting
July 22	August 14	Cognitive	2010 Operational Civics (4,8,12)	109 items (6 blocks)	Review during week of Aug. 10
October 13	November 4	Cognitive	2013 Pilot Reading Passages (4,8)	15 passages	

√ Item review completed

Accessible Booklet Study – Phase II

The NAEP Validity Studies (NVS) Panel and other groups have been interested in methods to improve measurement at the lower end of the National Assessment of Educational Progress (NAEP) scale. To address this issue, “accessible blocks” were developed by adapting existing NAEP blocks. The accessible blocks were made up of items that were designed to be fully aligned with the objectives of the NAEP Framework, but with cognitive targets appropriate for a lower scoring population and all construct-irrelevant sources of difficulty removed.

In phase I of this study, accessible blocks were developed for a 2008 pilot test with 4th grade mathematics and 4th grade reading. The results for the accessible mathematics blocks showed that the items were in fact more accessible to the students, while the results for the accessible reading blocks were mixed.

In phase II, the researchers are benefiting from the lessons of phase I to develop additional accessible blocks that can be pilot tested with larger samples. The pilot tests (in 2010 for mathematics and 2011 for reading) will be designed to allow the accessible blocks to be scaled with standard NAEP blocks, thereby providing a more rigorous test of the shift in difficulty achieved with the modified blocks, as well as testing the hypothesis that the modified blocks assess the same construct as the regular blocks.

Item modification guidelines, which were developed by the mathematics team in phase I, will be applied in both subject areas in phase II. In addition, in order to construct accessible reading blocks, the researchers have concluded that it is necessary to begin the development process with shorter reading passages (approximately 300 – 500 words) than those typically found in recent NAEP assessments (about 800 – 1000 words). Simply adjusting the item will not increase the accessibility of the item.

In order to identify candidate reading passages of the appropriate length, the researchers will review grade 4 operational passages as well as those that were previously submitted to NAGB for use in item development, but not approved. The goal of the meeting will be to review the latter passages for use in the accessible booklet study. NCES is seeking support from the ADC committee for this purpose.

Steps in the item development process include:

- Applying item modification guidelines,
- Validating content through expert item review, and
- Conducting cognitive labs

Tentative Schedule:

	Mathematics	Reading
Item development and review	11/08-6/09 (completed)	10/09-6/10
Pilot test	1/10-3/10	1/11-3/11
Analysis of pilot test data	4/10-5/10	4/11-5/11

