Technology and Engineering Literacy Assessment and Item Specifications for the 2014 National Assessment of Educational Progress

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CHAPTER ONE: OVERVIEW

Need for a Framework and Assessment Specifications in Technology and Engineering Literacy

To what extent can young people analyze the pros and cons of a proposal to develop a new source of energy? Construct and test a model or prototype? Use the Internet to find and summarize data and information in order to solve a problem or achieve a goal?

The exploding growth in the world of technology and the need to answer questions similar to those above led the National Assessment Governing Board (Governing Board) to sponsor the development of a framework and specifications for a national assessment of technology and engineering literacy. For generations students have been taught about technology and have been instructed in the use of various technological devices, but there has been no way to know exactly what students understand about technologies and their effective use.

As the framework and specifications were being developed, it became clear that the terms “technology,” “engineering,” “information communication technology,” “21st century skills,” and “literacy” are defined and used in significantly different ways in formal and informal education, in standards, by professional organizations, and in legislation. Therefore, the development committees recommended a change of the framework and specifications titles from “technological literacy” to “technology and engineering literacy” to encompass general literacy about the use, effects, and designing of technologies. The 2014 NAEP Technology and Engineering Framework and Assessment Specifications is a statement about what should be expected of students in terms of their knowledge and skills with technology, written to be the basis for an assessment of technology and engineering literacy appropriate for all students. It opens the door to seeing what our K-12 students know about technology and engineering, in the same way that NAEP already assesses their knowledge and capabilities in reading, mathematics, science, and other subjects.

Technology and engineering literacy has been defined in a variety of ways, but here it will be thought of as the capacity to use, manage, and evaluate the technologies that are most relevant in one’s life, including the information and communication technologies that are particularly salient in the world today, as well as to understand technological principles and strategies needed to develop solutions and achieve goals.

Because technology is such a crucial component of modern society, it is important that students develop an understanding of its range of features and applications, the design process that engineers use to develop new technological devices, the trade-offs that must be balanced in making decisions about the use of technology, and the way that technology shapes society and society shapes technology. Indeed, some have argued that it is time for technology and engineering literacy to take its place alongside the traditional literacies in reading, mathematics, and science as a set of knowledge and skills that students are expected to develop during their years in school. Others go further in conceptualizing “new literacies” in which technologies are seen to restructure and support development of academic and workplace expertise through "cyberlearning" in the networked world (National Science Foundation [NSF], 2008).

As of 2008, all 50 states were required to report to the U.S. Department of Education on technology literacy, using information and communication technology (ICT) standards based on the National Education Technology Standards (NETS) for Students (International Society for Technology in Education [ISTE], 2007). Seven states have formal assessments for technology literacy (Metiri Group, 2009). The *Standards for Technological Literacy* developed by the International Technology and Engineering Educators Association (ITEEA) were being used in 41 states for technology education courses at either the state level or in the school districts (Dugger, 2007). A dozen states required technology education for students in at least some grades, and a total of 22 offered technology education as an elective. Engineering-based technology education may be offered as a separate subject, or embedded into other subject areas, such as science or social studies.

Reflecting the increasing importance of the role of technologies in 21st century life, the National Assessment Governing Board decided to develop a framework and specifications for a national assessment of technology and engineering literacy. In announcing the NAEP Technology and Engineering Literacy Assessment, the Governing Board stated that the goals and objectives of the framework and specifications should be based on the future needs of the nation and of individuals and on the levels of technology and engineering literacy likely to be expected of students in the first half of the 21st century.

This *Technology and Engineering Literacy Assessment and Item Specifications for the 2014 National Assessment of Educational Progress* is one of two documents that describe the assessment; it is intended for a technical audience, including the National Center for Education Statistics and the contractors that will support development of the 2014 NAEP Technology and Engineering Literacy Assessment. The specifications provide the "test blueprint," that is, information about item development and other aspects of test development. The other document, the *Technology and Engineering Literacy Framework for the 2014 National Assessment of Educational Progress*, presents the conceptual base and content of the assessment and is intended for a more general audience. It is important to note that the framework is an assessment framework, not a curriculum framework. That is, although it provides a definition of what students should know and be able to do concerning technology and engineering, it is not intended to tell teachers and administrators what should be taught in the classroom, when it should be taught, or how it should be taught.

In addition to laying out the need for a technology and engineering literacy assessment framework and specifications, this chapter offers background information on NAEP and provides a list of resources used to develop the framework and specifications, definitions of key terms, a description of the process used for developing the framework and specifications, an explanation of the challenges of developing a technology and engineering literacy assessment framework and specifications, and an overview of the assessment specifications.

Background of NAEP

For more than 35 years NAEP has measured student achievement nationally, state by state, and among 20 large urban districts. NAEP has served 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 measured by NAEP, a framework is used to provide recommendations on the content and processes to be assessed, the types of assessment questions to be asked, and the administration of the assessment. Each framework is designed to guide the assessment for about a decade until it is updated. 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. 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. The Trial Urban District Assessment (TUDA) was initiated in 2002 to report on the achievement of public school students in large urban districts. Under this program NAEP has administered its mathematics, reading, science, and writing assessments to samples of students in large urban districts that have volunteered to participate in NAEP.

Resources for Planning the Framework and Assessment Specifications

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 NAEP Technology and Engineering Literacy, the main purpose of the framework is to establish what students should know about and be able to do with technology and to set forth criteria for the design of the 2014 assessment and future assessments. Meeting this purpose requires a framework built around what the communities involved in technology, technology education, educational technology, and technology and engineering literacy consider to be the knowledge and skills that are most important for NAEP to report.

In prioritizing the content, the framework and specifications developers used the NAEP Technology and Engineering Literacy Steering Committee Guidelines (summarized later in this chapter). These guidelines recommended drawing from the following sources:

- Existing technology standards from various individual states;
- *National Education Technology Standards* by the International Society for Technology in Education (ISTE, 2007);
- *Standards for Technological Literacy: Content for the Study of Technology* by the International Technology and Engineering Educators Association (ITEA, 2007);
- *Framework for 21st Century Learning* from the Partnership for 21st Century Skills (P21, 2007);
- Influential technology standards from other countries (e.g., the United Kingdom);
- The *Science Framework for the 2009 National Assessment of Educational Progress* (National Assessment Governing Board, 2008);

- *Benchmarks for Science Literacy* from the American Association for the Advancement of Science (AAAS, 1993);
- The *National Science Education Standards* from the National Research Council (NRC, 1996);
- Definitions of technological literacy contained in the Federal No Child Left Behind Act of 2001 (NCLB, 2001) and the American Recovery and Reinvestment Act of 2009 (ARRA, 2009); and
- 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); The Intellectual and Policy Foundations of the 21st Century Skills Framework (P21, n.d.); Fostering Learning in the Networked World: The Cyberlearning Opportunity and Challenge (NSF, 2008).

Tables illustrating how the major assessment areas presented in Chapter Two are aligned with these source documents are presented in Appendices D, E, F, and G. These sources embody a wealth of information about technology and engineering literacy and technology education. All address similar issues of K-12 content and assessment, and in many ways they converge on a broad vision of technology and engineering literacy. However, the various documents do not always agree on definitions of terms, and in many cases they attach different meanings to phrases such as “educational technology” and “technology education,” which a reader outside the field would find confusing. Consequently, it is important to establish clear definitions for the purpose of the framework and specifications and the work of NAEP that will follow. (See the glossary in Appendix B for full definitions of relevant terms used in the framework and specifications.)

Definitions of Key Terms Used in the Framework and Assessment Specifications

Because of the variety of meanings associated with words and terms that are used throughout this document, meanings and usages specific to the framework and specifications are offered here. The particular words and terms at issue are technology, engineering, technology and engineering literacy, and educational technology. 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 technology and engineering literacy. No additional claim is made regarding the usefulness of these definitions for other purposes—and, in particular, they should not be used for the interpretation of state and local assessments, since these may be based on different definitions of technology and engineering literacy. The framework and specifications define technology, engineering, and technology and engineering literacy as:

Technology is any modification of the natural or designed world done to fulfill human needs or desires.

Engineering is a systematic and often iterative approach to designing objects, processes, and systems to meet human needs and wants.

Technology and engineering literacy is the capacity to use, understand, and evaluate technology as well as to understand technological principles and strategies needed to develop solutions and achieve goals. For purposes of this framework, it comprises three areas: Technology and Society, Design and Systems, and Information and Communication Technology.

The following sections expand and elaborate upon the above brief definitions of "technology," "engineering," and "technology and engineering literacy" with the goal of describing the knowledge and capabilities that are essential for citizens in the 21st century—and, in particular, in a way that can be assessed through an on-demand, large-scale assessment.

Technology

Research shows that most Americans associate technology mainly with computers and related electronic devices (Cunningham, Lachapelle, & Lindgren-Streicher, 2005). However, while the computer is certainly an important example of technology—and one that plays an especially important role in the framework and specifications—the term *technology* has a broader and deeper meaning. Broadly speaking, technology is any modification of the natural or designed 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 or a wooden flute, to the most complex, including the Internet, medical imaging devices, and a country's entire transportation system. Technology helps people do their jobs: giant particle colliders for physicists, oil paints and canvases for artists, and e-mail for just about everyone. Technology also makes leisure time more enjoyable: movies, music, and electronic games to entertain, automobiles to get people where they want to go, audio and imaging tools to support creative expression, and books (either e-books or the traditional paper version) to tell stories of other places and times. But technology is not just the products or things that people create. It includes the entire infrastructure needed to support the processes used to design, manufacture, operate, and repair technological artifacts, from corporate headquarters and engineering schools to manufacturing plants, media outlets, and distribution networks (Shakrani & Pearson, 2008). Technology also includes the cyberinfrastructure and participatory technologies that open up greater access to complex learning and connections of experiences across settings (NSF, 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 society. 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, genetic engineering has been harnessed to create specially designed 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, and to the past decade's explosion of electronic communication, and social networking (Solomon & Schrum, (2007). Technology has become an enabling force behind globalization, knowledge work, and entrepreneurship (Metiri Group, 2006). With each of these changes come new capabilities—and new challenges.

Engineering

Engineering is the process of designing the human-made world. The process typically begins with the specifications of needs or wants. Engineers identify constraints, analyze the features of systems, and devise plans for developing solutions. Solutions may take the form of artifacts such as computer chips or bridges. Solutions may also take the form of improved processes such as assembly lines or traffic control. Engineering processes are typically iterative, involving testing and revisions. Engineers understand the nature of the technology area to be modified, engage in systems thinking, work through engineering design processes, and conduct maintenance and troubleshooting.

Technology and Engineering Literacy

Having defined technology and engineering broadly in these ways, *technology and engineering literacy* can be defined in an equally broad fashion as the capacity to use, understand, and evaluate technology as well as to understand technological principles and strategies needed to develop solutions and achieve goals. Technology and engineering literacy is, like scientific, mathematical, or language literacy, a measure of how well individuals have mastered the processes and tools they need to participate intelligently and thoughtfully in the world around them. As described in reports from the National Academy of Engineering (NAE, 2006), the International Society for Technology in Education (ISTE, 2007), and the International Technology and Engineering Educators Association (ITEA, 2007), technological literacy includes knowledge, capabilities, and critical thinking and decision-making skills (McAnear, 2009). From these documents, lists can be extracted of what a person who is literate in technology and engineering should know and be able to do.

Figure 1 depicts the major assessment areas and practices of the NAEP Technology and Engineering Literacy Framework and Assessment Specifications. At the center, in blue, are the three areas of technology and engineering literacy that will be assessed by NAEP: Technology and Society, Design and Systems, and Information and Communication Technology (ICT). The surrounding yellow circle represents three overarching types of thinking and reasoning that generalize across the major assessment areas. These cross-cutting practices will apply across tasks and individual test questions, also referred to as items, in the areas of Technology and Society, Design and Systems, and ICT. Below these key components of the 2014 NAEP Technology and Engineering Literacy Framework and Assessment Specifications are described.

Three Areas of Technology and Engineering Literacy

In recent decades, students in the United States have experienced three quite different (though by no means inconsistent) approaches to technology and engineering literacy. These are the science, technology, and society approach; the technology education approach; and the information and communication technology approach. In recognition of the importance, educational value, and interdependence of these three approaches, the framework and specifications include all three under its broad definition of technology and engineering literacy, and in recognition of the distinct goals and teaching methods involved in each, the framework and specifications recommend that assessment results be reported for each of the separate areas in order to make it possible to monitor and analyze the results of each approach over time. The next few paragraphs present a brief description of each of these approaches.

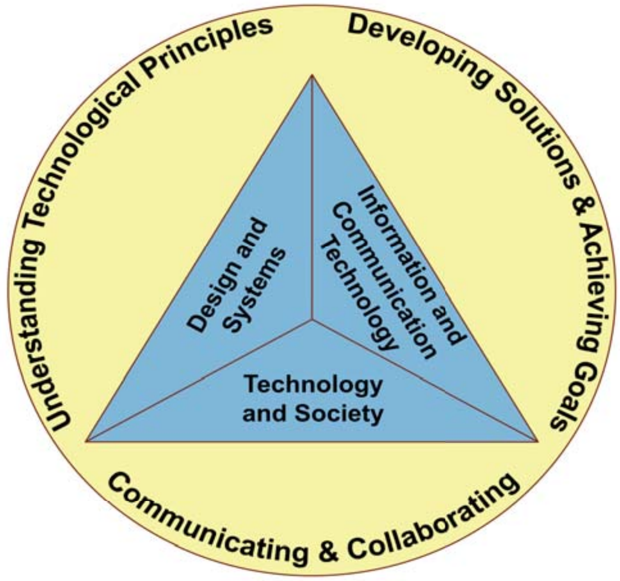


Figure 1 – Major Assessment Areas and Practices of Technology and Engineering Literacy

• The assessment area of Technology and Society has it roots in the science, technology, and society (STS) approach. 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, including such things as 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 & Akcay, 2008). A survey of engineering and technology in state science standards found that a majority of state standards reflect the STS approach (Koehler, Faraclas, Giblin, Kazerounian, & Moss, 2006). The STS approach is represented in the framework and specifications under the heading "Technology and Society."

• The assessment area of Design and Systems is partly rooted in the school subject known as industrial arts (Dugger, 2005), a popular subject area 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 instruction on industrial processes. As conceived today by the field's professional organization, the International Technology and Engineering Educators Association (ITEEA), 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). Goals in technology education include creating a broad understanding of both technology and engineering as well as developing specific capabilities 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 those whose standards relate to STS. The engineering design approach is represented in the framework and specifications under the heading “Design and Systems.”

• Information and communication technology (ICT) is a third approach that has been growing in importance over the past three decades. The pervasiveness of technology in school, home, work, and play has profound implications for learning in schools and throughout life (P21, n.d.). 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, having expanded from the earlier vision of technology as a teaching tool to today’s philosophy of technology as a learning tool. That is, the focus is no longer on using technology to assist teachers but rather on giving students new and more powerful ways to gather and assess information, think creatively, solve problems, and communicate. As expressed in the society’s National Educational Technology Standards (ISTE, 2007), ICT includes a variety of student skills that overlap with other areas, such as creativity and innovation; communication and collaboration; research and information fluency; and critical thinking, problem solving, and decision-making. These skills are applied specifically to the use of digital technologies and media, including the Internet and other networking applications.

Although these information technologies make up one component 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. 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). Media, telecommunication, and networked technologies are evolving into powerful support systems for acquiring skills needed in the 21st century (P21, n.d.) “Every young person will need to use ICT in many different ways in their adult lives, in order to participate fully in a modern society” (Organisation for Economic Co-operation and Development [OECD], 2006). The ICT approach to technology and engineering literacy is represented in the framework and specifications under the heading “Information and Communication Technologies.”

Three Practices

A person who is literate in technology and engineering should be able to apply *cross-cutting practices* that are generalizable ways of thinking, reasoning, and acting that are important across all areas of technology and engineering literacy. As depicted in the diagram in Figure 1, these practices are employed within and across the three major assessment areas. The practices can be grouped into three broad categories as shown below, with several examples of each type of practice:

<u>Understanding Technological Principles</u>

- Understands the nature of technology in its broadest sense.
- Is aware of the various digital tools and their appropriateness for different tasks.

- 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.
- Understands how cultural differences can affect technological choices.

<u>Developing Solutions and Achieving Goals</u>

- Demonstrate appropriate usage of a wide range of technological tools and systems, ranging from kitchen appliances and alarm clocks to cars, computers, communication devices, and the Internet.
- Can apply technological concepts and skills creatively, including those of engineering design and information technology, to solve problems and meet goals.
- Collects and analyzes data to develop a solution and complete a project.
- Uses multiple processes and diverse perspectives to explore alternative solutions.
- Can evaluate claims and make intelligent decisions.

<u>Communicating and Collaborating</u>

- Communicates information and ideas effectively to multiple audiences using a variety of media and formats.
- Participates thoughtfully and productively in discussing critical societal issues involving technology related to humans, the environment, knowledge, and citizenship.
- Collaborates with peers and experts.

The framework and specifications recommend that results of the NAEP Technology and Engineering Literacy Assessment be reported separately for the three major assessment areas of Technology and Society, Design and Systems, and ICT, although it cannot be stressed strongly enough that today’s youth are expected to acquire knowledge and skills in all three areas of technology and engineering literacy. These areas are neither learned separately nor applied separately; they overlap and interact. A person who is literate in technology and engineering 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 example of a common use of the term “technology.” Broadly speaking, the field of educational technology is concerned with the use of various types of equipment as aids in teaching and learning. Many of today’s teachers remember a time when overhead projectors were in widespread use or when whiteboards replaced chalkboards. Advocacy for the use of computers in classrooms began more than 20 years ago, and the uses of computers have evolved rapidly from computers-as-teachers to computers-as-learning-tools.

Today a vast array of computer applications is available for use in all school subjects, and these applications are fundamentally altering the way students learn in school, giving them unprecedented input into and control of their own learning. Some devices, such as interactive whiteboards, combine technologies for entirely new purposes. An area of digital or cyber literacy is emerging that encompass the use of newer forms of technology and media (Kress, 2003; Livingstone, van Couvering, & Thumin, 2008). Traditions of media and information literacy are converging and focusing on skills needed to take advantage of digital systems for representing and distributing information (Livingstone, 2002). The variety and use of such tools for learning, expression, and communication is expected to expand rapidly over the next decade, affecting the way all people, not just students, work, collaborate, and communicate (New Media Consortium, 2009). The 2014 NAEP Technology and Engineering Literacy Assessment will take advantage of new developments in educational technology as one of the first NAEP assessments to be administered entirely by computer.

The Relationship Among Science, Technology, Engineering, and Mathematics

Science, technology, engineering, and mathematics are closely interlinked areas—so closely interlinked that it is often difficult to know exactly where one starts and the other ends. Students in science classes are often taught about technology, engineering, and mathematics, while students in technology classes learn about science, engineering, and mathematics. Technologies are changing fundamentally the ways scientists work and are becoming important components of science education. Students' skills in using the tools of science are becoming components of the "new literacies" (Quellmalz & Haertel, 2008). In a recent report on cyberlearning, the National Science Foundation points out that research has demonstrated that "incorporating information and communications technology into science and mathematics can restructure the necessary expertise for reasoning and learning in these domains, in effect opening up greater access to complex subject matter." Examples include multiple linked representations in mathematics and modeling and visualizations for understanding and investigating complex science (NSF, 2008, p. 13).

For the purposes of designing a framework and specifications to assess technology and engineering literacy, it is important to keep the distinctions among the science, technology, and engineering clear. The relationship among engineering, science, and technology is explained this way in the joint National Academy of Engineering/National Research Council 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 (NAE & NRC, 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 & NRC, 2002, p. 13).

Of the three terms—science, technology, and engineering—the clearest parallel is between science and engineering, since both represent an approach to knowledge taken 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."

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 acronym STEM.

The Framework and Assessment Specifications Development Process

In October 2008, the Governing Board awarded a contract to WestEd to develop a framework and specifications for assessing technology and engineering literacy. In carrying out its work, WestEd collaborated with the Council of Chief State School Officers (CCSSO), ISTE, ITEEA, the Partnership for 21st Century Skills, and the State Educational Technology Directors Association (SETDA). In working 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 steering committee and a planning committee provided the expertise to develop the framework and specifications as specified by the Governing Board. (See Appendix A 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 from a variety of fields and subject areas, including 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 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.

Summary of the Steering Committee Guidelines

- The following definition of technological literacy should be used: Technological literacy is the capacity to use, understand, and evaluate technology as well as to understand technological principles and strategies needed to develop solutions and achieve goals. The Steering Committee also suggested that the Planning Committee examine other definitions of technological literacy, especially those used by the states.
- The assessment should consist of technological content areas, to be reported as scale scores, and technological practices that characterize the field. The content areas must include Design and Systems, Information and Communications Technology, and Technology and Society.
- Three practices should be addressed in the assessment: Understanding Technological Principles, Developing Solutions and Achieving Goals, and Communicating and Collaborating.
- The content and context for the assessment should be informed by existing state standards and assessments, national and international standards, and research.
- Assessment tasks and items should minimize the need for prior knowledge of specific technologies other than ICT; tasks should relate to real-world problems and contexts.
- As far as possible, life situations familiar to students and local and contemporaneous conditions should be used to design tasks as a way to confer relevance to each grade level being assessed.
- The assessment should focus on a broad base of knowledge and skills, not on specific technological processes that may change.
- The assessment should use innovative computer-based strategies that are informed by research on learning and are related to the assessment targets.
- The computer-based assessment strategies should be informed by what is known about all learners, including English language learners and students with disabilities.
- All the items and tasks included as exemplars in the framework and specifications documents should have feasible responses that can be awarded score points.

The Planning Committee, as supported by the project staff, was the development and production group responsible for drafting the framework, specifications, recommendations for background variables, and preliminary technology and engineering literacy achievement level definitions.

This committee was composed 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 (see summary box above – for full text, see Appendix C). In addition to the sources cited previously, the Planning Committee relied on guidance provided by *NAEP 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 work was carried out in a series of meetings, with numerous telephone calls and e-mail exchanges 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 Committee 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), ITEEA, the Organisation for Economic Co-Operation and Development (OECD) International ICT Research Workshop, CCSSO, SETDA, ISTE, and the Partnership for 21st Century Skills Webinar. (See Appendix A for more complete lists of individuals and organizations that contributed to the development of the framework and specifications.) The Planning Committee reviewed feedback from these groups as well as from the Steering Committee and made revisions, as it deemed appropriate. Governing Board members and staff closely monitored the project and provided comments on draft documents. After final approval from the Steering Committee, the framework was submitted to the National Assessment Governing Board for action.

Challenges of Developing the NAEP Technology and Engineering Literacy Framework and Assessment Specifications

There were a number of challenges in developing the 2014 NAEP Technology and Engineering Literacy Framework and Assessment Specifications that were not necessarily encountered in developing other NAEP frameworks and specifications. These included: (1) the newness of the endeavor, (2) diffuse curricula, (3) varying definitions, (4) measurement constraints, (5) time and resource constraints, (6) designing an entirely computer-based assessment, and (7) predicting future changes in technology. Each of these challenges is discussed below.

Newness of the Endeavor

Technology and engineering literacy is a growing and evolving area. Unlike other NAEP subjects, such as reading or mathematics, there is no existing NAEP framework and specifications to draw on. Moreover, the existing item banks in the United States and other countries are very limited (NAE, 2006). The technology and engineering literacy staff and committee members obtained only a limited number of sample items from outside sources, reflecting the current immature state of assessing technology and engineering literacy.

Diffuse Curriculum

Unlike science and mathematics, which have a sequential curriculum taught by subject-area specialists in high school or by generalists in elementary school, technology and engineering education as a whole does not have a unified scope and sequence. Some individual courses (e.g., Science, Technology, and Society [STS], pre-engineering, computer modeling) are likely to follow state standards and have a specified curriculum with a scope and sequence, but these individual courses are generally not grouped together under the rubric of technology courses or, when they are, the courses under such a heading may vary from place to place. ICT, as well, has been integrated into the curriculum in a variety of different ways. While ICT learning is often infused into existing core subjects, it is not always assessed and reported as part of these subjects. Additionally, there is not a clear scope and sequence for ICT knowledge and skills, either as a stand-alone curriculum or integrated into core subjects, which may result in an inconsistent application of technology literacy standards across different grades, different subjects, and different states. As mentioned earlier, all teachers have a role in teaching technology, so in most cases teachers are not singled out as technology teachers in the same way that, for example, mathematics or history teachers are identified with those subject areas. The result (and implication for this assessment) is that the specific technology concepts and practices to which students have been exposed are hit and miss and mostly unknown. Students can say what mathematics or science courses they have taken, but specifying the full range of their education in technology and engineering and their use is more ambiguous.

Varying Definitions

One of the most debated issues in developing the framework and specifications was the definition of technology and engineering literacy, as different definitions abound. Indeed, even the terms are not agreed upon, as some organizations refer to “technological literacy” while others refer to “technology literacy” or “engineering literacy.” In this report, for consistency, the term “technology and engineering literacy” will be used throughout while recognizing that this terminology differs from what is used by some groups. ITEEA, the National Research Council, and ISTE have definitions of technology and engineering literacy. Meanwhile, the Federal No Child Left Behind Act of 2001 (NCLB) required that every student be “technologically literate by the time the student finishes the eighth grade” but the law itself is vague in defining what technological literacy is. States have therefore had flexibility in determining what technology and engineering literacy means and how it should be assessed.

Many states have adopted a common definition worked out by SETDA in 2002, which states, “Technology literacy is the ability to responsibly use appropriate technology to communicate, solve problems, and access, manage, integrate, evaluate, and create information to improve learning in all subject areas and to acquire lifelong knowledge and skills in the 21st century.” The Federal American Recovery and Reinvestment Act of 2009 adds real-world consequences to this shared definition by providing grants to state and local agencies and schools based on their abilities to meet goals defined by long-range educational technology plans, most of which include this definition

The NAEP Technology and Engineering Literacy Framework and Assessment Specifications attempts to unify the concepts and skills presented in these and other definitions under one umbrella definition. The definition presented earlier in this chapter is used only as a means for understanding the results of the NAEP assessment in technology and engineering literacy. While this framework, specifications, and subsequent NAEP results may be informative to education administrators, policyholders, industry and business leaders, and the general public, the definition of technology and engineering literacy presented here should not be used to interpret results from other assessments used at state and local levels. In order to further distinguish the 2014 NAEP Technology and Engineering Literacy Assessment from other technology and engineering literacy assessments, the project committees have recommended that the results be reported in terms of three individual scores, each of them reflecting performance in one of the three main areas of technology and engineering literacy: Technology and Society, Design and Systems, and Information and Communication Technology. An overall composite score will also be reported.

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 Technology and Engineering 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 content to be assessed by NAEP has been identified as that considered central to technology and engineering literacy.

As a result, some important outcomes of technology and engineering literacy (broadly defined) that are valued by general educators, engineers, teachers of technology, and the business community but that are difficult and time-consuming to measure—such as habits of mind, sustained projects, and collaboration—will be only partially represented in the framework and specifications and on the NAEP Technology and Engineering Literacy Assessment. Moreover, the wide range of technology and engineering standards in the guiding national documents that were incorporated into the framework and specifications 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 specified by technology and engineering education documents.

Time and Resource Constraints

Time and resources limit what NAEP can assess. Like most standardized assessments, NAEP is an "on demand" assessment. That is, it is given as scheduled event outside the normal classroom routine with uniform conditions for all of the students being assessed. In particular, NAEP has a limited amount of time—in this case, approximately one hour per student—to ascertain what students know and can do. However, standards presented by professional associations and the states contain goals that require an extended amount of 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 curricula, it would be necessary to know a number of things about the students, including their:

- Reasoning while framing their goals;
- Planning for projects and the implementation of the plan;
- Skills in using technologies to gather, manage, and analyze data and information related to project goals;
- Capabilities 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 peers and experts 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 technology and engineering literacy. In addition to describing the content and format of an examination, assessment frameworks and specifications, such as these, 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, so far only the NAEP writing assessment has been totally computer-based. The design challenges of creating such an assessment include:

- Developing the requisite number of tasks and items (test questions), especially since so few tasks and items currently exist that can serve as samples.
- Constructing tasks and items that provide 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 topics (e.g., core subjects, such as the humanities, mathematics, etc.) or technologies (e.g., transportation, health, or electronics) within the context. Items must not require students to have prior knowledge of specific technologies, and the knowledge required about particular technologies must be presented in the item.

- Determining the features and functions of the complete tools students will use.
- Determining what aspects of student responses to an item need to be assessed. Are the attempts a student makes while trying out a design or using a simulation important to capture? 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 issues, 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 aware of these factors when developing the framework, but they focused on the design factors, leaving the challenge of determining how best to administer the NAEP Technology and Engineering Literacy Assessment to those involved in the assessment development phase.

Predicting Future Changes in Technology

The framework and specifications attempt to strike a balance between what can reasonably be predicted about future technology and engineering literacy 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 smart phones and personal digital assistants [PDAs]) would not have been familiar to students a decade ago and may well be obsolete a decade from now.

The framework and specifications are intended to be both forward-looking (in terms of what technology content and usage 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 2014 should be revisited in response to future developments.

It is a significant challenge to write a framework and specifications for the future, and the challenge is especially great for the subject of technology and engineering literacy.

Introduction to the Assessment and Item Specifications

This document is a companion to the *Technology and Engineering Literacy Framework for the 2014 NAEP*. The framework lays out the basic design of the assessment by describing the technology and engineering literacy content that should be tested and the types of assessment questions that should be included. It also describes how the various design factors should be balanced across the assessment. The assessment and item specifications give more detail about the development of items and conditions for the 2014 NAEP Technology and Engineering

Literacy Assessment. It contains much of the same information that is in the framework about the technology and engineering literacy content and other dimensions of the assessment, but adds further detail. The intended audience for the specifications is test developers and item writers.

The following text describes the content of the remaining five chapters of the *Technology and Engineering Literacy Assessment and Item Specifications for the 2014 NAEP*.

Chapter Two: Areas of Technology and Engineering Literacy

This core chapter identifies the assessment targets for the 2014 NAEP assessment of technology and engineering literacy. The targets are grouped into the three major areas: Technology and Society, Design and Systems, and Information and Communication Technology (ICT). Each of the major areas is broken down into sub-areas. Each sub-area has a listing of key principles and a chart identifying what students should know and be able to do at grades 4, 8, and 12. Each sub-area has between six and fifteen assessment targets.

Chapter Three: Practices and Contexts for Technology and Engineering Literacy

Chapter Three has two major purposes. First, it articulates the kinds of thinking and reasoning that students are expected to demonstrate when responding to the assessment tasks and items. Three practices are presented: (1) understanding technological principles; (2) developing solutions and achieving goals; and (3) communicating and collaborating. Each practice is applied to the three major technology and engineering literacy areas in a chart. There are also tables that apply the practices to selected principles and to the sub-areas. Illustrative tasks and items suggest how the practices can be represented along with targets in each of the areas and sub-areas.

Next the chapter describes the contexts for the assessment—that is, the core school subjects and areas of technology, such as humanities, social sciences, medical imaging, publishing, or recycling, that will serve as backdrops for assessment questions. The choice and presentation of contexts is important because the framework and specifications cannot assume that students have prior knowledge of a specific topic or technology. If information about a specific type of technology is needed to respond to an item, this information must be provided to students in the item as contextual detail. Potential contexts are discussed within the three major areas: Technology and Society, Design and Systems, and Information and Communication Technology. Each of the three areas has a chart that provides examples of how different contexts can be used to formulate tasks and items in each of the three assessment areas.

Chapter Four: Overview of the Assessment Design and Specifications for Item Design

Chapters Four and Five of the specifications address, respectively, the first and second halves of Chapter Four of the framework. Chapter Four of the specifications provides an overview of the major components of the assessment design and provides examples of how items might be developed. It begins with a brief description of the 2014 NAEP Technology and Engineering Literacy Assessment and follows that with 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 technology and engineering literacy as well as across the practices. The types of items to be included in the assessment are described, and examples are provided.

Chapter Five: Assessment Design and Student Diversity

The purpose of this chapter in the specifications is to provide a more detailed discussion of the issues that are raised in the final section of Chapter Four of the NAEP Technology and Engineering Literacy Assessment Framework concerning how the assessment should be designed to ensure the greatest level of access for all. In the first section, guidelines are given about the design of the assessment delivery system. In the second section, the general principles of universal design that apply to a complex computer based assessment are outlined and discussed. In the third section, the particular accommodations needs of students with physical, sensory, cognitive, and other disabilities are described, and strategies are outlined for ensuring inclusion of those students in the assessment. In the fourth section, the accommodations required by students who are English Language Learners are discussed along with recommendations for assessment development that ensures inclusion of such students. The fifth section describes how a development process can ensure that the assessment meets its targets for optimal accessibility for all students and the fullest levels of inclusion of students in the sample selected to take the Technology and Engineering Literacy Assessment.

Chapter Six: Scoring and Reporting

The purpose of this final chapter is to explain how the probe for the 2014 NAEP Technology and Engineering Literacy Assessment will be scored and the results reported. The probe will be administered in 2014 as a trial of the NAEP Technology and Engineering Literacy Assessment. In the NAEP context, a probe is a smaller-scale, focused assessment on a timely topic that explores a particular question or issue and may be limited to particular grades. The description in this chapter is for the initial probe assessment, but can be applied to future administrations of the assessment beyond that first assessment. Key sections of the chapter are as follows:

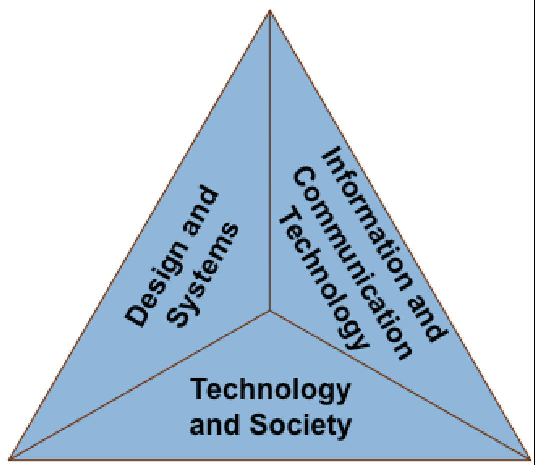
- Overview of the Scoring Processes
- Potential Measurement Methods
- How NAEP Results are Reported;
- Reporting Scale Scores and Achievement Levels;
- Reporting Background Variables; and
- Uses of NAEP Reporting.

Chapter Two: Areas of Technology and Engineering Literacy

Introduction

This chapter describes the essential knowledge and capabilities that will be assessed on the NAEP Technology and Engineering Literacy Assessment beginning in 2014. Although it is not possible to assess every aspect of technology and engineering literacy, the framework and specifications identify a set of assessment targets related to the nature, processes, and uses of technology and engineering that are thought to be essential for 21st century citizens. The assessment targets are organized into three *major areas*: Technology and Society, Design and Systems, and Information and Communication Technology.

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



This chapter provides descriptions of each of the major areas of technology and engineering literacy as well as sub-areas and tables of assessment targets that specify what students in grades 4, 8, and 12 should know and be able to do. The assessment targets describing what students should be able to do foreshadow the cross-cutting *practices*—ways of thinking and reasoning—that are described in Chapter Three.

It will be apparent when reading assessment targets across the grade-level rows that learning is cumulative—that is, later grades build on what has been learned in earlier grades, so that students develop a greater sophistication and depth of understanding as they advance in school. For instance, elementary school students think of a technological change in terms of a succession of *products*, as in the evolution of writing technology from clay tablets to pen and paper and to computers and printers. Middle school students are able to think in terms of technological *processes*, such as the processing of food, or the extraction of metal from ore. High school students have learned to think in terms of technological *systems*, such as a city's public transportation system, or water purification system.

Readers will find that there is 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 it serves to emphasize that individuals who are literate in technology and engineering can bring any and all of these ways of thinking and acting to bear on any problem or goal they might encounter. Thus, ICT knowledge and skills are called upon during the design of technologies; information and communication technologies are developed by engineering design processes; and the myriad technologies designed to meet human needs, including the ubiquitous information and communication technologies, are influenced by and have impacts on society.

The three major assessment areas of technology and engineering literacy and their corresponding sub-areas are presented in Table 2.1 and briefly summarized below.

Table 2.1 Major areas and sub-areas of 2014 NAEP Technology and Engineering Literacy Assessment

Technology & Society	Design & Systems	Information & Communication Technology (ICT)
A. Interaction of Technology and Humans 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. Nature of Technology B. Engineering Design C. Systems Thinking D. Maintenance and Troubleshooting	A. Construction and Exchange of Ideas and Solutions B. Information Research C. Investigation of Problems D. Acknowledgement of Ideas and Information E. Selection and Use of Digital Tools

Technology and Society

A. Interaction of Technology and Humans 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 the positive and negative ways that technologies affect the natural world.

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

D. Ethics, Equity, and Responsibility concerns the profound effects that technologies have on people, how those effects can widen or narrow disparities, and the responsibility that people have for the societal consequences of their technological decisions.

Design and Systems

A. Nature of Technology offers 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. Systems Thinking is a way of thinking about devices and situations so as to better understand interactions among components, root causes of problems, and the consequences of various solutions.

D. Maintenance and Troubleshooting is the set of methods used to prevent technological devices and systems from breaking down and to diagnose and fix them when they fail.

Information and Communication 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.

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

C. Investigation of Problems concerns the use of information and communication technology to define and solve problems in core school subjects and in practical situations.

D. Acknowledgement of Ideas and Information involves respect for the intellectual property of others and knowledge of how to credit others' contributions appropriately, paying special attention to the misuse of information enabled by rapid technological advances.

E. Selection and Use of Digital Tools includes both knowledge and skills for choosing appropriate tools and using a wide variety of electronic devices, including networked computing and communication technology and media.

Resources Used in the Development of Assessment Targets

The process of developing the assessment targets drew heavily on prior documents 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);
- *Engineering in K-12 Education* (NRC, 2009);
- *Framework for 21st Century Learning* (Partnership for 21st Century Skills, 2007);
- *National Educational Technology Standards* (ISTE, 2007);
- *National Science Education Standards* (NRC, 1996);
- *Science for All Americans* (AAAS, 1989);
- *Standards for Technological Literacy* (ITEA, 2002);
- *Standards for the 21st Century Learner* (American Association of School Librarians, 2007).

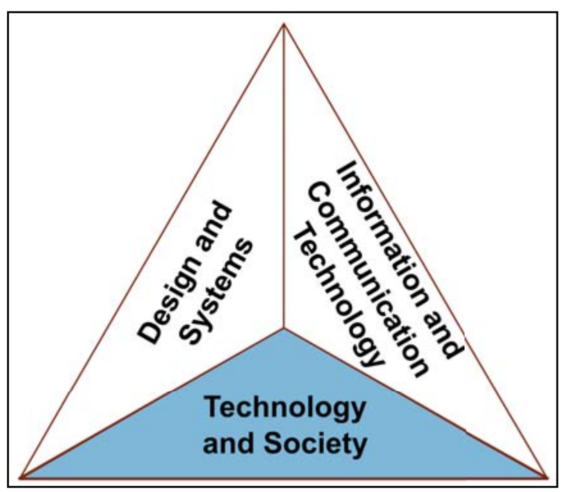
- *Tech Tally: Approaches to Assessing Technological Literacy* (NAE, 2006); and
- *Technically Speaking: Why All Americans Need to Learn More About Technology* (NRC & NAE, 2002).

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

- Assessment and Teaching of 21st Century Skills (ATC21S) Cisco/Intel/Microsoft project;
- *Benchmarking for Success: Ensuring U.S. Students Receive a World Class Education* (National Governors Association, Council of Chief State School Officers, and Achieve, Inc., 2008);
- Best practices in various state frameworks on science, technology, and engineering;
- *Key Competencies for Lifelong Learning: European Reference Framework* (European Communities, 2007);
- *PISA 2006: Science Competencies for Tomorrow's World* (Organization for Economic Co-Operation and Development, 2007);
- *Science Framework for the 2009 National Assessment of Educational Progress* (National Assessment Governing Board, 2008); and
- Trends in International Mathematics and Science Study (TIMSS) (National Center for Education Statistics, 2008).

The steering and planning committees recognize and appreciate efforts by Achieve, Inc., the American Association for the Advancement of Science, the International Society for Technology in Education, the International Technology and Engineering Educators 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, for giving permission to quote the materials when desired, and for assisting in developing the framework and specifications.

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 physical world and world of knowledge to meet their needs and wants, to extend the reach of their bodies, hands, and minds, to span rivers, and to traverse continents. From arrowheads to communication devices, technologies have always been an intrinsic part of civilization, and this is particularly true today, in the early part of the 21st century. This relationship is reflected in all of the national standards documents reviewed for the framework and specifications. It follows that awareness of the relationship between technology and society is an essential aspect of technology and engineering literacy.

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

A. Interaction of Technology and Humans;

B. Effects of Technology on the Natural World;

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

D. Ethics, Equity, and Responsibility.

A fundamental principle in the area of Interaction of Technology and Humans 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 aspects of society as well as their capability to analyze historical and current examples of the technology-society relationship using concepts such as criteria, constraints, trade-offs, and consequences. Students should weigh societal and behavioral changes along with purely technological solutions. For example, encouraging the recycling and reuse of household materials may be more cost effective than building new waste facilities.

Effects of 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 the 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.

Effects of Technology on the World of Information and Knowledge addresses the increasing access permitted by information technology to expertise and information, the many powerful methods for storage and management of information, the expansion of the capability to express ideas and 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 technology and engineering literacy—the fact that technological decisions made by some people have significant impacts on others. Many of the thorniest technological issues in current society concern effects that cross borders, such as acid rain, and many of them have global implications, such as the attribution and ownership of ideas and products and the effects of fossil fuel use on climate. The focus on this area is on general principles that can be applied when thinking about ethical issues that concern various technologies, although individual assessment items will inevitably tend to focus on a specific technology. The framework and specifications identify the knowledge and skills that students should have for analyzing the issues, gathering evidence that could support multiple perspectives, and presenting alternative solutions to technological issues that have ethical implications. It does not take positions on controversial issues.

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 2014 NAEP Technology and Engineering Literacy Assessment in the area of Technology and Society.

A. Interaction of Technology and Humans

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 their societies and their relationship to other societies through such mechanisms as trade, communication, war, and assimilation.

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

Although the effects of technological change are more difficult to discern when the period of observation 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 lifetimes. 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 new kinds of media, computers, and communication systems; the development of more fuel-efficient cars; the construction of new or improved buildings, roads, and bridges; and new foods and types of clothing.

Key principles in the area of Interaction of Technology and Humans that all students can be expected to understand at increasing levels of sophistication are as follows:

- The relationship between technology and society is reciprocal. Society drives technological change, while changing technologies in turn shape 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 which only become apparent over time as the technology becomes more pervasive or more powerful.
- Technological solutions are developed and evaluated on the basis of criteria and constraints.

Fourth-graders are expected to know that people's needs and desires determine which technologies are developed or improved. For example, cell phones were invented, produced, and sold because people found it useful to be able to communicate with others wherever they were. Students should also know that these new products, tools, and machines in turn affect the lives of individuals, families, and whole communities. An example is 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 long series of transportation systems from horses and wagons to cars and airplanes. They should also recognize that technologies may have effects that were not anticipated and that do not become apparent until the technology becomes widespread. For example, it was not until cell phones were widely used that it became apparent that people would use them while driving, creating an increased risk of accidents. Finally, eighth-graders should be able to compare the effects of the same technology 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 be able to use various principles of technology design—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. For example, the development of modern medical technologies has greatly increased average lifespan, but many of these new technologies are very costly and not available to everyone. The availability of advanced medical technologies also differs from country to country as a result of both differing economic and political conditions and different cultural values.

Table 2.2 Interaction of Technology and Humans assessment targets for grades 4, 8, and 12

A. Interaction of Technology and Humans		
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 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:** Economic, political, social, and cultural aspects of society drive 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: The introduction of a new tool, product, or machine usually brings both benefits and costs, and it may 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 often 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 and can change over time. 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 technology 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:** Choose an appropriate technology to help 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 like without those technologies.	**T.8.4:** Compare the impacts of a given technology on different societies, noting factors that may make a technology appropriate and sustainable in one society but not in another.	**T.12.4:** Analyze cultural, social, economic, or political changes (separately or together) 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 technology and engineering 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.

Individuals who are literate in technology and engineering 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 in order to conserve energy and reduce waste, and the expansion of alternative energy sources such as wind power.

In finding a balance between technological development and environmental protection, a key overarching principle is that one should attempt, when possible, to find sustainable solutions. 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 understand at increasing levels of sophistication are as follows:

- The use of technology may affect the environment positively or negatively.
- Some technological decisions put environmental and economic concerns in competition with one another, while others have positive effects for both the economy and the environment.
- Reusing, recycling, and using fewer resources can reduce environmental impacts.
- Resources such as oceans, fresh water, and air, which are shared by everyone, need to be protected by careful planning and regulation of technological systems.
- 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 (Brundtland Commission, 1987).

At the fourth-grade level students are expected to know 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 in producing the products.

Eighth-graders are expected to recognize that technology and engineering 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. 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 know that designers can reduce waste by taking the entire life cycle of a product into account during design. For example, students should be able to 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. Students should be able to analyze the effects of different technologies on the environment—for example, by using data on the environmental impacts of power plants that use different types of fuel to inform decisions on which types of new power plants to build. Students should also be able to analyze complex human activities, such as energy generation, and propose sustainable solutions. Students could, for example, research the environmental impacts of energy generation and create a presentation to a United Nations council on the trade-offs of various solutions.

Table 2.3 Effects of Technology on the Natural World assessment targets for grades 4, 8, and 12

<table>
<tr><th colspan="3">B. Effects of Technology on the Natural World</th></tr>
<tr><td colspan="3">Fourth-graders should be aware that the use of technology can affect the environment, that the environment affects technology, and that reusing and recycling products can avoid damaging the environment. 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.</td></tr>
<tr><th>Grade 4</th><th>Grade 8</th><th>Grade 12</th></tr>
<tr><td>Students know that:
T.4.5: The use of technology can affect the environment, including land, water, air, plants and animals. The environment also affects technology by providing sources of energy and raw materials.</td><td>Students know that:
T.8.5: Some technological decisions involve trade-offs between environmental and economic needs, while others have positive effects for both the economy and environment.</td><td>Students know that:
T.12.5: Many technologies have been designed to have a positive impact on the environment and to monitor environmental change over time to provide evidence for making informed decisions.</td></tr>
<tr><td>T.4.6: Reusing and recycling materials can save money while preserving natural resources and avoiding damage to the environment.</td><td>T.8.6: Resources such as oceans, fresh water, and air, which are essential for life and shared by everyone, are protected by regulating technologies in such areas as transportation, energy, and waste disposal.</td><td>T.12.6: Development and modification of any technological system needs to take into account how the operation of the system will affect natural resources and ecosystems.</td></tr>
<tr><td>Students are able to:
T.4.7: Identify the impact of a specific technology on the environment and determine what can be done to reduce negative effects and increase positive effects.</td><td>Students are able to:
T.8.7: Compare the environmental effects of two alternative technologies devised to solve the same problem or accomplish the same goal and justify which choice is best, taking into account environmental impacts as well as other relevant factors.</td><td>Students are able to:
T.12.7: Identify a complex global environmental issue, develop a systematic plan of investigation, and propose an innovative sustainable solution.</td></tr>
</table>

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

Human civilization owes its current form to a number of major revolutions in the capacity to communicate and pass along information. The genesis of writing, a technological development that began at least 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 15th century, which made it possible for ideas to be passed along to many people at widely distributed locations and times. Inventions of the telephone, telegraph, radio, movies, television, and the Internet all extended communication and expression. These revolutions changed the world of information and knowledge, resulting in transformative effects on society.

Rapid advances in information and communication technologies during the latter half of the 20th and early 21st centuries are creating an information age revolution. These technologies have made possible the storage, organization, and manipulation of vast quantities of data, far beyond what was possible for a physical library, and have greatly facilitated access to the information by anyone, anywhere. Together these technologies are modifying the world of information and knowledge itself, with implications for individuals, organizations, and entire societies.

It is important for all citizens to understand the societal needs that led to the development of current information and communication technologies and the effects, both positive and negative, of these technologies on the creation, extension, and use of knowledge and the expression of ideas. Students can acquire these insights and capabilities by taking courses in technology or simply through daily activities, such as studying the traditional subjects in school and pursuing personal interests at home. In other words, the process of using various technologies to access and interact with information and knowledge can yield valuable learning about the technology itself, and therefore contributes to students' technology and engineering literacy.

In contrast to the assessment targets later in this chapter under Information and Communication Technology, which are concerned with student knowledge and use of various technologies, the assessment targets in this sub-area emphasize the revolutionary consequences of the information age—the ways in which society affects what information and knowledge is available and how the availability of that information profoundly affects society.

Key principles in the area of Effects of Technology on the World of Information and Knowledge that all students can be expected to understand at increasing levels of sophistication are as follows:

- Information technology is evolving rapidly, enabling ever-increasing amounts of information and data to be stored, managed, enhanced, analyzed, and accessed through a wide array of devices in various media formats.
- Information and communication technology (ICT) enables the creation and modification of information and knowledge products by remotely connected individuals and teams.
- The emergence of intelligent information technologies and the development of sophisticated modeling and simulation capabilities 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, that it 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 should be able to identify examples of positive and negative impacts of these tools. For example, students should be able to identify positive effects of being able to send data to others. They should also be able to identify such negative effects as hasty e-mail responses.

Eighth-graders should be aware of the rapid progress in development of ICT, should know how information technologies can be used to analyze, display, and communicate data, and should be able to collaborate with other students to develop and modify a knowledge product. For example, students should understand that translation tools on personal communication devices permit collaboration with students from other countries on a school project, such as digital storytelling. Eighth-graders should also understand that problems can be caused by using digital information or video without verifying quality.

By twelfth grade students should have a full grasp of the types of data, expertise, and knowledge available online and should be aware of intelligent information technologies and the uses of simulation and modeling. They should also understand the potential disadvantage of uncritical use of the technologies. For example, they should know that false information can spread rapidly through the Internet and that these falsehoods, once established, can be difficult to correct. Students should be aware that the ubiquitous use of information communication and dissemination affects governments, news, and other organizations as well as individuals, and they should understand the extent to which ICT has enabled a revolution in the world of knowledge.

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

C. Effects of Technology on the World of Information and Knowledge		
Fourth-graders should know that information, knowledge, and expertise can be accessed, collected, and shared by using information and communication technologies with positive and negative effects. Eighth-grade students should be able to critically weigh how information and communication technologies are rapidly evolving and changing the ways that people interact with information and each other. Twelfth-graders should know that sophisticated information and communication technologies have transformed the world of information and knowledge itself, with positive and negative 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. This can result in positive and negative effects.	**Students know that:** **T.8.8:** Information technologies are developing rapidly so that the amount of data that can be stored and made widely accessible is growing at a faster rate each year.	**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, solve problems, and inform the decision-making process.
T.4.9: Information technologies can be used to modify and display data in various ways that can be helpful or deceptive.	**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. These uses may result in positive or negative impacts.	**T.12.9:** Information technologies such as artificial intelligence, image enhancement and analysis, and sophisticated computer modeling and simulation, create new types of information that may have profound effects on society. These new types of information must be evaluated carefully.
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 development of communication technologies that enable people to access vast quantities of information and publish their ideas globally has implications for governments, 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 information and communication technologies to collaborate with others on the creation and modification of a knowledge product that can be accessed and used by other people.	**Students are able to:** **T.12.11:** Give examples to illustrate the effects on society of the recording, distribution, and access to information and knowledge that have occurred in history and discuss effects of those revolutions on societal change.

D. Ethics, Equity, and Responsibility

Although technological advances have improved quality of life, newer technologies have sometimes resulted in negative effects, which in turn may have various ethical implications. Consequently, it is becoming increasingly important for citizens 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 the recognition that such effects are occurring, followed by concrete steps to mitigate the problem.

The term *ethics* generally refers to a code of behavior or to a set of rules or guidelines for distinguishing between right and wrong. In general, there is no such thing as a universally agreed-on set of ethical guidelines since a behavior considered ethical in one culture or professional group may be considered unethical by a different group of people. Nonetheless, there are some ways of behaving and thinking that most people consider ethical, such as honesty and integrity (Resnik, 2007). The term *equity* generally refers to fairness, or equality of opportunity, while *responsibility* generally means holding oneself accountable to accomplish certain things, or to be trustworthy.

While ethics, equity, and responsibility are important considerations in all human endeavors they are especially important for the design, production, inspection, and use of technologies, since these have an immediate effect on people’s lives. Innumerable examples come to mind, such as the collapse of buildings during earthquakes, the failure of bridges due to poor maintenance, the distribution of poisonous foods due to unsafe processing methods, and lapses in the testing and correction of mechanical failures in automobiles. Prevention of such human tragedies involves discussion of ethical practices and the responsibilities of individuals from technicians to engineers and policymakers.

One sector of the current technological infrastructure that is especially vulnerable to unethical behaviors is the telecommunications sector and, particularly, the Internet. 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 to use these tools (and others 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 and to take personal responsibility for doing so.

Key principles in the area of Ethics, Equity, and Responsibility that all students can be expected to understand at increasing levels of sophistication 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 affects the lives of people in other areas.
- Storing information digitally requires a heightened attention to remote security threats.
- It is important for people to take responsibility for the appropriate use of technology.

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 their use can lead to accidents in which people are seriously injured. Students should also recognize that technology can be used in ways that hurt others, such as when a false rumor is posted about someone online.

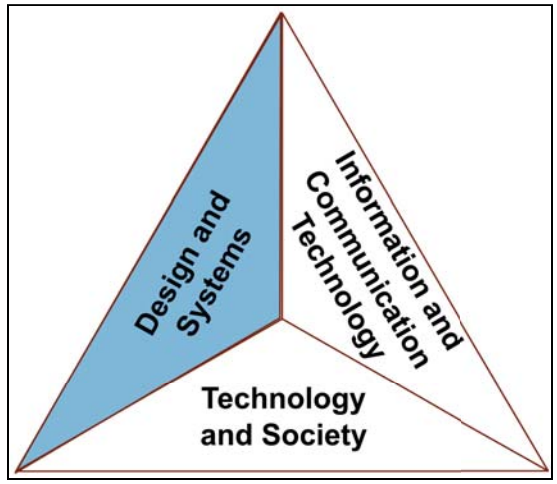
Eighth-graders should be able to recognize that the potential for misusing technologies always exists and that the possible consequences of such misuse must be taken into account when making decisions. They should have a grasp of the technological inequalities around the world—as illustrated by the existence of countries where few people can afford refrigerators and few schools have computers—and students should understand 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 who live in other areas. For example, they might consider avoiding the use of products that have been produced in ecologically vulnerable areas, such as the Amazonian rainforest. 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 be able to take into account both intended and unintended consequences in making technological decisions. They should understand the worldwide inequalities in technology access and know that efforts to transplant a technology from one culture to another should not be undertaken without a consideration of the costs and benefits to the society receiving the technology. 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 2.5 Ethics, Equity, and Responsibility assessment targets 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 the same technologies are not available to everyone and should take responsibility to reduce the negative impacts of technologies and increase their positive impacts. Twelfth-graders should be able to take into account 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 affect 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: The technologies that people have available for such essential tasks as farming, cooking, medicine, transportation, and communication are vastly different in different parts of the world.	**T.8.13:** People who live in different parts of the world have different technological choices and opportunities because of such factors as differences in economic resources, geographic location, and cultural values.	**T.12.13:** Disparities in the technologies available to different groups of people have consequences for public health and prosperity; but deciding whether or not to introduce a new technology should consider local resources and the role of culture in acceptance of the new technology.
Students are able to: **T.4.14:** Explain the benefits and 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:** Explain why it is important for citizens to reduce the negative impacts and increase the positive 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 the ways that someone might harm someone else through the misuse of communication technologies, and kinds of information that could lead to abuse if widely shared.	**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 and ethical use of information and communication technologies by distinguishing between kinds of information that should and should not be publicly shared and describing the consequences of a poor decision.

Design and Systems



Human beings 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 vast network of products and systems—often called "the designed world"—that is constantly changing. The study of engineering design and systems is the study of the world in which all humans live and which all 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, plastic, or re-usable 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 technology and engineering literacy are divided into four sub-areas:

A. Nature of Technology;

B. Engineering Design;

C. Systems Thinking; and

D. Maintenance and Troubleshooting.

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. No one can create a perpetual motion machine, for example, since machines always require more energy input than they provide as useful output.

Students are also expected to distinguish between science, technology, and engineering, and to recognize that science enables improvements in technology, while technological improvements created by engineers often lead to advances in science. Students should also recognize that some problems can be solved through behavioral rather than physical changes, for example, by 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, evaluating the design, and redesigning if needed; and, eventually, communicating the results.

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

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

Each of the above sub-areas relates to one of the broad categories included in the ITEEA *Standards for Technological Literacy.* A table illustrating these connections is presented in Appendix G.

A. Nature of Technology

Two out of every three people in the United States think of "technology" as meaning computers and the Internet (Rose & Dugger, 2002; Rose, Gallup, Dugger, & Starkweather, 2004). Some people conceptualize technology somewhat more broadly to include cell phones and other electronics. However, technology includes every way in which people manipulate the natural environment to satisfy their needs and wants. Thus 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 share it 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 disseminated much more freely 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 taken on by a single person. An example of science pushing technology can be found in the breakthroughs in genetics that have made possible new crops with higher yields and greater resistance to disease. Examples of technology pushing science can be found in the way that engineers provide more precise instruments, better collaboration tools, and ever more powerful computers.

Tools and materials have also improved over time. From hand tools and power tools to computer probes and simulations, tools extend human capabilities, allowing people to see further and 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 understand at increasing levels of sophistication 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.
- Science, technology, engineering, mathematics, and other disciplines are mutually supportive.
- The pace of technological change has been increasing.
- Tools help people do things efficiently, accurately, and safely.

Fourth grade students are expected to distinguish natural and human-made materials, to be 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, should recognize that sometimes a technology developed for one purpose is later adapted to other purposes, and should understand that technologies are constrained by natural laws. They should also know 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 have 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 2.6 Nature of Technology assessment targets 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:** Scientists ask questions about the world; engineers create and modify technologies to meet people’s needs and desires.	**Students know that:** **D.8.1:** Science is the systematic investigation of the natural world. Technology is any modification of the environment to satisfy people’s needs and wants. Engineering is the process of creating or modifying technologies and is constrained by physical laws and cultural norms and economic resources.	**Students know that:** **D.12.1:** Advances in science have been applied by engineers to design new products, processes, and systems, while improvements in technology have enabled breakthroughs in scientific knowledge.
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:** Engineers use science, mathematics, and other disciplines to improve technology, while scientists use tools devised by engineers to advance knowledge in their disciplines. This interaction has deepened over the past century.
D.4.3: Tools are simple objects that help people do things better or more easily, such as the cutting, shaping, and combining of materials that occur when making clothing.	**D.8.3:** Tools have been improved over time to do more difficult tasks and to do simple tasks more efficiently, accurately, or safely. Tools further the reach of hands, voices, memory, and the five human senses.	**D.12.3:** The evolution of tools, materials, and processes has played an essential role in the development and advancement of civilization, from the establishment of cities and industrial societies to today’s global trade and commerce networks.
Students are able to: **D.4.4:** Inspect materials with different properties and determine which is most suitable for a given application.	**Students are able to:** **D.8.4:** Simulate tests of various materials to determine which would be best to use for a given application.	**Students are able to:** **D.12.4:** Take into account trade-offs among several factors when selecting a material for a given application.
D.4.5: Choose an appropriate tool for accomplishing a task.	**D.8.5:** Redesign an existing tool to make it easier to accomplish a task.	**D.12.5:** Design a new tool to accomplish a task more efficiently.

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 the framework and specifications, engineering design is a broad term, including such processes as architectural design, manufacturing design, industrial design, and software design.

Much like scientific inquiry, engineering design is a dynamic process, not a rigid method. Since engineering and science are often confused, it’s helpful to draw a distinction. Scientific inquiry begins with a question and proceeds to generate and test hypotheses until the question is answered. In contrast, engineering design begins with a problem and proceeds to generate and test solutions until a preferred solution or solutions are reached. Whereas science seeks to understand, engineering seeks to meet people’s needs.

The engineering design process usually begins by stating a need or want as a clearly defined challenge in the form of a statement with criteria and constraints. A group of engineers might be given the task of designing, for example, a cell phone with a particular set of features, of a particular size and weight, with a certain minimum battery life, and able to be manufactured at a particular cost. *Criteria* are characteristics of a successful solution, such as the desired function or a particular level of efficiency. *Constraints* are limitations on the design, such as available funds, resources, or time. Together, the criteria and constraints are referred to as the *requirements* for a successful solution.

Once the challenge is defined, the next steps are often to investigate relevant scientific and technical 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 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), or a computer program (such as a video game or software to forecast the weather or model financial markets).

When designing, it is important to take into account the entire life cycle of the product or process, including maintenance, troubleshooting, potential failure modes, impacts on the environment, and effects 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 given less weight. 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 engineering design is not a rigid method. Different instructional materials define it differently, although most definitions specify a sequence of steps, ranging from five steps for elementary students to eight or ten steps for high school students. The 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 best to restart the process from the beginning. Regardless of these differences in definition and use, engineering design always begins with a problem and ends with one or more solutions.

Key principles in the area of Engineering Design that all students can be expected to understand at increasing levels of sophistication 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, aesthetic considerations, and policies.
- 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 other constraints are minimized.
- Engineering design usually requires one to develop and manipulate representations and models (e.g., prototypes, drawings, charts, and 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, redesign, 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 2.7 Engineering Design assessment targets for grades 4, 8, and 12

<table>
<tr><th colspan="3">B. Engineering Design</th></tr>
<tr><td colspan="3">Fourth-graders should start to answer the question “How are technologies created?” by confronting simple yet systematic design challenges. Eighth-graders should be able to use a more elaborate engineering design process, including problem definition, the use of prototypes, testing and iteration, and trade-offs. Twelfth-graders should have a deep understanding and a broad array of design skills, including optimization.</td></tr>
<tr><th>Grade 4</th><th>Grade 8</th><th>Grade 12</th></tr>
<tr><td>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.</td><td>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.</td><td>Students know that:
D.12.6: Engineering design is a complicated 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.</td></tr>
<tr><td>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.</td><td>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 making trade-offs between competing requirements and desired design features.</td><td>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.</td></tr>
<tr><td>Students are able to:
D.4.8: Use a systematic process to design a solution to a simple problem.</td><td>Students are able to:
D.8.8: Carry out a design process to solve a moderately difficult problem by identifying criteria and constraints, determining how they will affect the solution, researching and generating ideas, and using trade-offs to choose between alternative solutions.</td><td>Students are able to:
D.12.8: Meet a sophisticated design challenge by identifying criteria and constraints, predicting how these will affect the solution, researching and generating ideas, and using trade-offs to balance competing values in selecting the best solution.</td></tr>
<tr><td>D.4.9: Construct and test a simple model to determine if it meets the requirements of a problem.</td><td>D.8.9: Construct and test a model and gather data to see if it meets the requirements of a problem.</td><td>D.12.9: Construct and test several models to see if they meet the requirements of a problem. Combine features to achieve the best solution.</td></tr>
<tr><td>D.4.10: Communicate design ideas using drawings and models.</td><td>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.</td><td>D.12.10: Communicate the entire design process from problem definition to evaluation of the final design, taking into account relevant criteria and constraints, including aesthetic and ethical considerations as well as purely logical decisions.</td></tr>
</table>

C. 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, as technological objects all have a life cycle, being made from raw materials, used, and eventually being discarded, at which point they may be recycled or added to landfills. More broadly, there are many examples of systems that are not technological in origin or else are only partly technology: ecosystems, financial systems, political systems, and so on.

Beyond understanding that systems exist, citizens who are literate in technology and engineering should be comfortable with the broader skill of systems thinking, a set of cognitive tools that increases in sophistication and power over time. Systems thinking is the capability to investigate—or think about—a system using certain principles. It enables people to understand complicated 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 the nation's transportation system, among other things. The transportation system consists of a vast network of roads and rails and millions of vehicles. It is dependent on a second system that extracts oil from wells halfway around the world and carries that oil 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 affect the global climate system as well. 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.

Systems thinking can be applied equally well to understanding systems other than purely technological ones—to analyze the way that communication technologies influence society and in turn are influenced by society, for example, or to think about the interplay between energy technologies and global climate change, and to predict future conditions given current trends and changes people may choose to make. It is a cognitive tool that helps people analyze problems they encounter in various settings 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 parts 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 understand at increasing levels of sophistication are as follows:

- Technological systems have parts that work together to accomplish a goal.
- Systems may include subsystems and may interact with other systems. Systems may also be embedded within larger systems.
- Dynamic technological systems require energy with more complicated systems tending to require more energy and to be more vulnerable to error and failure.
- Technological systems are designed for specific purposes. They incorporate various processes that transform inputs into outputs. Two important features of technological systems are feedback and control.

- Various methods can be used to increase the reliability of technological 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 technological 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 identify the subsystems and components of a device by using reverse engineering—the process of analyzing a system to see how it works in order to design a different device that performs the same function. Eighth-graders 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 are the product of 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. (Negative feedback tends to stabilize systems while positive feedback leads to instability.) 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 assessment targets for grades 4, 8, and 12

C. Systems Thinking		
Fourth-graders should be able to identify systems, subsystems, components, and boundaries in their everyday world and to construct simple systems designed to accomplish particular goals. Eighth-graders should be able to describe goals, inputs, outputs, and processes of systems, to use reverse engineering and life cycles to analyze systems in terms of feedback and the flow of energy, and to modify and construct moderately complicated systems. Twelfth-graders should understand that systems are embedded in larger systems, to recognize factors that stabilize systems, to use systems for forecasting, and to redesign complicated systems to improve reliability.		
Grade 4	**Grade 8**	**Grade 12**
Students know that: **D.4.11:** All technological systems require energy and have parts that work together to accomplish a goal.	**Students know that:** **D.8.11:** Technological systems are designed to achieve goals. They incorporate various processes that transform inputs into outputs. They all use energy in some form. These processes may include feedback and control.	**Students know that:** **D.12.11:** The stability of a system depends on all of its components and how they are connected, with more complicated systems tending to require more energy and to be more vulnerable to error and failure. Negative feedback loops tend to increase the stability and efficiency of systems.
D.4.12: Many systems have subsystems within them and are defined by boundaries. Many systems are parts of larger systems.	**D.8.12:** Technological systems can interact with one another to perform more complicated functions and tasks than any individual system can do by itself.	**D.12.12:** Technological systems are embedded within larger technological, social, natural, and environmental systems.
Students are able to: **D.4.13:** Given a product, identify its systems, subsystems, and components by taking it apart.	**Students are able to:** **D.8.13:** Examine a product or process through reverse engineering by taking it apart step by step to identify its systems, subsystems, and components, describing their interactions, and tracing the flow of energy through the system.	**Students are able to:** **D.12.13:** Examine a system to predict how it will perform with a given set of inputs in a given situation and how performance will change if the components or interactions of the system are changed.
D.4.14: Create a diagram of a machine that contains multiple subsystems. Label the subsystems to explain what each one does.	**D.8.14:** Measure and compare the production efficiency of two machines, a simple machine and a complex machine, designed to accomplish the same goal.	**D.12.14:** Redesign a complex machine by modifying or rearranging its subsystems in order to optimize its efficiency.
D.4.15: Construct a simple system to accomplish a goal, based on knowledge of the function of individual components.	**D.8.15:** Construct and use a moderately complicated 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.12.15:** Construct and test a manufacturing system composed of several machines to accomplish a given goal. Redesign the system to optimize its efficiency.

D. 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 humans are surrounded by and dependent upon complicated 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 person who is literate in technology and engineering is aware that all technological systems fail at one time or another and is therefore equipped with a foundation of concepts and skills 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 skills are maintenance and troubleshooting.

In the 2014 NAEP Technology and Engineering Literacy Framework and Assessment Specifications, 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 periodically 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 the sound missing, or the picture, or both? If the power light is not on, it may be unplugged. If that is not the problem, the next 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. Troubleshooting is not confined to mechanical and electronic systems. Artists, writers, and musicians also encounter problems that require troubleshooting.

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.

When designing technological 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 in which complicated 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 understand at increasing levels of sophistication 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 life cycle of a product is an important part of designing.

At the fourth-grade 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 know that if something does not work as expected, it is possible to find out what the problem is in order to 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.

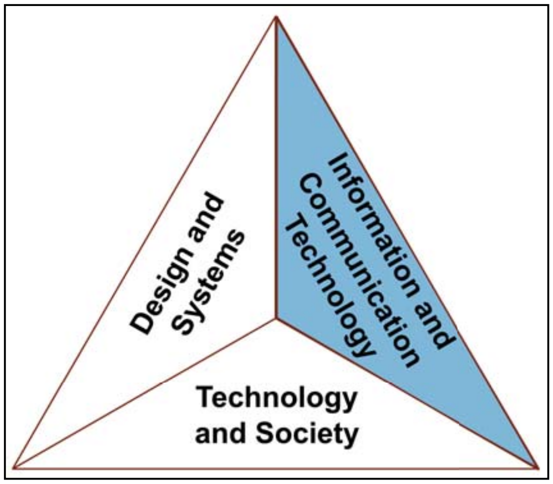
Eighth-graders should be familiar with the concept of maintenance and should understand that failure to maintain a device can lead to a malfunction. They should also be able to carry out troubleshooting, at least in simple situations. For example, they should be able to safely use tools and instruments 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 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 useful life.

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 a malfunction is less likely to 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 2.9 Maintenance and Troubleshooting assessment targets for grades 4, 8, and 12

D. 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.4.16:** It is important to care for different tools and machines in appropriate ways so that they are available to be used when needed.	**Students know that:** **D.8.16:** Many different kinds of products must undergo regular maintenance, including lubrication and replacement of parts before they fail so as to ensure proper functioning.	**Students know that:** **D.12.16:** Products and structures of various kinds can be redesigned to eliminate frequent malfunctions and reduce the need for regular maintenance.
Students are able to: **D.4.17:** Change one aspect of a machine or tool at a time to discover why it is not working. Retest after each change has been made.	**Students are able to:** **D.8.17:** Diagnose a problem in a technological device using a logical process of troubleshooting. Develop and test various ideas for fixing it.	**Students are able to:** **D.12.17:** Analyze a system malfunction using logical reasoning (such as a fault tree) and appropriate diagnostic tools and instruments. Devise strategies and recommend tools for fixing the problem.
D.4.18: Identify the cause of failure in a simple system and suggest ways that failure could be avoided in the future.	**D.8.18:** Modify a moderately complicated system so that it is less likely to fail. Predict the extent to which these modifications will affect the productivity of the system.	**D.12.18:** Analyze a complicated system to identify ways that it might fail in the future. Identify the most likely failure points and recommend safeguards to avoid future failures.
D.4.19: Recognize that all products have a life cycle, starting with raw materials and ending with disposal or recycling.	**D.8.19:** Trace the life cycle of a repairable product from inception to disposal or recycling in order to determine the product's environmental impact.	**D.12.19:** Taking into account costs and current trends in technology, identify how long a product should be maintained and repaired and how it might be redesigned to lessen negative environmental impacts.

Information and Communication Technology (ICT)



The integration of Information and Communication Technologies (ICT) into every sphere of contemporary life has had profound implications for how people learn in school, solve practical problems, and function in the workplace. Networked computing and communications technologies and media have become essential tools of practically every profession and trade, including those of 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 in various professions and trades, such as word processors, spreadsheets, audio, video, and 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 the framework and specifications 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, computer-based and otherwise, will continue to bring about new approaches to education, work, entertainment, and daily life.

As the term is used in the framework and specifications, 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, managing, creating, and communicating information.

Although ICT is just one among many different types of technologies, it has achieved a special prominence in technology and engineering literacy because familiarity and facility with ICT 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 vast collections 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.

Students should be aware of these devices and know how and when to use them. They must have mastered a wide range of ICT tools in common use, and they must have the confidence and capability to learn to use new ICT tools as they become available. Although students are not expected to understand the inner workings of these devices, they should have enough of an understanding of the principles underlying them to appreciate the basics of how they work. 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 Problems;

D. Acknowledgement of Ideas and Information; and

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), and standards and frameworks developed by the Partnership for 21st Century Skills, the American Association of School Librarians, and the International Technology and Engineering Educators Association. The link between these sub-areas and the NETS•S and the Framework for 21st Century Learning is outlined in Appendix F.

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. Several lines of research have shown that teams are more productive than individuals for generating solutions to many kinds of problems, provided team members are effective collaborators. The findings extend to teams that collaborate online as well as face-to-face (Hennessey and Amabile, 2010). For schools, this continuing evolution translates into an 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. In order to be 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. Since the assessment will be administered only to individuals, tasks involving collaboration with others and sending and receiving communications will need to provide virtual, computer-based renditions of remote collaborators.

Key principles in the area of Construction and Exchange of Ideas and Solutions that all students can be expected to understand at increasing levels of sophistication are as follows:

- Communication and collaboration are affected (in terms of quantity, quality, and results) by the choice of digital tools used.
- Digital tools offer many options for formal and non-formal expression in nearly every academic and professional discipline.
- Teams need people with a variety of skills.

Fourth-grade students should understand what is expected from members working as part of a team and should realize that teams are better than individuals at solving many kinds of problems. Students 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 and improving their teamwork. They should be able to synthesize information from different sources and communicate with multiple audiences.

Table 2.10 Construction and Exchange of Ideas and Solutions assessment targets for grades 4, 8, and 12

<table>
<tr><th colspan="3">A. Construction and Exchange of Ideas and Solutions</th></tr>
<tr><td colspan="3">Fourth-grade students should be able to collaborate and communicate by working with other members of a (virtual) 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 (virtual). 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.</td></tr>
<tr><th>Grade 4</th><th>Grade 8</th><th>Grade 12</th></tr>
<tr><td>Students know that:
I.4.1: People collaborating as a team can often produce a better product than people working alone. There are common digital tools that can be used to facilitate virtual or face-to-face collaboration.</td><td>Students know that:
I.8.1: Collaboration can take many forms. Pairs or teams of people can work together in the same space or at a distance, at the same time or at different times, and on creative projects or on technical tasks. Different communications technologies are used to support these different forms of collaboration.</td><td>Students know that:
I.12.1: Effective collaboration requires careful selection of team members, monitoring of progress, strategies for reaching agreement when there are opposing points of view, and iterative improvement of collaborative processes. Information and communication technologies can be used to record and share different viewpoints and to collect and tabulate the views of groups of people.</td></tr>
<tr><td>Students are able to:
I.4.2: Utilize input from (virtual, that is, computer-generated) collaborators and experts or sources in the decision-making process to design a product or presentation.</td><td>Students are able to:
I.8.2: Provide feedback to a (virtual) collaborator on a product or presentation, taking into account the other person’s goals and using constructive, rather than negative, criticism.</td><td>Students are able to:
I.12.2: Work through a simulation of a collaborative process. 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.</td></tr>
<tr><td>I.4.3: Communicate information and ideas effectively to an audience in order to accomplish a specified purpose.</td><td>I.8.3: Communicate information and ideas effectively using a variety of media, genres, and formats for multiple purposes and a variety of audiences.</td><td>I.12.3: Synthesize input from multiple sources to communicate ideas to a variety of audiences using various media, genres, and formats.</td></tr>
</table>

B. Information Research

Research and information capability 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 also 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. And they must 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 understand at increasing levels of sophistication are as follows:

- Increases in the quantity of information available through electronic means and the ease with 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 ensuring 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 and to help solve problems.

Eighth-grade students should be aware of digital and network tools and be able to use them efficiently. 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 for timeliness and accuracy, and they should have developed strategies to check the credibility of sources.

Table 2.11 Information Research assessment targets for grades 4, 8, and 12

<table>
<tr><th colspan="3">B. Information Research</th></tr>
<tr><td colspan="3">Fourth-grade students can use digital and network tools to find information and identify sources that may be biased in some way. Eighth-grade students are able to use digital resources to find information and also 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.</td></tr>
<tr><th>Grade 4</th><th>Grade 8</th><th>Grade 12</th></tr>
<tr><td>Students know that:
I.4.4: Digital and network tools and media resources are helpful for answering questions, but they can sometimes be biased or wrong.</td><td>Students know that:
I.8.4: 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.</td><td>Students know that:
I.12.4: 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.</td></tr>
<tr><td>Students are able to:
I.4.5: Use digital and network tools and media resources to collect, organize, and display data in order to answer questions and solve problems.</td><td>Students are able to:
I.8.5: Select and use appropriate digital and network tools and media resources to collect, organize, analyze, and display supporting data to answer questions and test hypotheses.</td><td>Students are able to:
I.12.5: Select digital and network tools and media resources to gather information and data on a practical task, and justify choices based on the tools' efficiency and effectiveness for a given purpose.</td></tr>
<tr><td>I.4.6: Search media and digital sources on a community issue and identify sources that may be biased.</td><td>I.8.6: Search media and digital resources on a community or world issue and identify specific examples of distortion, exaggeration, or misrepresentation of information.</td><td>I.12.6: 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.</td></tr>
</table>

C. Investigation of Problems

In addition to helping students find information, digital tools are widely used in core school subjects to support students' critical thinking, problem solving, and decision-making. In language arts courses, for example, 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 confident 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.

This sub-area is closely related to the previous one, Information Research, but the focus here is on problem solving and critical thinking as opposed to searching for information. In practice, of course, the two sets of skills will often be applied at the same time, but for the purpose of assessment it is useful to keep them separate.

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

Key principles in the area of Investigation of Problems that all students can be expected to understand at increasing levels of sophistication are as follows:

- Digital tools can be very helpful in generating ideas and solving problems in academic subjects as well as in researching practical problems.
- Digital models can be used to create simulations and test solutions.
- Digital tools can be used to conduct experiments and investigate practical problems.

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 authentic issues by building models and conducting simulations in which they vary certain quantities to test “what if” scenarios.

Twelfth-grade students should be able to use digital tools to research 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 approaches they used in designing the investigation as well as the implications of the results. Twelfth-grade 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 2.12 Investigation of Problems assessment targets for grades 4, 8, and 12

C. Investigation of Problems		
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 hardware or software products.		
Grade 4	**Grade 8**	**Grade 12**
Students are able to: **I.4.7:** Use digital tools and resources to identify and investigate a local issue and generate possible solutions.	**Students are able to:** **I.8.7:** Use digital tools to identify a global issue and investigate possible solutions. Select and present the most promising sustainable solution.	**Students are able to:** **I.12.7:** Use digital tools and resources to identify a complicated global issue and develop a systematic plan of investigation. Present findings in terms of pros and cons of two or more innovative sustainable solutions.
I.4.8: Use digital tools to test simple hypotheses in various subject areas.	**I.8.8:** Use digital tools to gather and display data in order to test hypotheses of moderate complexity in various subject areas. Draw and report conclusions consistent with observations.	**I.12.8:** Use digital tools to collect, analyze, and display data in order to design and conduct complicated investigations in various subject areas. Explain rationale for the design and justify conclusions based on observed patterns in the data.
I.4.9: Use digital models to describe how parts of a whole interact with each other in a model of a system.	**I.8.9:** Use a digital model of a system to conduct a simulation. Explain how changes in the model result in different outcomes.	**I.12.9:** Having conducted a simulation of a system using a digital model, draw conclusions about the system, or propose possible solutions to a problem or ways to reach a goal based on outcomes of the simulation. Critique the conclusions based on the adequacy of the model.

D. Acknowledgement of Ideas and Information

Digital citizenship is an essential element of technology and engineering literacy. As rapid technological advances have increased people's capacity 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. There is therefore a certain amount of overlap between that sub-area and this one, but this sub-area is focused specifically on an especially important category of ethical issues: 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 understand the importance of respecting copyrighted materials so that they will be more likely as adults to continue to honor intellectual property rights and laws protecting patents, trademarks, copyrights, 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 understand at increasing levels of sophistication are as follows:

- Copyright laws and policies are designed to protect intellectual property.
- Fair use guidelines are designed to support the use of copyrighted materials for academic purposes and for journalism and other forms of writing and commentary.
- There are multiple guiding principles (laws, policies, and guidelines) 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 true not just for tests and homework, but also even in everyday conversation. They should also know that copyrighted materials cannot be shared freely.

Eighth-grade students should be aware of general principles concerning the use of other people's ideas and know that these principles are the basis for such things as school rules and federal laws governing such use. 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 understand the importance of giving appropriate credit for others’ ideas and contributions, and they should know how to give such credit.

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 2.13 Acknowledgement of Ideas and Information assessment targets for grades 4, 8, and 12

D. Acknowledgement of Ideas and Information		
Fourth-grade students exhibit digital citizenship by understanding that it is permissible to use others' ideas as long as appropriate credit is given but 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.		
Grade 4	**Grade 8**	**Grade 12**
Students know that: **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.	**Students know that:** **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.	**Students know that:** **I.12.10:** Legal requirements governing the use of copyrighted information and ethical guidelines for appropriate citations are intended to protect intellectual property.
Students are able to: **I.4.11:** Identify or provide examples demonstrating respect for copyrighted material, such as resisting the request from a friend to copy a song from a CD or placing copyrighted material online.	**Students are able to:** **I.8.11:** Identify or provide examples of fair use practices that apply appropriate citation of sources when using information from books or digital resources.	**Students are able to:** **I.12.11:** Identify or provide examples of responsible and ethical behavior that follow 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.

E. Selection and Use of Digital Tools

Until recently, classroom uses of technology tended to focus almost exclusively on helping students become competent users of the technology itself. Educators today have come to 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. Nonetheless, students still require basic operational skills and concepts in order to be effective users of technology for learning. These skills include the capabilities 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 understand at increasing levels of sophistication are as follows:

- Knowledge about the common uses of readily available digital tools supports effective tool selection.
- A fundamental aspect of technology and engineering 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 2.14 Selection and Use of Digital Tools assessment targets 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.4.12:** Different digital tools have different purposes.	**Students know that:** **I.8.12:** Certain 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.12.12:** 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.4.13:** Use digital tools (appropriate for fourth-grade students) effectively for different purposes, such as searching, organizing, and presenting information.	**Students are able to:** **I.8.13:** Use 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.12.13:** Demonstrate the capability to use a variety of digital tools to accomplish a task or develop a solution for a practical 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 the knowledge and capabilities related to technology that will be assessed on the 2014 NAEP Technology and Engineering Literacy Assessment. While these assessment targets represent an important component of technology and engineering literacy, they are not intended to limit the scope of concepts and capabilities that could be addressed in curricula. Since NAEP is an on-demand test, important knowledge and capabilities that should form a part of every students' education but are difficult to assess have been excluded from the framework and specifications.

Although Chapter Two is central to the design of the NAEP Technology and Engineering Literacy Assessment, it is not sufficient in itself to describe the kinds of reasoning to be expected from students, the context or subject matter that will be used to construct test items, or the overall shape of the entire assessment. These issues are taken up in Chapters Three and Four.

CHAPTER THREE: PRACTICES AND CONTEXTS FOR TECHNOLOGY AND ENGINEERING LITERACY

Introduction

Chapter Two described the assessment targets for technology and engineering literacy, both knowledge and skills that NAEP will assess. This chapter describes three generalizable *practices* that represent the kinds of thinking and application that will be expected of students across the three major assessment areas. The chapter also explains the *contexts*, or situations and types of problems, in which assessment tasks and items will be set. These three elements and their relationships are portrayed in Figure 2.

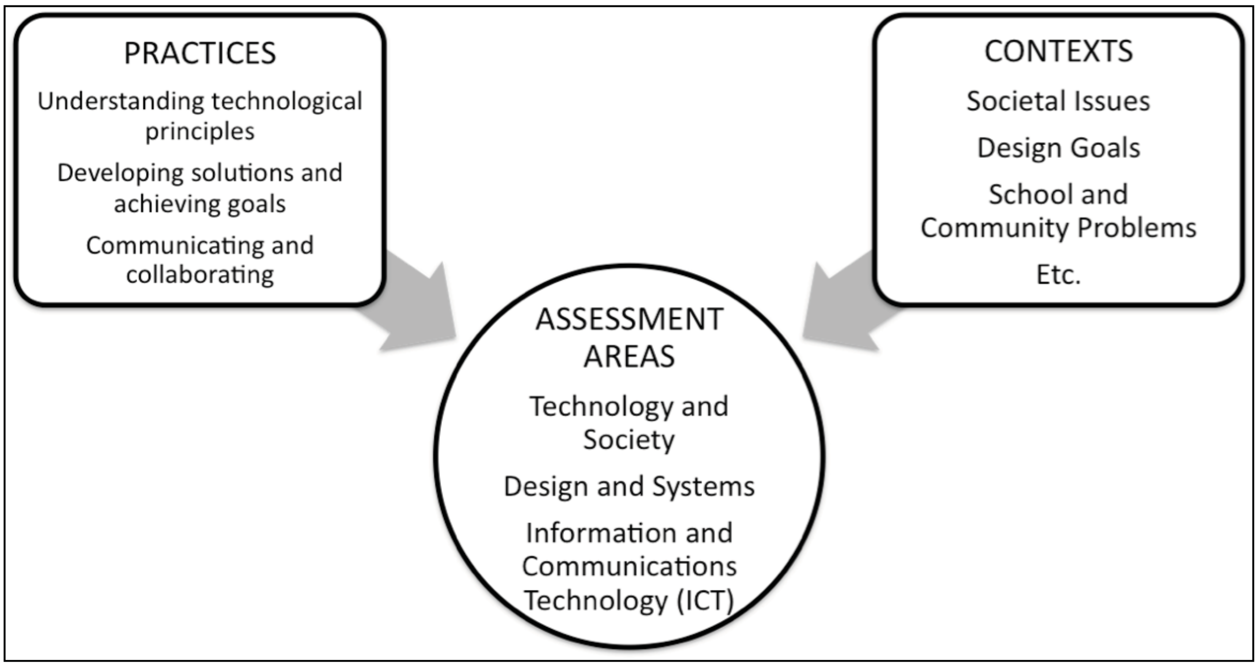


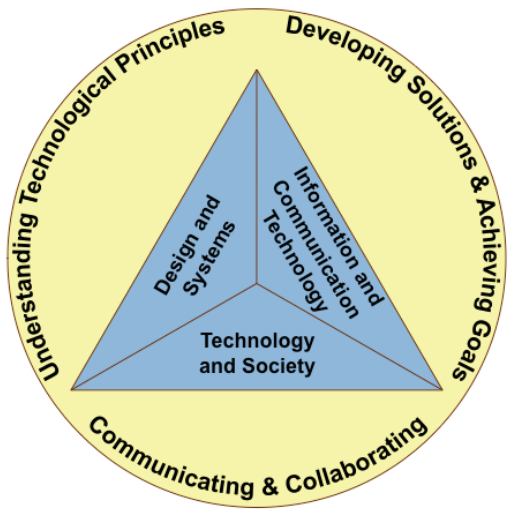
Figure 2 – Elements of the NAEP Technology and Engineering Literacy Assessment

As indicated in Figure 2, the practices expected of students are general, cross-cutting reasoning processes that students must use in order to show that they understand and can use their technological knowledge and skills. The contexts in which technology and engineering literacy tasks and items appear will include typical issues, problems, and goals that students might encounter in school or practical situations. The particular knowledge and skills that are the targets of the assessment lie in the three assessment areas. Together, the assessment targets, practices, and contexts provide a structure for the generation of tasks and items. This chapter describes the practices and contexts in some detail and provides examples of the types of tasks and items that result when these three elements are combined. Some of these illustrative tasks and items were not developed by the original test program to assess technology and engineering literacy. Explanations are provided for such illustrative items for how the tasks and items could be modified to directly assess targets in the framework and specifications.

Practices

Practices contribute to the framework and specifications by articulating the general kinds of thinking and reasoning that students are expected to demonstrate when responding to assessment tasks and items. The framework and specifications specify three generic kinds of practices that apply across the three assessment areas: (1) understanding technological principles; (2) developing solutions and achieving goals; and (3) communicating and collaborating.

Building on the pyramid of major assessment areas introduced in Chapter Two, the practices are distributed around a circle in which the pyramid sits. As critical components of technological literacy, these cross-cutting practices are applied across all three major assessment areas. For example, communicating effectively and collaborating with others are necessary skills for understanding the effects of technology on the natural world, designing an engineering solution to a technological problem, and achieving a goal using information and communication technologies.



The *Science Framework for the 2009 National Assessment of Educational Progress* served as the primary source for these practices. Developers of the science framework had examined the sections on Science and Technology and the Designed World from the *National Science Education Standards* as well as *Benchmarks for Scientific Literacy* and cognitive research on science learning. Learning research has shown that these three kinds of cognitive processes represent how all individuals build their content knowledge and understanding in a subject area and how they develop strategies for using their knowledge in their thinking, reasoning, and application to new situations. To create the practices for the NAEP Technology and Engineering Literacy Framework and Assessment Specifications, the cross-cutting practices from the *Science Framework for the 2009 NAEP* were modified so that they applied to processes relevant to technological literacy, primarily by indicating that technology and engineering literacy depends on having and using knowledge about technologies to reason, develop solutions, communicate and collaborate. In addition, the national, international, and state technology and engineering 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 cross-cutting practices will help developers produce a range of rich and challenging assessment tasks and items. A brief description of each of these three practices is offered below.

Understanding Technological Principles focuses on students' knowledge and understanding of technology and their capability to think and reason with that knowledge. This practice ranges from the knowledge of simple declarative facts and concepts to higher-level reasoning about facts, concepts, and principles and their interrelationships. Students should be able to call upon their recognition and understanding of technological principles to explain features and functions of technologies and systems, how components fit together, and to make predictions, comparisons, and evaluations. The assessment targets that elicit this practice require students to identify examples, explain, describe, analyze, compare, relate, and represent the technological principles specified in Chapter Two. This practice also includes understanding the relationships among components of systems and interactive processes.

Developing Solutions and Achieving Goals refers to students' systematic application of technological knowledge, tools, and skills to address problems and achieve goals presented in societal, design, curriculum, and realistic contexts. This practice includes both procedural and strategic capabilities—knowing how to apply simple steps and use technological tools to address authentic tasks, as well as when and where to apply the tools and design and problem solving strategies. This practice draws upon the previous practice—to understand technological principles—and adds the dimension of applying this knowledge to solve problems and achieve goals. This practice involves using fundamental problem solving processes such as planning, monitoring, evaluating, and revising, and how these generic problem solving strategies can be employed in the three assessment areas. It may engage students in analyzing goals, planning, designing, and implementing as well as in iteratively revising and evaluating possible solutions to meet the requirements of a problem or to achieve a goal. For the NAEP Technology and Engineering Literacy Assessment, a distinguishing feature of this practice is that the students respond to questions and tasks during the process of solving a multi-stage problem or working through how best to achieve a goal, using their understanding of technological principles to do so.

Communicating and Collaborating centers on students' capabilities 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, models, arguments, and presentations. Effective teamwork and collaboration with peers and experts who are either present or in another location are important skills that can help students achieve their goals. In the assessment, collaboration tasks will engage individual students with virtual (computer-generated) peers and experts. Communication and collaboration are critical, cross-cutting practices in all subject domains. For technology and engineering literacy, these practices are distinguished by students' facility with a range of technologies to communicate and collaborate.

Table 3.1 presents generic examples of how these three practices can be used to classify targets in the three major assessment areas. These are sample ideas for items and tasks and will not be used in the actual assessment. It should again be noted that the boundaries between the practices are not entirely distinct, but referring to these three practices can be helpful in the development of tasks and items and the interpretation of student performance for a range of cognitive demands.

Table 3.1 Classification of types of assessment targets in the three major assessment areas according to the practices for technology and engineering literacy

	Technology and Society	Design and Systems	Information and Communication Technology
Understanding Technological Principles	**Analyze** advantages and disadvantages of an existing technology **Explain** costs and benefits **Compare** effects of two technologies on individuals **Propose** solutions and alternatives **Predict** consequences of a technology **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** and compare relevant features **Critique** a process or outcome **Evaluate** examples of effective resolution of opposing points of view **Justify** tool choice for a given purpose
Developing Solutions and Achieving Goals	**Select** appropriate technology to solve a societal problem **Develop** a plan to investigate an issue **Gather and Organize** data and information **Analyze and Compare** advantages and disadvantages of a proposed solution **Investigate** environmental and economic impacts of a proposed solution **Evaluate** trade-offs and impacts of a proposed solution	**Design and Build** a product using appropriate processes and materials **Develop** forecasting techniques **Construct and Test** a model or prototype **Produce** an alternative design or product **Evaluate** trade-offs **Determine** how to meet a need by choosing resources required to meet or satisfy that need **Plan** for durability **Troubleshoot** malfunctions	**Select and Use** appropriate tools to achieve a goal **Search** media and digital resources **Evaluate** credibility and solutions **Propose and Implement** strategies **Predict** outcomes of a proposed approach **Plan** research and presentations **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 **Represent** alternative analyses and solutions **Display** positive and negative consequences using data and media **Compose** a multimedia presentation **Produce** an accurate timeline of a technological development **Delegate** team assignments **Exchange** data and information with virtual peers and experts	**Display** design ideas using models and blueprints **Use** a variety of media and formats to communicate data, information, and ideas **Exhibit** design of a prototype **Represent** data in graphs, tables, and models **Organize, Monitor, and Evaluate** the effectiveness of design teams **Request** input from virtual experts and peers **Provide and Integrate** feedback	**Plan** delegation of tasks among team members **Provide and Integrate** feedback from virtual peers and experts to make changes in a presentation **Critique** presentations **Express** historical issues in a multimedia presentation **Argue** from an opposing point of view **Explain to** 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 Understanding Technological Principles, Developing Solutions and Achieving Goals, and Communicating and Collaborating can be used to classify the general types of thinking and reasoning intended by the assessment targets in the three major assessment areas of Technology and Society, Design and Systems, and Information and Communication Technology (ICT).

Practices Applied in 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.

Understanding Technological Principles

To provide evidence that they understand principles in these three sub-areas, students could be asked to perform a variety of tasks, such as recognizing examples of the effects of technologies; identifying examples of ethical and equity issues; describing local and global effects of technologies; explaining the effects of rapidly changing technologies on knowledge creation, access, and management; analyzing beneficial and negative impacts; recognizing examples of responsible, ethical uses of technologies; comparing costs and benefits of technologies; predicting potential impacts on society and the environment; and explaining the relationships among technologies.

Developing Solutions and Achieving Goals

Students must *use* their understanding of the technological principles for Technology and Society specified in Chapter Two to *apply* that knowledge as they address novel issues and problems. To demonstrate their capacity to address issues and problems in the assessment area of Technology and Society, students could be asked, for example, to develop alternative proposals for a new technology based on an analysis of potential positive and negative impacts. Problem solving practices could be demonstrated in a series of tasks and items involved in 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 communicate and collaborate with others (virtual others in the assessment) in the course to responding to an issues, students must *draw upon* their understanding of the technological principles specified in Chapter Two and *apply* their knowledge as they work through given problems and issues. For example, 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. Students can evaluate the qualifications, credibility, and objectivity of virtual experts. Tasks can require students to demonstrate their capability to interact, collaborate, and contribute to work as a team. Students can use various media and representations to share their analyses and recommendations.

Table 3.2 provides some examples of how the three practices can be applied to assessment targets for Technology and Society in order to generate tasks and items at the middle school level. The key principles and targets were selected from Tables 2.2-2.5 in Chapter Two. These are sample ideas for items and tasks and will not be used in the actual assessment. Simpler tasks could be developed for grade 4 targets and more complex tasks could be developed for grade 12 targets.

Table 3.2 Examples of grade 8 tasks representing practices in each sub-area of Technology and Society

Selected Principles / Practices	A. Interaction of Technology and Humans	B. Effects of Technology on the Natural World	C. Impacts on the World of Information and Knowledge	D. Ethics, Equity, and Responsibility
	The relationship between technology and society is reciprocal. Society drives technological change, while changing technologies in turn shape society.	Reusing, recycling, and using fewer resources can reduce environmental impacts.	Information technology is evolving rapidly, enabling ever-increasing amounts of information and data to be stored, managed, enhanced, analyzed, and accessed through a wide array of devices in various media formats.	Technology by itself is neither good nor bad, but its use may affect others.
Understanding 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?
Developing Solutions and Achieving Goals	The community has decided to implement a new wind turbine system. Design an investigation into the impact on the community.	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 (virtual) 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.	Present a set of images from two artists of the period that represent different perspectives on a major event.	Debate with a virtual team member the privacy and safety issues involved in establishing international projects.

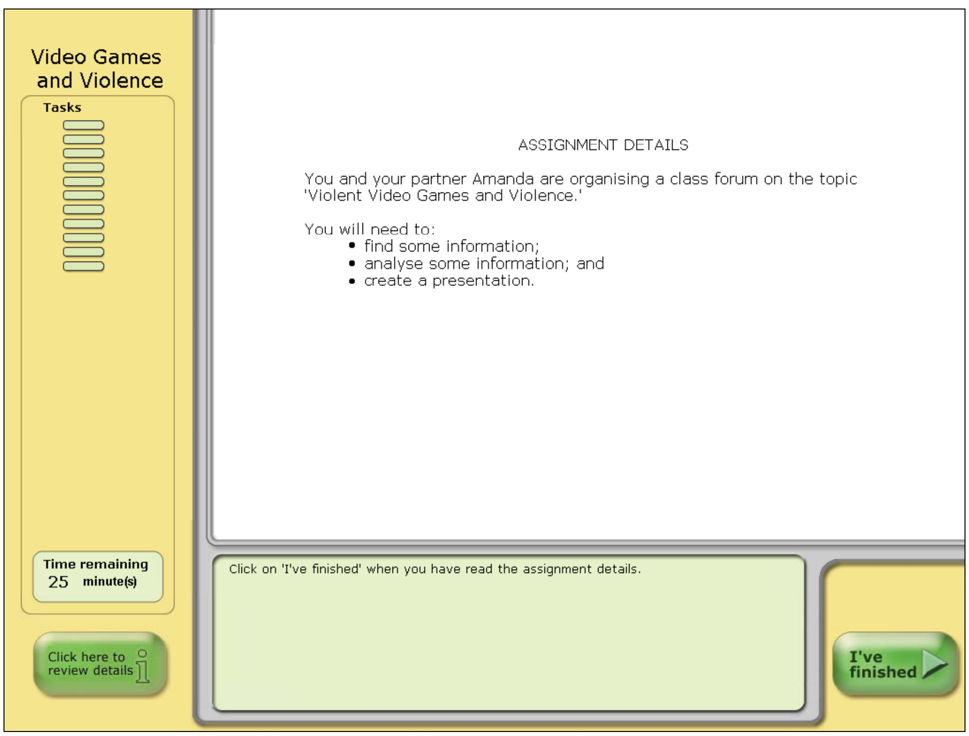
Illustrative Tasks and Items

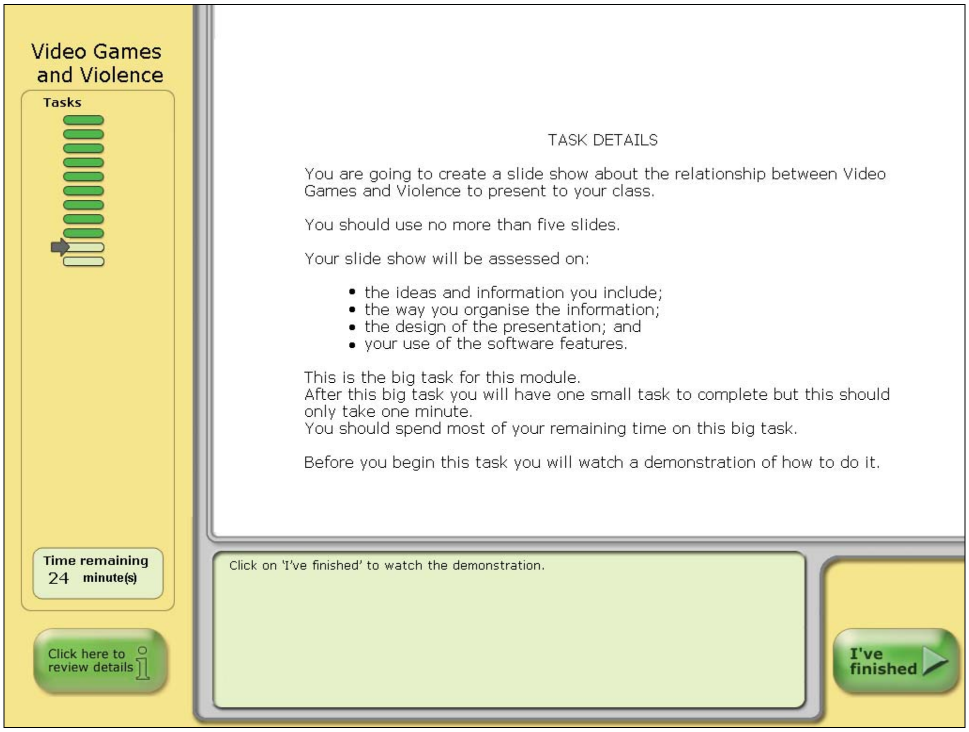
The following examples represent three types of tasks and items that could be used to assess targets related to the Technology and Society assessment area. The first example is a scenario-based set of items, and the next two are familiar, conventional constructed and selected response items.

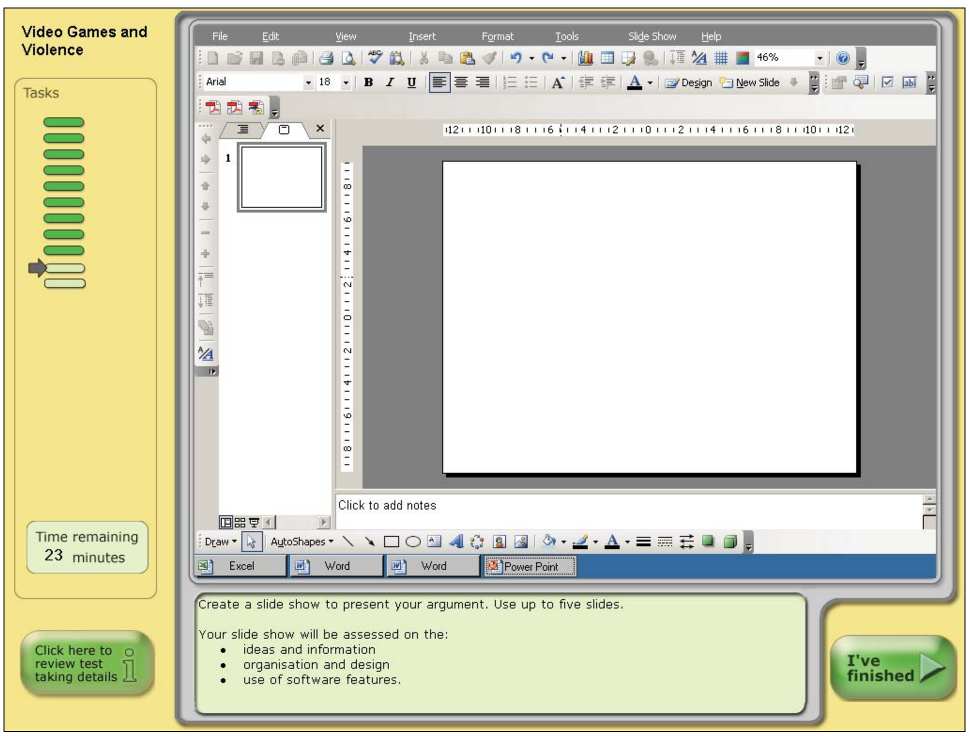
Scenario-Based Item Sets

Items of this type present students with a problem or goal set within a broader context. The example below calls upon the student to employ the practice of Developing Solutions and Achieving Goals. In this task, the student must use ICT tools to analyze the impacts of technology on human society. This example employs a computer-based interactive format in which students search for information concerning video games and violence and then use word processing, spreadsheet, and Web-based tools to develop a PowerPoint presentation. The PowerPoint presentation calls upon the cross-cutting practice of Communicating and Collaborating.

Context: Human Society
Topic: Video Games and Violence
Target Level: Grade 12







(Source: Australian Ministerial Council for Education, Early Childhood Development and Youth Affairs [MCEECDYA], 2008)

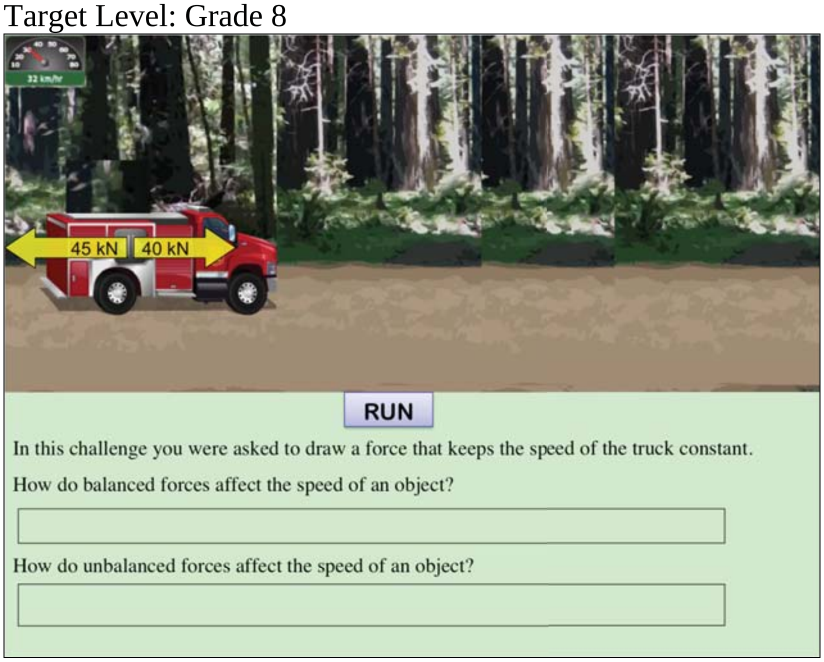
Conventional Items

These items will ask for students to select or construct their answers. The examples below are of the familiar constructed and selected response formats.

Constructed Response

This task illustrates students' skill in using simulations in a problem solving activity. The student *constructs* a response by manipulating force arrows in a simulation-based scenario in which an emergency rescue truck must deal with various problems along a fire road in a forest. The student *constructs* text-based explanations of the balanced and unbalanced forces acting on the truck. While designed to be used as a middle school science item about force and motion, such a simulation could be adapted for the NAEP Technology and Engineering Literacy Assessment to study how the design of the technological system (transportation) affects the environment positively by making it possible to contain forest fires and rescue people and also negatively because of the cutting of trees and the disruption of wildlife habitat. This task also illustrates an interactive item in which students can manipulate different factors in a simulated environment and then provide responses to questions related to the scenario. For the NAEP Technology and Engineering Literacy Assessment, a series of items could call upon the practices of Understanding Technological Principles (e.g., describing positive and negative effects of roads in the forest) and Developing Solutions and Achieving Goals (e.g., designing a fire road that would not cross wildlife migration corridors).

Context: Transportation
Topic: Emergency Rescue
Target Level: Grade 8



(Source: Quellmalz, Timms, & Buckley, 2009)

Selected Response - Multiple Choice

In this conventional multiple choice item, the student selects an answer that describes the effect of fossil fuel on the natural environment, employing the practice of Understanding Technological Principles to analyze positive and negative effects. This item assesses student understanding of the interaction of a technology (energy production) and climate change. The combination of the two can be thought of as a system, with each affecting the other, and the item below also assesses a student's system thinking, albeit on a relatively simple level. Similar items in the NAEP Technology and Engineering Literacy Assessment could focus on the effects of technology on the environment.

Context: Natural World
Topic: Climate Change
Target Level: Grade 8

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) A warmer climate

(B) A cooler climate

(C) Lower relative humidity

(D) More ozone in the atmosphere

(Source: Trends in International Mathematics and Science Study, 2003)

Practices Applied in 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.

<u>Understanding Technological Principles</u>

Technological principles for Design and Systems in Chapter Two specify for this assessment the core understandings that students should have about the different types of technologies, processes for designing technologies, approaches to preventing failures, and how components of technological systems interrelate. The practices for Understanding Technological Principles in these areas could, for example, ask students to draw upon their knowledge to identify examples of technologies, components of the design process, 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.

Developing Solutions 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 skills in assessment tasks for this area. Such tasks could require them to develop designs, to propose or critique solutions to problems after being given criteria and constraints, to select appropriate resources by considering trade-offs, to construct and test a model or prototype, to troubleshoot systems and applications, or to determine the consequences of making a change in a system. Students must use their understandings about the technological principles specified for Design and Systems in Chapter Two as they plan, try out, critique, and revise attempted solutions.

Communicating and Collaborating

Communication and collaboration practices are integral to achieving the goals of technological design and systems. Students can demonstrate teamwork in tasks where design assignments are distributed among team members, progress and results are integrated and shared, and products are 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. Students must *use* their understandings of the technological principles specified for both Design and Systems and ICT in Chapter Two to use tools and strategies to communicate and collaborate. Since students are completing the assessment individually on the computer, collaborators will be virtual, that is, presented by the computer.

Table 3.3 offers examples of how the three practices can be applied to assessment targets for Design and Systems to generate tasks and items for the middle school level. The key principles and grade 8 targets were selected from Tables 2.6-2.9 in Chapter Two. The Chapter Two tables present simpler versions of the targets for grade 4 and more challenging versions of the targets for grade 12. Again, these are sample ideas for items and tasks and will not be used in the actual assessment.

Table 3.3 Examples of grade 8 tasks representing practices in each sub-area of Design and Systems

	A. Nature of Technology	B. Engineering Design	C. Systems Thinking	D. Maintenance and Troubleshooting
Selected Principles / **Practices**	Technologies developed for one purpose are sometimes adapted to serve other purposes. Technological development involves creative thinking.	Requirements for a design challenge include the criteria for success and the constraints or limits that cannot be violated in a solution.	All technological systems have parts that work together to accomplish a goal.	Tools and machines must undergo regular maintenance to ensure their proper functioning.
Understanding 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.	How do the physical and human components of the school cafeteria food service system work together? (animation)	Why do Bill and Sally oil their bike chains and axles and check the brakes each month? What may happen if they do not?
Developing Solutions 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.	Design modifications to the cafeteria for people with a particular physical disability (e.g., vision, mobility). (animation)	Bill's new bike gears are not working correctly. What should he do?
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?	Collaborate with a virtual group of people to re-design the tasks of the cafeteria staff, given the new machines.	Bill, Sally, and many other students would like to ride their bikes to school. Present a design for a bike parking lot at the school.

Illustrative Tasks and Items

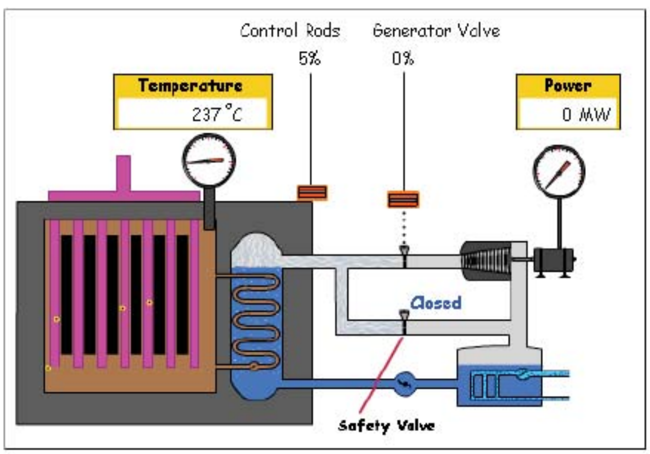
These items from existing tests were selected as examples that could be adapted for assessing targets in Design and Systems. Each item is analyzed for the ways in which it would call upon the practices.

Scenario-Based Item Set

In this example, students are asked a series of questions related to a simulation of a nuclear reactor. In the NAEP Technology and Engineering Literacy Assessment, the questions might relate to all three practices. Students may be asked to demonstrate the practice of Understanding Technological Principles by identifying the inputs and outputs of the system or analyzing the potential hazards. Students might employ the practice of Developing Solutions and Achieving Goals in items asking for results of investigations based on manipulating the simulation to find safe levels of temperature and power. The practice of Communicating and Collaborating could be elicited in tasks involving virtual (that is, computer-generated) experts in preparing a report of findings.

Context: Energy
Topic: Nuclear Reactor
Target Level: Grade 8

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: Organisation for Economic Co-operation and Development, 2005)

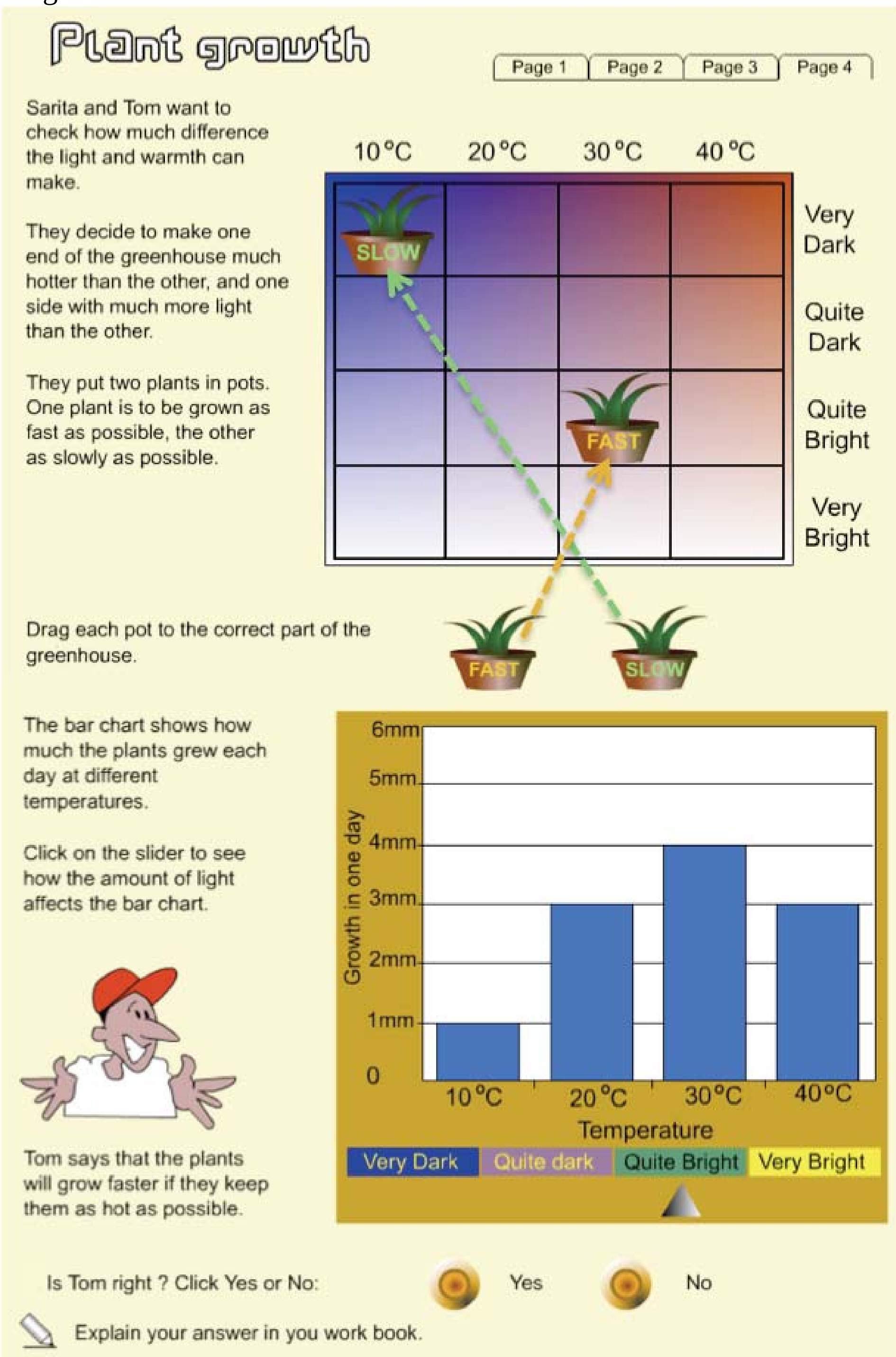
Conventional Items

These items will ask for students to select or construct their answers. The examples below are of the familiar constructed and selected response formats.

Constructed Response

Similar to the previous example, this item represents a sample task in which students must use their knowledge about the engineering design process to answer a constructed response item. The practice of Understanding Technological Principles is measured by this computer-based item. In this item, students use various tools to explore the factors that affect plant growth in a greenhouse. In the NAEP Technology and Engineering Literacy Assessment, a similar item might ask students to evaluate different greenhouse designs in terms of their effects on plant growth.

Context: Plant Growth
Topic: Designing a Greenhouse
Target Level: Grade 12



(Source: Adapted from Ripley, 2009)

Selected Response – Multiple Choice

The following item is another conventional item type—in this case, multiple choice. Students would employ the practice of Understanding Technological Principles by demonstrating their knowledge about the engineering design process.

Context: Product Design
Topic: The Design Process
Target Level: Grade 12

An assignment for the design of an emergency light is described in the box below.

Design and build an emergency light. It must have its own battery, provide a bright light, and have a built-in charger. It must be capable of operating while being charged. It must have a watertight enclosure with a handle on the top.

After receiving this assignment, which of the following **most likely** would be the next step in the engineering design process?

A. testing and evaluation

B. selecting the best solution

✓ **C.** investigation and research

D. construction of a prototype

(Source: Massachusetts Department of Elementary and Secondary Education, 2009)

Practices Applied in Information and Communication Technology (ICT)

ICT literacy includes the capability to communicate ideas and solutions, to collaborate with peers and experts, 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.

Understanding Technological Principles

The principles in the ICT assessment area involve understanding the variety of ICT tools and how and when they can be used to accomplish a wide variety of tasks in school and in practical, out-of-school situations. Students will need to know about the general features and functions of types of ICT tools, which tools are appropriate for particular purposes, and to understand criteria for determining if the tools were used appropriately and well.

Developing Solutions and Achieving Goals

ICT tools can be employed to support problem solving and achievement of goals in all three of the technology and engineering 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, investigating problems, meeting the needs of society, constructing and exchanging information and ideas, and acknowledging 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 ICT tools to solve a problem or achieve a goal; or to use ICT tools to plan an approach to solving a problem, represent data, analyze results, and summarize and present findings. Students must *use* their understandings about the features and functions of ICT tools in order to *apply* the tools appropriately and effectively to develop solutions and achieve goals for given tasks and problems.

Communicating and Collaborating

ICT capabilities rely heavily on students' command of communication and collaboration skills. Students can be asked to demonstrate the capability to contribute effectively to a body of knowledge or to take part in group deliberations through social media (simulated in the assessment) and the use of other contemporary communication tools and structures. Students can be asked to investigate a problem or pursue a goal as individuals or with a group (virtually), to integrate input (provided in the task) from multiple collaborators (virtual) who are peers or experts, 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. To communicate and collaborate effectively, students will need to *use* their understandings about features and functions of communication and collaboration tools and *apply* their knowledge and understanding of the ICT tools and strategies to communicate and collaborate effectively.

Table 3.4 provides some examples of how the three practices can be applied to assessment targets for Information and Communication Technologies to generate tasks and items at the middle school level. The key principles and grade 8 targets were selected from Tables 2.10-2.14 in Chapter Two. Those tables further describe simpler targets at grade 4 or more complex targets at grade 12. These are sample ideas for items and tasks and will not be used in the actual assessment.

Table 3.4 Examples of grade 8 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. Acknowledg-ement of Ideas and Information**	**E. Selection and Use of Digital Tools**
Selected Principles / **Practices**	Digital tools offer many options for formal and non-formal expression in nearly every academic and professional discipline.	Important strategies for ensuring 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 very helpful in generating ideas and solving problems in academic subjects as well as in researching practical problems.	There are multiple guiding principles (laws, policies, and guidelines) that govern the use of ideas and information.	Knowledge about the common uses of readily available digital tools supports effective tool selection.
Understanding Technological Principles	Describe how graphics, text, and tables convey a message.	From among a group of Web pages select the particular one 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 an appropriate way to give credit to another student's graphic.	Critique a digital tool suggested for designing an online story.
Developing Solutions and Achieving Goals	Develop an online survey for elementary school students concerning the design of a new playground.	Create a digital story about a 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 (computer-generated) collaborators explaining why the search results of only one of the collaborators have 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.

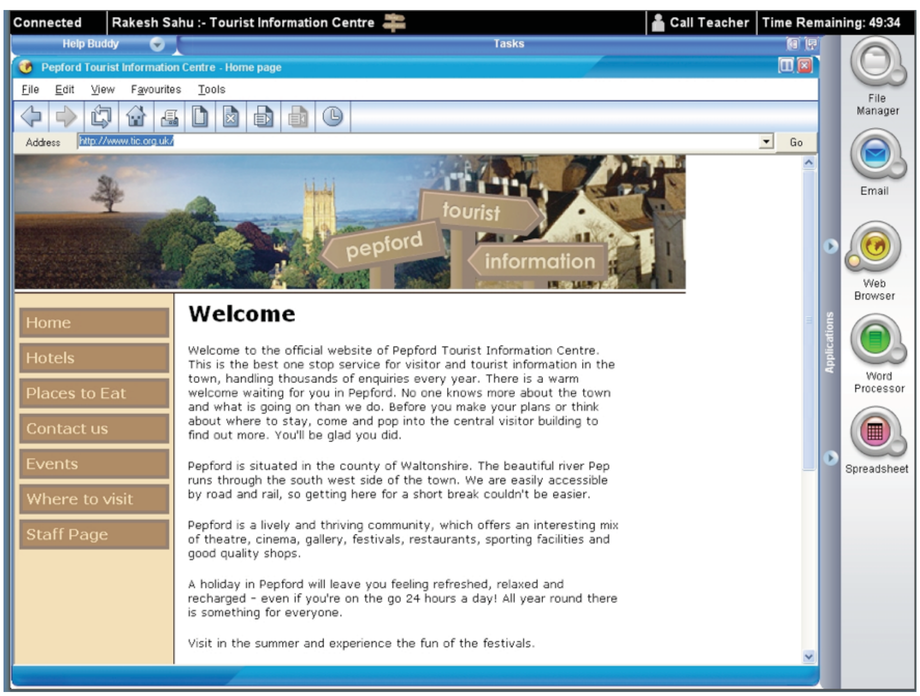
<u>Illustrative Tasks and Items</u>

The following tasks and items illustrate how the three practices apply to ICT assessment targets. The practices may be elicited by extended, scenario-based task and item sets or by separate items.

Scenario-Based Item Sets

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 use these ICT tools to accomplish the task, not on the quality of the brochure. The process is more important than the outcome. Students use the practice of Understanding Technological Principles by calling upon their knowledge of which ICT tools to use to accomplish the goal and how to use them. Students also apply the practice of Developing Solutions and Achieving Goals as they conduct their information research. The practice of Communicating and Collaborating is not assessed directly in this task, although it could be added by including tasks assessing the quality of the brochure for communicating to the intended audience and tasks involving the assignment of information gathering from virtual (computer-generated) collaborators and the integration of their (virtual) input into the brochure.

Context: Travel and Tourism
Topic: Promotional Brochure
Target Level: Grade 8



(Source: Ripley, 2009)

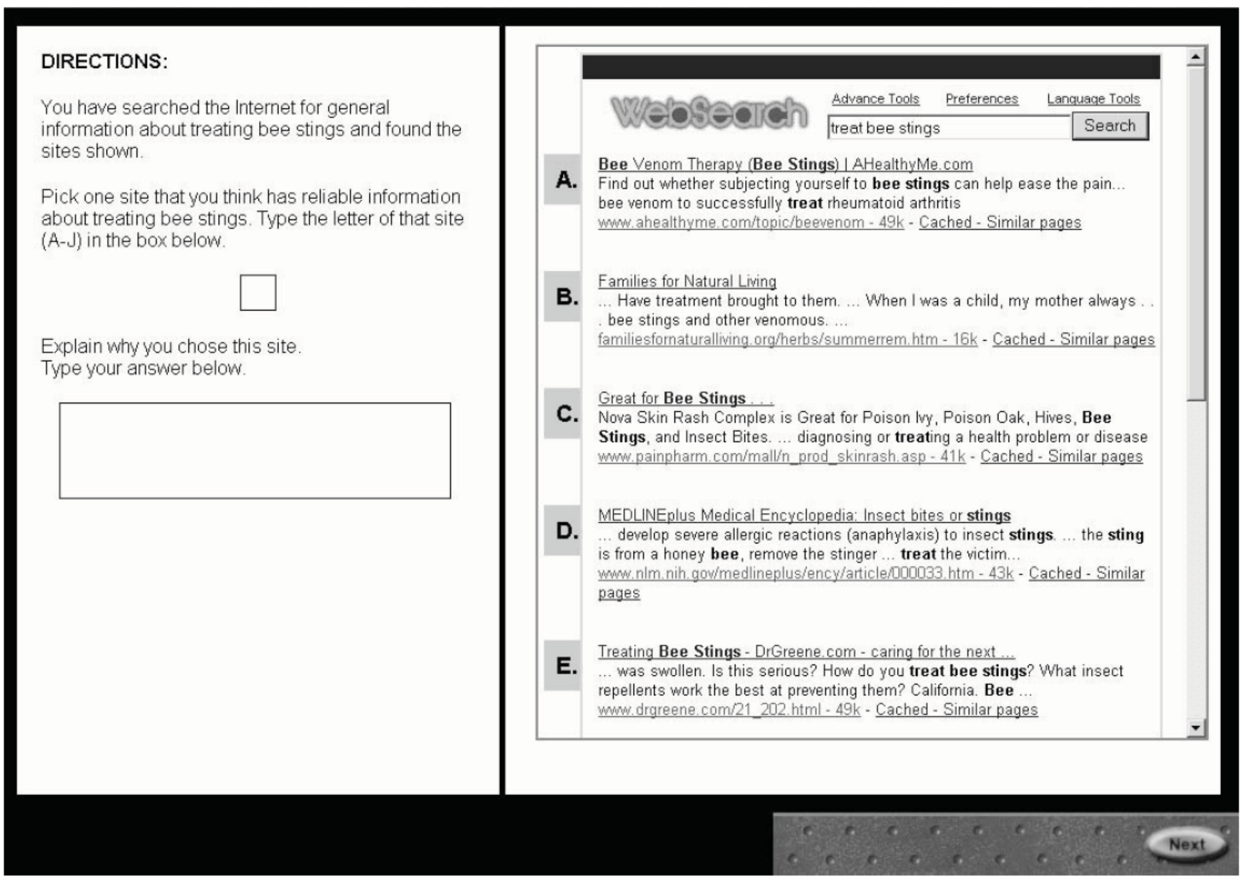
Conventional Items

These items will ask for students to select or construct their answers. The examples below are of the familiar constructed and selected response formats.

Constructed and Selected Response

In this task, students are presented with a list of Web sites from the results of a Web search. Students must decide which website has the most reliable information and justify their response. The practice of Understanding Technological Principles is applied to students' knowledge of criteria for how to judge the credibility and quality of information sources—one of the ICT targets in Information Research.

Context: Medicine
Topic: Web Search
Target Level: Grade 8

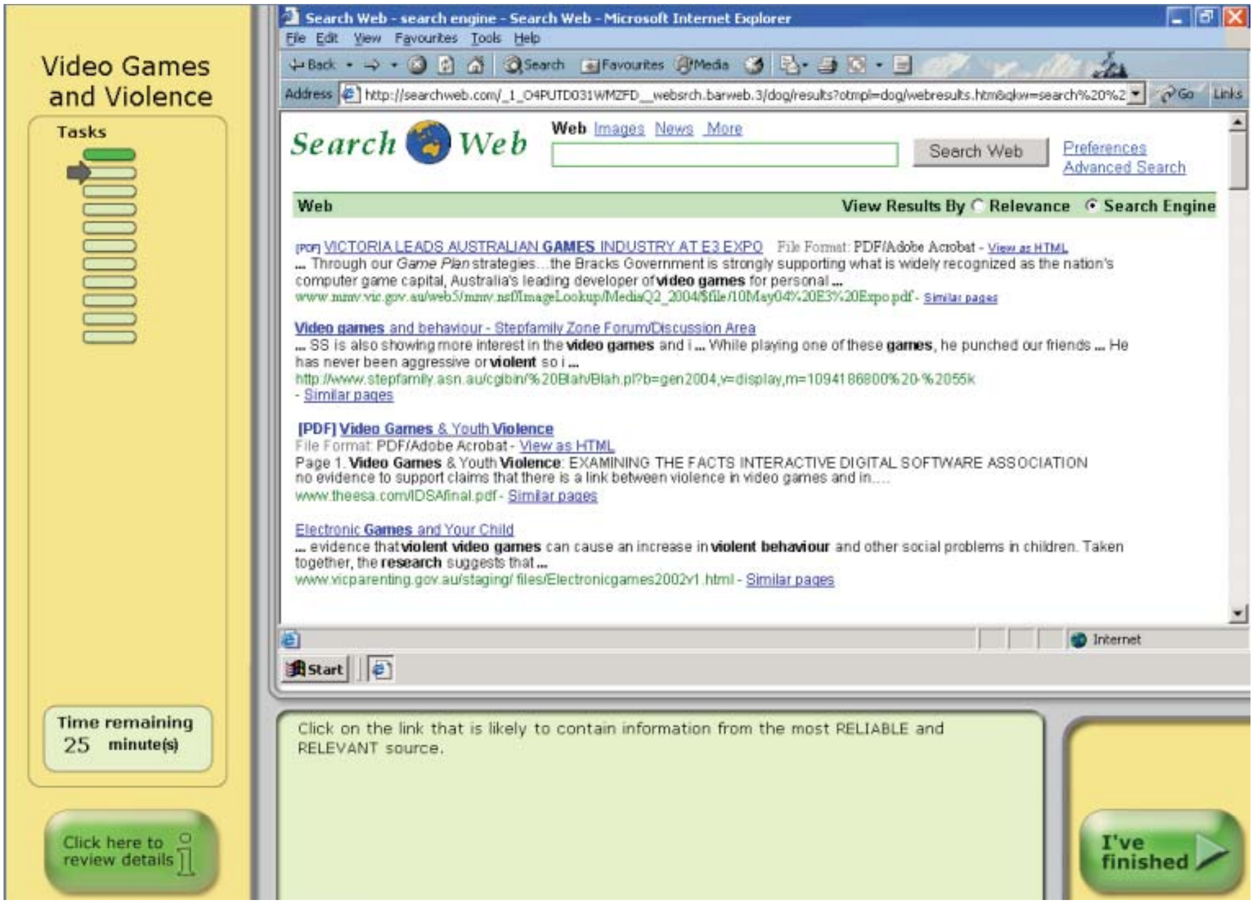


(Source: Lennon et al., 2003)

Selected Response - Multiple Choice

This multiple choice item also assesses a student's capability to evaluate Web sites, an example of the practice Understanding Technological Principles. This example also demonstrates a computer-based selected response format.

Context: The Internet
Topic: Website Search
Target Level: Grade 12



(Source: Australian MCEECDYA, 2008)

Contexts

Technology and engineering 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 effects on society, and use technological principles and tools to develop solutions to problems and meet goals. Consequently, NAEP Technology and Engineering Literacy assessment items will measure students' technology and engineering literacy in the context of relevant societal issues, design problems, and school and community goals. Since the three areas of technological literacy to be measured by NAEP tend to focus on somewhat different types of issues, problems, and goals, the contexts and situations that will frame the technology assessment items in these areas will differ somewhat as well.

Contexts in 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 these devices while operating their vehicles. Similarly, farming practices have increased crop production, but they have also risked contaminating sources of groundwater. Such issues can clearly be used as contexts for NAEP Technology and Engineering Literacy Assessment items (as illustrated in ISTE's NETS, the framework of the Partnership for 21st Century Skills, and ITEEA's Standards for Technology Literacy). The contexts for tasks and items in the area of Technology and Society may include such technologies with positive and negative effects and may also present 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; and
- Electronic communications context: personal communication devices.

Table 3.5 Examples of how different contexts may be used to generate tasks and items for Technology and Society for grade 8

	A. Interaction of Technology and Humans	B. Effects of Technology on the Natural World	C. Effects of Technology on the World of Information and Knowledge	D. Ethics, Equity, and Responsibility
Key Principles	Society drives technological change, while changing technologies in turn shape society.	Some technological decisions put environmental and economic concerns in competition with one another, while others have positive effects for both the economy and the environment.	Information technology is evolving rapidly, enabling ever-increasing amounts of information and data to be stored, managed, enhanced, analyzed, and accessed through a wide array of devices in various media formats.	Technology by itself is neither good nor bad, but its use may affect others.
Context: Agriculture and Health: 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: Energy: 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 effect that wind turbines might have on others in the community.
Context: Electronic Communication	What are the positive and negative effects that personal communication devices may have on traditional human communication?	Describe the effect 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 effect be of allowing personal communication devices to be used in school?

Contexts in Design and Systems

Nearly all of the products and processes in human society result from the development of one or more kinds of technology. Homes, factories, and farmhouses are built using construction technologies. Fruits and vegetables are grown and processed using agricultural technologies and are brought to market and to the dinner table with transportation technologies. Methods of extracting and using fuels to produce power 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, the framework and specifications identify the following technology areas that can be used as contexts to measure students' understanding of design and systems (drawn primarily from ITEA, 2007):

- Agricultural and related biotechnologies;
- Construction technologies;
- Energy and power technologies;
- Information and communication technologies;
- Materials and manufacturing;
- Medical technologies; and
- Transportation 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. The scenarios would be simpler for grade 4 and more complex for grade 12.

Table 3.6 Examples of how different contexts may be used to generate tasks and items for Design and Systems for grade 8

	A. Nature of Technology	B. Engineering Design	C. Systems Thinking	D. Maintenance and Troubleshooting
Key Principles	Scientists are concerned with what exists in nature; engineers modify natural materials to meet human needs and wants.	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.	Systems may include subsystems and may interact with other systems. Systems may also be embedded within larger systems.	Tools and machines must undergo regular maintenance to ensure their proper functioning.
Context: Transportation	How have transportation methods changed over time?	Propose two different ways to modify an intersection to make it safer.	What are the advantages of container cargo ships over other ways to transport goods to market?	What problems might occur if engines are not oiled periodically?
Context: Medical Technology	What were the technological advances that allowed medical researchers to develop vaccines?	Identify the requirements for a prosthetic arm that will enable a person to play tennis.	Name several elements of the nation’s medical system and describe how they are related.	What procedures would you recommend for maintaining the school’s first aid kits?
Context: Energy: Wind Turbine	What natural constraints exist in a city 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, identify the goals, inputs, processes, outputs, and feedback and control features.	Using the simulation model of a residential wind turbine, describe which parts of the machine would require the most maintenance.
Context: Information and 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.	Explain two ways in which personal communication devices can work together for a team to achieve its project goal.	Describe a set of troubleshooting steps that would be appropriate for analyzing a problem with a printer.

It is important to note that students are not expected to be familiar with the specific components and working details of any particular 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 may be used to provide the context for 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 2014 NAEP Technology and Engineering Literacy Framework and Assessment Specifications, and that is Information and Communication Technology (ICT).

Contexts in 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 society, and some level of technology and engineering 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 all the particular contexts for items that NAEP will design to assess students' knowledge of it and their capabilities to put it to use. ICT knowledge and skills can be applied in the context of developing and using any of the technologies included in Table 3.7, 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 in and out of school for solving problems or working to meet a goal. ICT tools have become integral supports for learning school subjects. People who are literate in technology and engineering should be able to select and use technological tools to research a period in history, compare cultures, collect and display data in a scientific investigation, develop a story or presentation, or produce a work of art. The types of scenarios used to assess students' knowledge and skills in this area will require that the item provide an opportunity for students to demonstrate their understanding of and capabilities to use ICT to address goals and problems in Technology and Society, in Design and Systems, and, more generally, in various disciplines, and in real-world, 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 sub-areas of ICT.

Table 3.7 Examples of how different contexts may be used to generate tasks and items for Information and Communication Technology (ICT) for grade 8

	A. Construction and Exchange of Ideas and Solutions	B. Information Research	C. Investigation of Problems	D. Acknowledg-ement of Ideas and Information	E. Selection and Use of Digital Tools
Key Principles	Digital tools offer many options for formal and non-formal expression in nearly every academic and professional discipline.	Important strategies for ensuring quality of information include 1) assessing the source of information and 2) using multiple sources to verify the information in question.	Digital tools can be very helpful in generating ideas and solving problems in academic subjects as well as in researching practical problems.	Fair use guidelines are designed to support the use of copyrighted materials for academic purposes and for journalism and other forms of writing and commentary.	A fundamental aspect of technological literacy is the possession of foundational ICT skills in the use of common productivity tools.
Context: Practical Applications: 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 the appropriate use of media to provide information to appropriate audiences and also the appropriate citation of sources.	Synthesize data from a variety of sources (census, local economy, demographics, industry, history) to show 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 at a local community meeting and then make decisions as to the 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: Energy: 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 associated resources from a wind turbine manufacturer and determine how best to give appropriate credit for the information and images used in a presentation to promote residential wind turbines.	Using the information provided in the text, choose from the available digital tools and create a multimedia information packet to promote residential wind turbines.
Context: School Subject: History	Taking the role of a student during the Civil War, refer to examples from the online archives to compose a letter and photo essay describing the First Battle of Bull Run.	Conduct research in online libraries (e.g., Library of Congress) synthesizing news accounts and pictures on the events and their impacts.	Working with online archives, compare the hardship endured by civilians during the First Battle of Bull Run and during the Battle of Gettysburg.	Develop credits and acknowledgements for your online sources.	Explain how the ICT tools you used contributed to a presentation on the Battle of Gettysburg.

The intent of placing technology and engineering literacy assessment tasks and items in a range of contexts is to ensure that students have the opportunity to demonstrate what they know and can do across many types of problems and situations. By sampling student knowledge and skills in a variety of contexts and practices, the assessment will provide a broad and deep picture of technology and engineering literacy proficiencies.

CHAPTER FOUR: OVERVIEW OF THE ASSESSMENT DESIGN AND SPECIFICATIONS FOR ITEM DESIGN

Introduction

This chapter provides an overview of the major components of the assessment design. It begins with a brief description of the 2014 NAEP Technology and Engineering Literacy Assessment and follows that with a discussion of the types of assessment tasks and items, how they can be used to measure student understanding and skills, how students will respond to these tasks, and how their responses will be monitored and evaluated. In addition, this chapter describes how the assessment should be balanced across the major assessment areas in technology and engineering literacy as well as across the practices. The types of items to be included in the assessment are described, and examples are provided.

Chapter Five, which follows this one, addresses accessibility issues that also need to be considered in the design of the tasks and items, and in the design of the system that will deliver the assessments.

Overview of the NAEP Technology and Engineering Literacy Assessment

In 2014 the NAEP Technology and Engineering Literacy Assessment will likely be conducted at one grade level. The assessment will include tasks and items sampled from the domain of technology and engineering literacy achievement identified by the intersection of the three major areas of technology and engineering literacy and the cross-cutting 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. Within each of these types of tasks there will be a variety of selected response items and short and extended constructed response items. Student responses will be measured both directly and, in the scenario-based tasks, through their interactions with simulated tools and their manipulation of components of systems.

Types of Tasks and Items

Allowing students to demonstrate the wide range of knowledge and skills detailed in the NAEP Technology and Engineering Literacy Assessment targets will require a departure from the typical assessment designs used in other NAEP content areas. Thus students will be asked to perform a variety of actions using a diverse set of tools in the process of solving problems and meeting 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 include conventional item types, such as selected response items, and also monitor student actions as they manipulate components of the systems and models that are presented as part of the task.

The following sections describe in detail the scenario-based assessment sets and the sets of discrete, conventional items that will be developed for the NAEP Technology and Engineering Literacy Assessment. Note that the examples of items shown are drawn from what is available at the time of developing this framework and specifications (Spring 2010). It is expected that, as the use of such innovative items expands and technology advances, these examples will become dated, but they still illustrate the principle components that are important in this assessment.

The assessment will be administered to a nationally representative sample of students to report on student achievement at the group level. The assessment is not designed to measure the performance of 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 any individual student, so subsets of items will be selected to administer to each individual student. The NAEP Technology and Engineering Literacy Assessment will be given in approximately 50 minutes, with additional time for background questionnaire completion. The assessment sets that will be developed for the NAEP Technology and Engineering 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 approximately 25 minutes. The short scenarios will take students about 12-15 minutes to respond. The two types of scenarios have common characteristics, but they differ in the complexity of the scenario and the number of embedded assessment tasks and items to which a student is asked to respond. Long scenarios will provide about 10-15 measures of performance, while the short scenarios will capture approximately 5-10 measures of performance. Measures will include innovative measures of a student’s interaction with aspects of the scenario as well as conventional selected response items and short constructed response items. The different measures are discussed later in this chapter.

Discrete Item Sets

One of the challenges for this assessment is that the use of scenario-based assessment sets reduces the number of independent measures in the assessment as a whole. Because of their capability to replicate authentic situations examinees may encounter in their lives, scenarios have the potential to provide a level of authenticity other types of assessment tasks cannot provide which, in turn, may contribute to the validity of the entire assessment. At the same time, however, the choice to use these complex tasks reduces the number of measures that can be included in any one test and causes many of the measures to be interdependent because they are related to the same scenario. To counteract this interdependency and ensure reliability, the NAEP assessment of technology and engineering 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

As the framework and specifications are being written, the use of computer-based scenarios for assessment purposes is an emerging, but growing area. The Science Framework for the 2009

NAEP called for the use of interactive computer tasks as part of its assessment, and in 2009 three long and six short interactive tasks were administered to national samples of students in grades 4, 8 and 12. Another set of interactive assessment tasks has been used in state tests of science achievement 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.

Here a descriptive outline is provided of the main features of the scenarios that will be developed for the NAEP Technology and Engineering Literacy Assessment. 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 reflect tasks that might be performed in society, either within an academic setting or outside of school. In addition, near the start of the scenario, a motivating question or goal will be introduced. This goal provides the driving rationale for the tasks that the student will perform, and it offers a storyline that helps define the relevance and coherence of the tasks and motivates the student to undertake them. The motivating goal might be to solve a particular problem or to achieve a certain goal within the scenario.

An advantage of computer delivery of the assessment is that the introductions to the scenarios can use appropriate multimedia to present the settings for the assessment tasks. As a result, there is less need for text and therefore less of a reading demand. The multimedia can include video segments or animations that the student observes, and it will also generally use text, numbers, and graphics to convey information necessary for the tasks to be accomplished. All of the representations, such as graphics, video, or simulations, must be carefully chosen to serve a purpose in the assessment tasks, and none should be present simply for visual interest.

One type of assessment scenario will include a representation of a system. Depending on the context for the particular scenario, this might be an engineering system such as an irrigation system or a dam. 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 a part of the system) and see a resulting change of state in the system (e.g., a rise in water levels or flooding of fields).

A second type of scenario will lay out an overarching goal that students will reach, or a problem they will solve by conducting various interrelated tasks. Such a goal might be, for instance, to develop a play on a historical period. Component tasks could involve searching for information about a famous incident in the period, determining the number of tickets that must be sold to pay for expenses, and creating a playbill advertising the production.

Within a scenario, students may be asked to select tools from a toolkit and use them within the system. Students might be asked, for example, to select a graphing or spreadsheet tool or to use a simulation. Various tools may be made available, depending on the scenario. Word-processing, texting, or presentation tools might be available for communication tasks, for example, and 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 are able to respond to tasks that ask them to explore alternative outcomes, control certain variables, and observe the resulting changes in the system. The 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 in using particular tools, and, finally, they can form conclusions.

In some cases it might be necessary to simulate virtual features of real-world equipment that can be used within a scenario. For example, a temperature gauge might give feedback from a heating system, an anemometer might be used to measure wind speed in a scenario about wind turbines, or a table might be used in an ICT scenario requiring the collection of data about the types of symbolism in Shakespeare's plays. 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 in order that students could take a table of data resulting from actions in the system and transform it into a graphical representation of their 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; to communicate to others about their actions, decisions, or results (e.g., texting a virtual team member); or, at the end, to convey their conclusions (e.g., creating a slideshow presentation).

Typical tools that are likely to be needed in the Technology and Engineering Literacy Assessment include standard office productivity tools such as word processing, spreadsheet, database, and presentation software applications; engineering design applications like computer aided design; and communications tools like email and text/chat software. This is not an exhaustive list and other tools may be necessary to include in the assessment. Appendix I contains a list of the types of tools that are likely to be needed for designing tasks and items in the Technology and Engineering Literacy Assessment, as well as the features and typical uses of these tools. Again, this list is intended to provide helpful guidance, but should not be regarded as a definitive list because the use of tools is closely connected to the design of tasks, and tool features may be needed for a particular task that cannot yet be envisioned. Also, over the period of time that the Technology and Engineering Literacy Assessment is to be administered, software will change and development of tasks and items will have to take account of this.

Discrete Item Sets

The discrete item sets will comprise approximately 10-15 stand-alone items to be completed within a 25-minute block. These items would not be part of a complex scenario or related to one another. Each discrete item would provide 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 computer-based NAEP Technology and Engineering Literacy Assessment, with its scenario-based assessment sets, there are opportunities to greatly extend the ways in which a student can respond to an assessment task. Thus this assessment can move beyond the old ways of thinking of response types in terms of simply multiple choice or written responses and begin to consider new types of responses.

In this assessment, three response types are used: short constructed response, long constructed response, and selected response. Although these are the same names as used in other NAEP assessments, in the context of the NAEP Technology and Engineering Literacy Assessment they have different and expanded meanings. These meanings are described in the following sections.

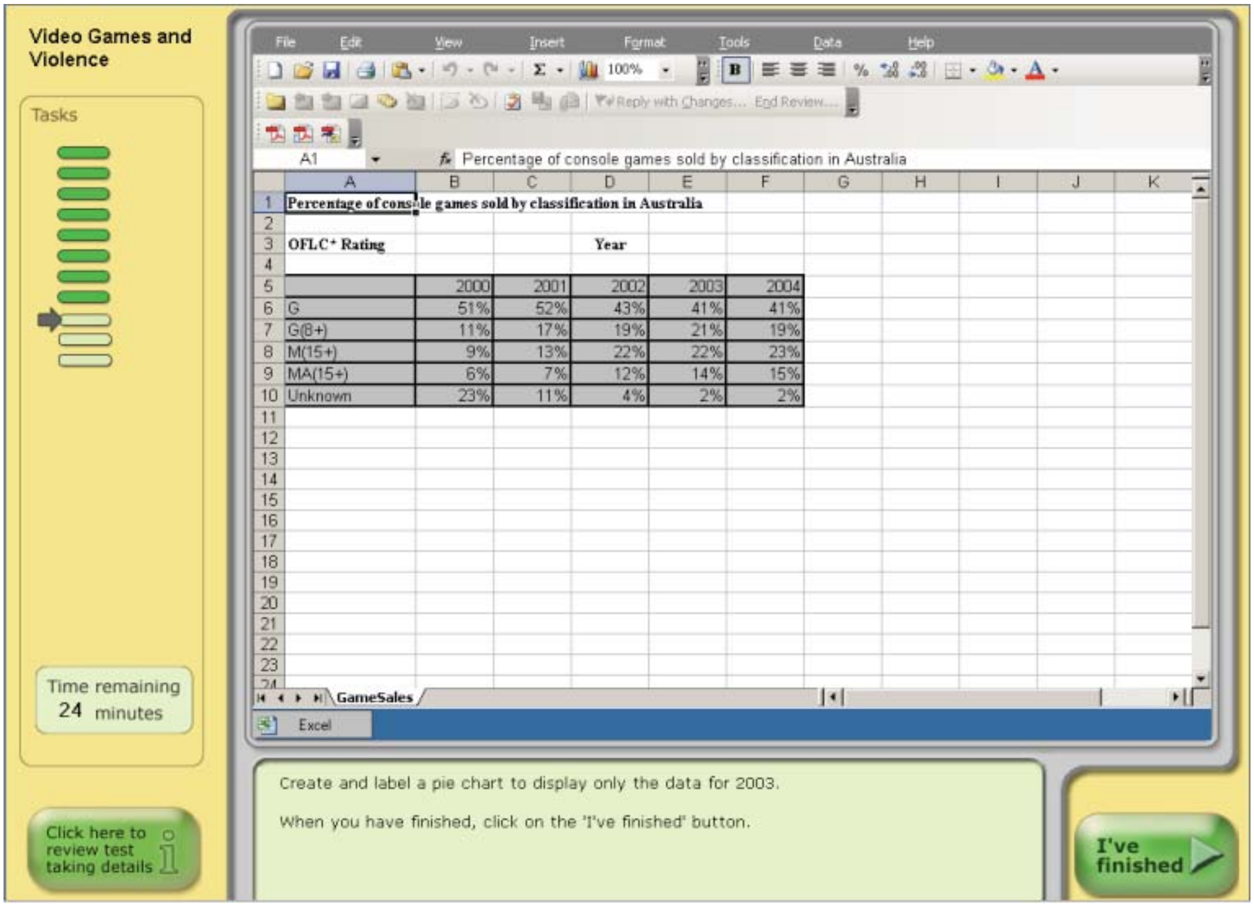
Constructed Response

Constructed responses are ones in which the student "constructs" the response rather than choosing a response from a limited set of alternatives, as is the case with selected response items. Constructed responses in the NAEP Technology and Engineering 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.

<u>Short Constructed Response</u>

Short constructed responses might be used in either the discrete-item assessment sets or in the 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 is the case 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. In this computer-based item, students use a spreadsheet program to create a pie chart.



(Source: Australian MCEECDYA, 2008)

<u>Extended Constructed Response</u>

Extended constructed responses will be used in the long scenario-based assessment sets. In a scenario-based assessment set, the real-world scenario is developed and elaborated upon as the student moves through the assessment set. As previously described, the introduction of the scenario will provide context and motivation for the tasks in the assessment set. As the scenario builds, the student undertakes a series of tasks that combine to create the response. For example, a student might be asked to enter a search term to gather information about a famous composer 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, or, in a different scenario, they 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.

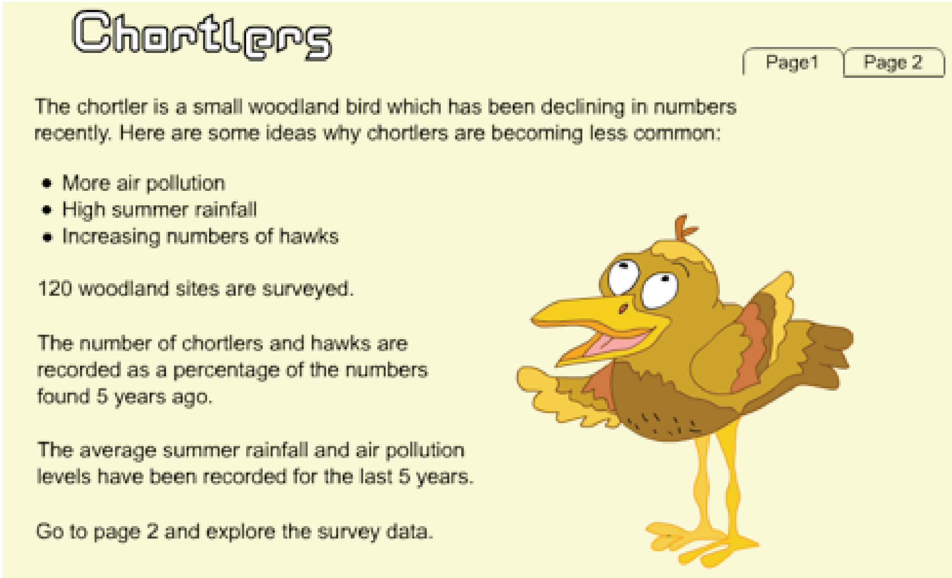
Additional measures of the students' responses can be made by capturing data about which combinations of components the students selected, whether they covered all possible combinations, and what data they chose to record from their tests of the components. A follow-on task might ask the students to select different types of graphic representations for the tabulated data they captured. Observing whether they have selected an appropriate type of graph provides additional information about how they use data analysis tools.

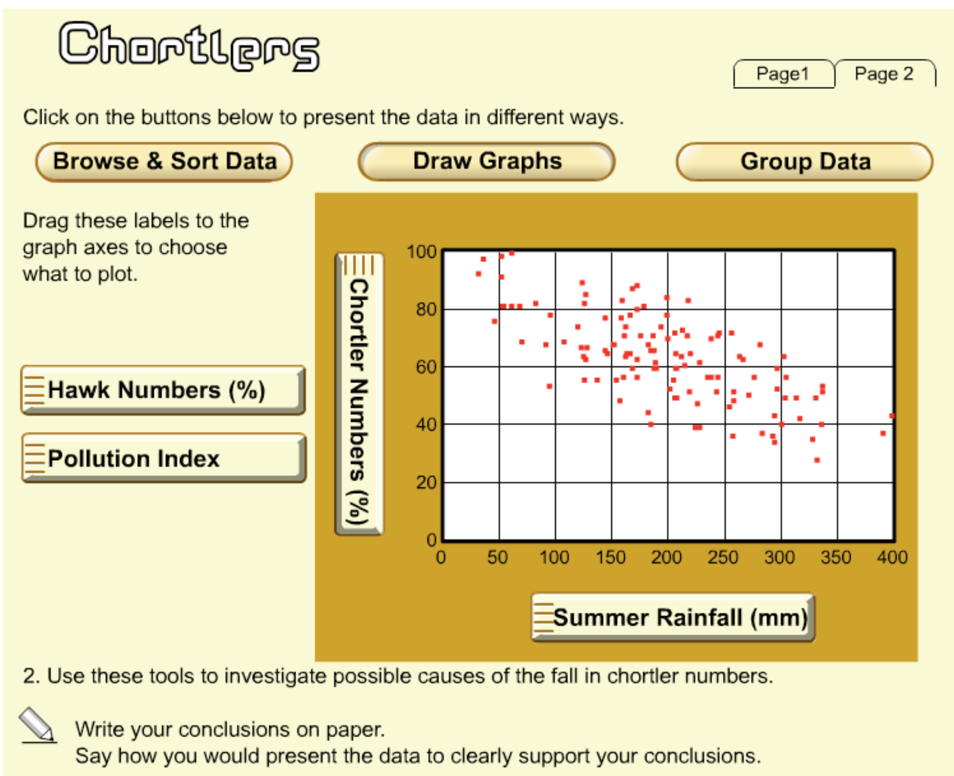
Finally, the students could be asked to interpret their data, make a recommendation for the best combination of turbine blade and generator, and justify their choice in a short written (typed) response. In this way, both the task and the response are extended.

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 the student to perform well-defined, meaningful tasks that yield measurable evidence about whether 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 scenario described above, students could run tests of combinations of certain turbine blades and generators, and their responses could be assessed. Then, the students 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 a student’s own data gathering and the data analysis stage is minimized. The goal is to make sure that mistakes or deficiencies in the first part of the task are not carried forward into the second part of the task, thereby giving all students the same opportunity to show their data analysis skills, regardless of how well they did on the first item in the task.

In the following simulation, students are given the scenario of a population of small birds—chortlers—whose population is declining. The students are asked to use various tools to analyze data in a variety of ways and to determine some possible causes for the population decrease so that they can then present their findings on the impacts on the chortlers. The multiple developments of the graphs are extended constructed responses, as is the development of the conclusions to be presented, which in this example are not written on the computer.





(Source: Ripley, 2009)

Extended responses can provide particularly useful insight into a student's level 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, as well as 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 technology and engineering literacy.

Selected Response

As the name implies, selected response items are those 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 the form of multiple choice items, in which students select an answer from the options provided. The choices include the most applicable response—the “answer”—as well as several “distractors.” The distractors should appear plausible to students but should not be justifiable as a correct response, and, when feasible, the distractors should also be designed to reflect current understanding about students’ mental models in the content area. The NAEP Technology and Engineering Literacy Assessment will include such multiple choice items within both the scenario-based and the discrete-item assessment sets as one type of selected response.

In addition to the conventional multiple choice selected response items, the scenario-based sets in the NAEP Technology and Engineering Literacy Assessment will include other types of selected response formats. The computer-based nature of the scenarios will allow a variety of 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 provides a measurable response that is, in essence, a selected response.

A selected response item 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 in order to produce a particular outcome, but the student might also have to justify or explain the selection. In this case, the first part of the answer is a selected response, but it might be necessary to score the two parts of the item together so that the selection and justification together determine the score. In complex, real-world scenarios, it might be the case that there is not a “correct” selection, and in such a situation what matters is that the selection is justified adequately.

An example of a selected response item that might be part of a series of items embedded in a scenario-based assessment set is shown below. The question was part of an ICT assessment about reintroducing lynx into a Canadian park overrun by hares. The assessment was designed for thirteen-year-olds.

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.

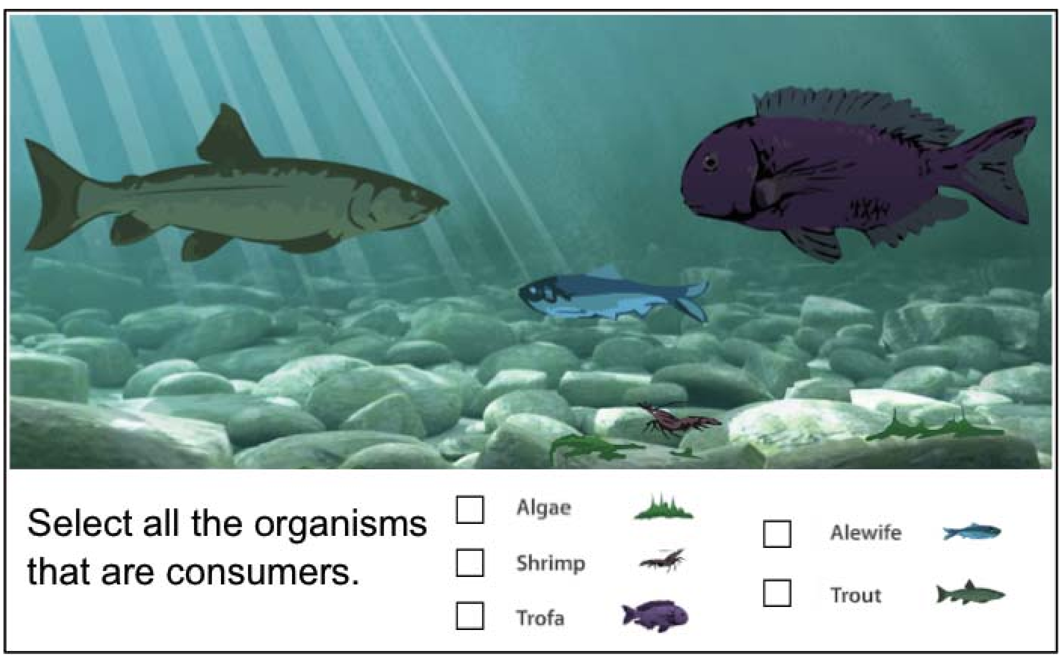
Pick a tool to use:

Word processor Spreadsheet Presentation

(Source: Quellmalz & Kozma, 2004)

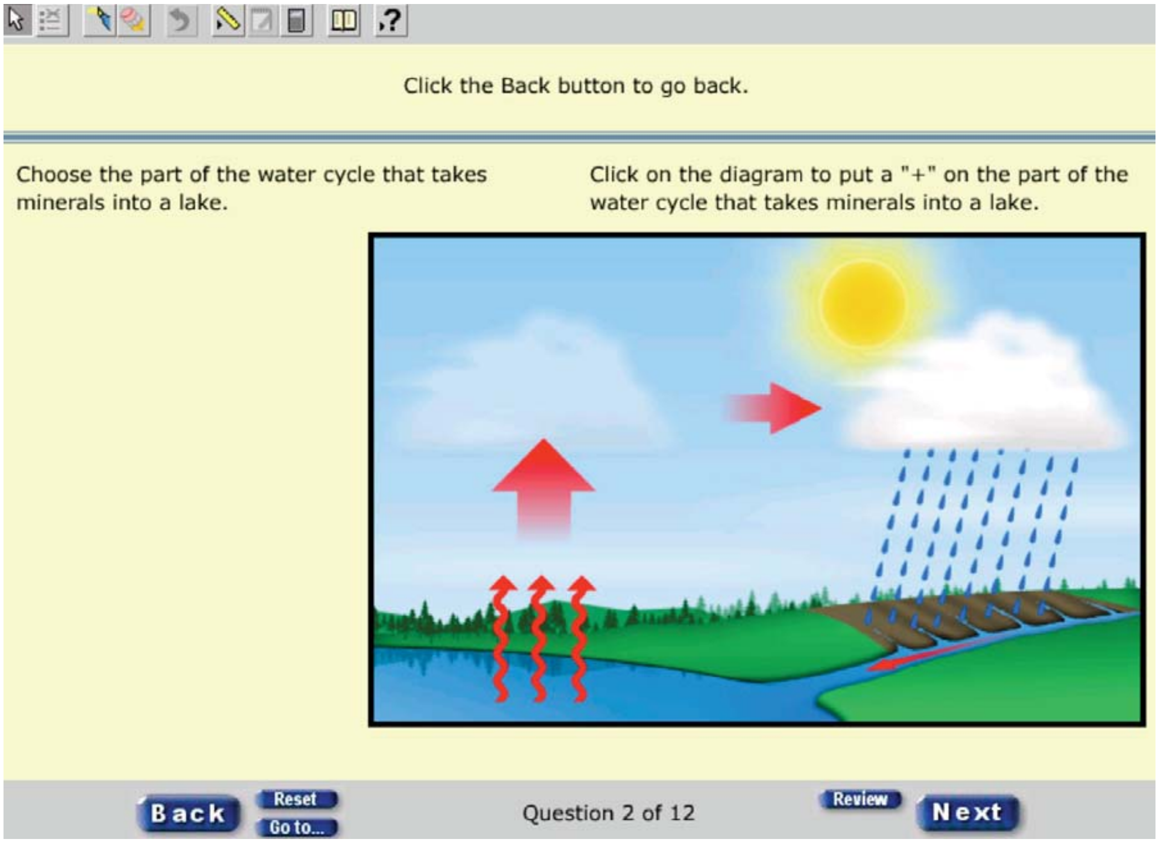
Other selected response types within a scenario-based assessment set might include a task in which a student selects all of the options that apply from a given set of choices. Again, in a real-world situation there might be one "best" combination of choices but also one or more other combinations that 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.

In the following item, students observe organisms interacting in an ecosystem before choosing all the organisms that are consumers. The assessment was designed for grade 8. In the NAEP Technology and Engineering Literacy Assessment, students might choose all the organisms in an ecosystem most immediately affected by a pollutant.



(Source: Quellmalz, Timms, & Buckley, 2009)

Another form of selected response is a “hot spot” in which a student answers by clicking on a spot on an image such as a map, picture, or diagram. The example below was designed for grade 8 students as part of a set of items on a state science test. For the NAEP Technology and Engineering Literacy Assessment, a task might be designed that asks students to click on the places in the image where pollution originated in the water system.



(Source: Minnesota Department of Education, 2009)

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’ capabilities as defined in the assessment targets. The range of measures will be greater than those generated in a typical NAEP assessment of other subjects, so it is necessary to describe how all these measures might be analyzed. 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, the student is asked a text-based question and given a limited set of choices from which to select the best answer. 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 observing 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. This is a student direct response because, although the student interacted with the system, none of that interaction was captured to score the appropriateness of the student response to the item. Only the written observation and explanation are to be scored.

One type of student direct response is selection from a set of choices—e.g., multiple choice, checking all the boxes that apply, or, in a scenario-based assessment, selecting an object or choosing 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 about whether the student possesses a skill that is an assessment target and that should, therefore, be captured, measured, and interpreted. For example, a student may have been asked to pinpoint a malfunction in a technological system, such as a leak in a lawn sprinkling system. In responding to that task, the student's manipulation of the components of the system shows whether the student is testing the sprinkler components in a random or systematic way. Thus 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 so as to provide a measure of whether the student possesses a particular skill related to troubleshooting.

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, did the student change the features of a Web search query (e.g., narrowing the topic) or vary the parameters that control a component of a system (e.g., changing the gauge of wire mesh for bird protection in a model of a rooftop wind turbine) or transform an object from one form into another (e.g., transforming database entries into a graph or table for a presentation)? Pattern-tracking measures might be used to assess certain aspects of communication or collaboration skills. For example, counting the number of times a student communicates with virtual team members with particular expertise can provide a measure of the efficiency of the student's collaboration strategies.

Examples of How Assessment Tasks and Items Might be Developed

This section provides examples of how scenarios and discrete items that embody the approaches described in this chapter might be developed. First are examples of how tasks and items for scenarios could be created are given, followed by examples of discrete item development.

Scenario Development

Development of scenarios can be aided by first creating a shell that outlines the major components of the tasks that will be included in the scenario. A scenario shell that defines general characteristics can be used for both long and short scenarios. An example of such a scenario shell is offered in Table 4.1 as an illustration, and it is not intended to be prescriptive of how the assessment developer might approach the task.

Table 4.1 Sample scenario shell

Grade	4, 8, or 12
Major Assessment Areas	Technology and Society Design and Systems Information and Communication Technology
Context	*What is the context of the scenario?*
Problem	*What are the big ideas and tasks for the student?*
Available Resources and Information	*What is given to the student to solve the problem?*
Tools Used	*What domain-specific tools will the student use?*
Practices	*Which of the NAEP practices will be addressed?*
Assessment Targets	*Which of the NAEP targets will be addressed?*

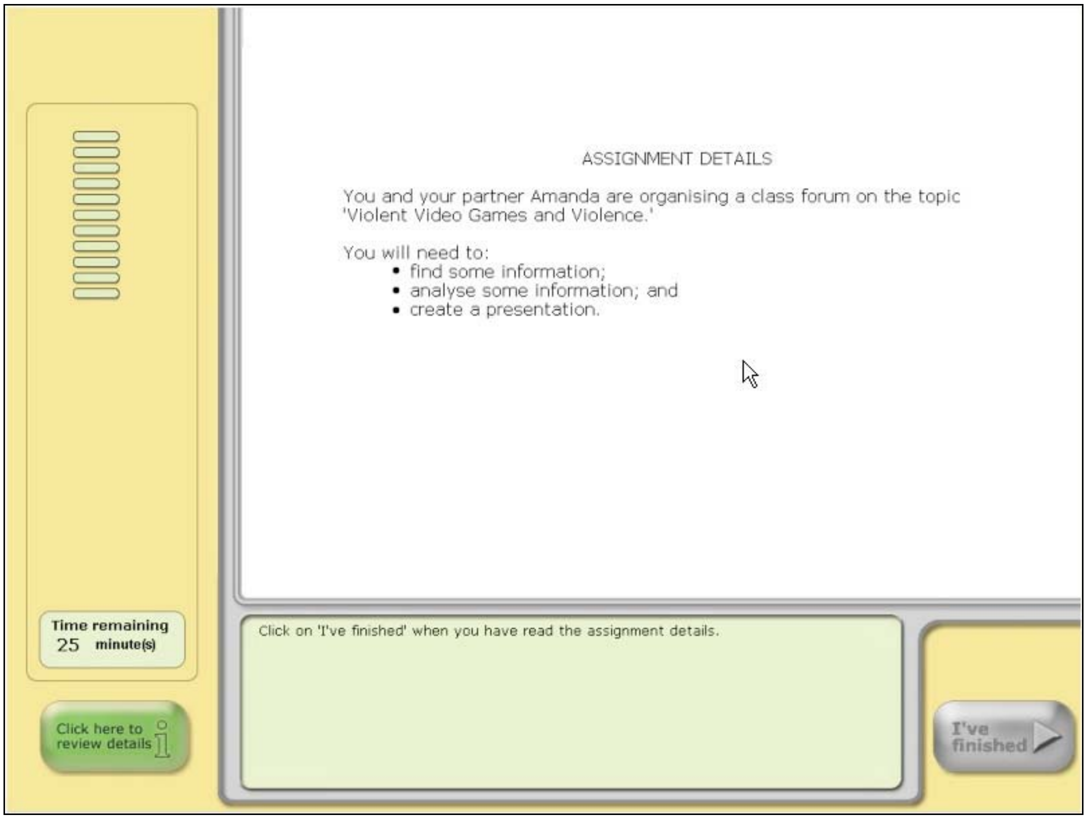
<u>Sample Short Scenario</u>

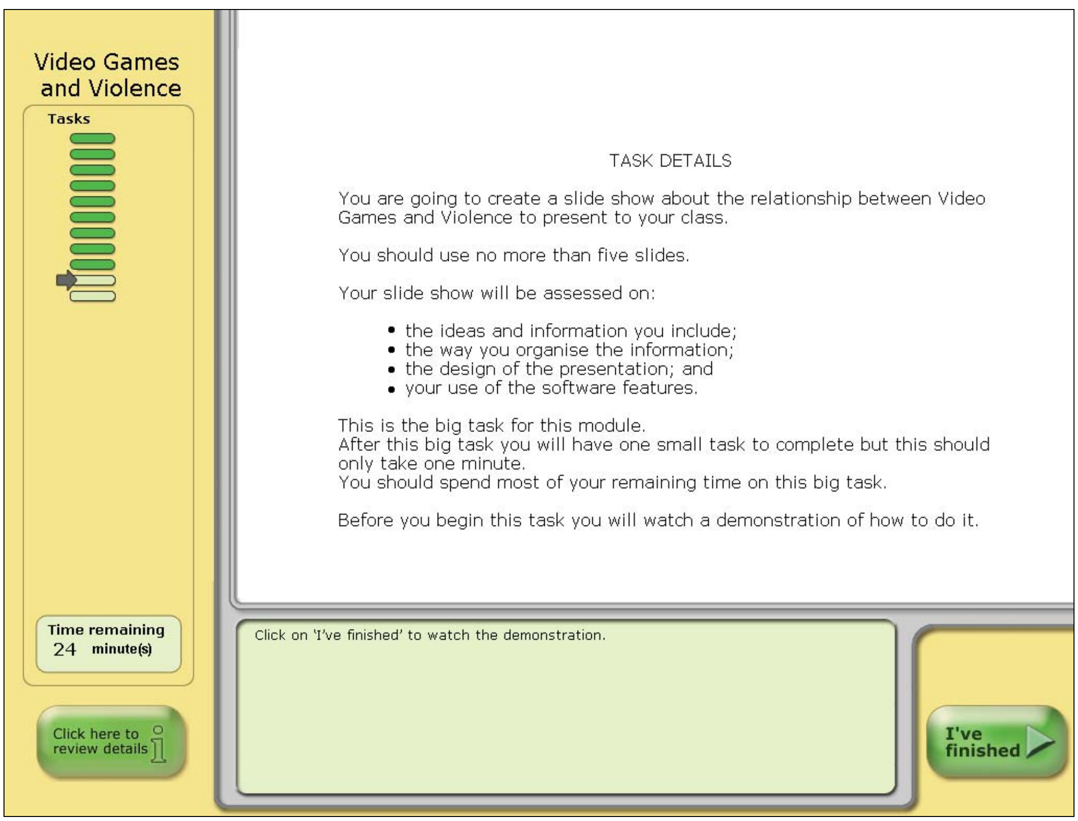
Table 4.2 below shows how the scenario shell from Table 4.1 could be used to generate an outline of a short scenario for grade 12 that would assess knowledge and skills in two major assessment areas: Technology and Society, and Information and Communication Technology. This example is based upon an existing assessment developed by the Ministerial Council for Education, Early Childhood Development and Youth Affairs in Australia, which is also shown in Chapter Three.

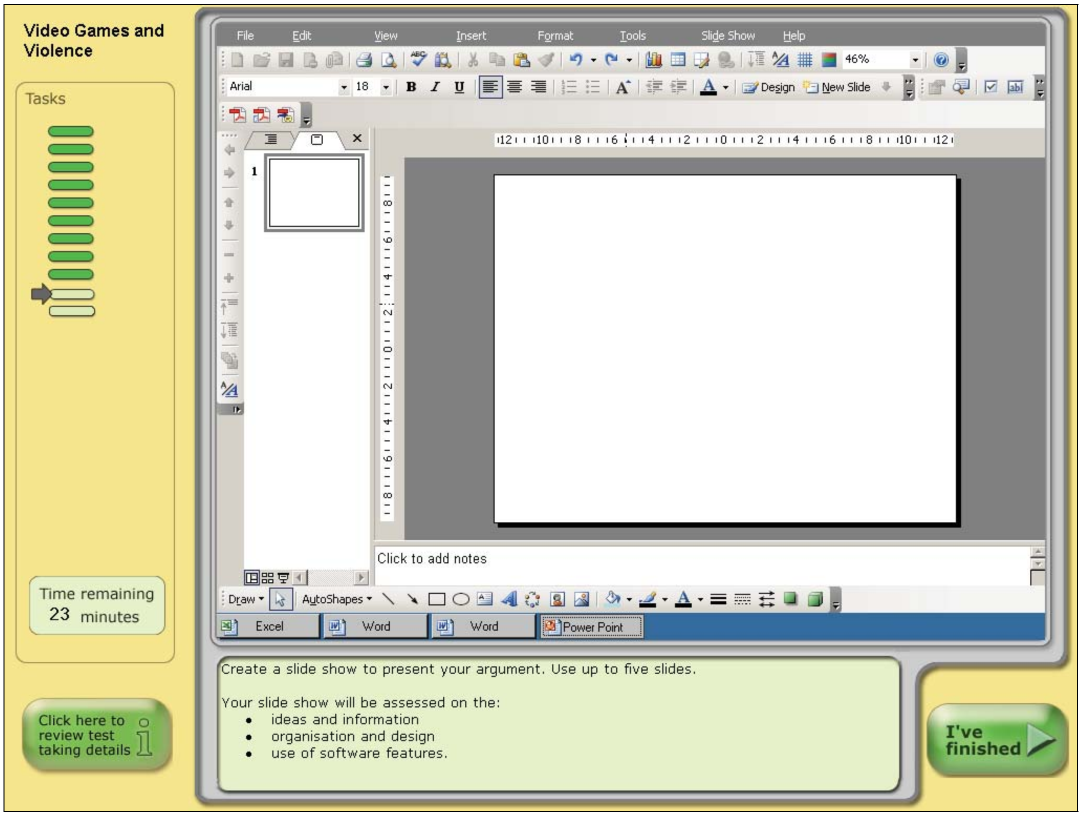
Table 4.2 Sample of a completed shell for a short scenario at grade 12

Grade	12
Major Assessment Areas	Technology and Society Information and Communication Technology
Context	Human Society; Video Games and Violence
Problem	Gather information, organize data, and prepare a presentation to describe several effects of video games on society
Available Resources and Information	Variety of sources available via simulated Internet and simulated collaborator
Tools Used	Web search, word processing, spreadsheet, presentation software
Practices	Communicating and Collaborating
Assessment Targets	I.12.2: Work through a simulation of a collaborative process. 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. I.12.3: Synthesize input from multiple sources to communicate ideas to a variety of audiences using various media, genres, and formats. I.12.6: 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. 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.

Once a scenario shell is created, it can be used to guide the development of tasks and items. Different items within the scenarios will be used to assess performance on the different targets. The sample task below calls upon the student to employ the practices of Understanding Technological Principles, and Developing Solutions and Achieving Goals. In this task, the student must use ICT tools to analyze the impacts of technology on human society. This example employs a computer-based interactive format in which students search for information concerning video games and violence and then use word processing, spreadsheet, and Web-based tools to develop a PowerPoint presentation. The PowerPoint presentation calls upon the cross-cutting practice of Communicating and Collaborating.


ASSIGNMENT DETAILS
You and your partner Amanda are organising a class forum on the topic 'Violent Video Games and Violence.'
You will need to:
• find some information;
• analyse some information; and
• create a presentation.
Time remaining 25 minute(s)
Click on 'I've finished' when you have read the assignment details.
Click here to review details
I've finished


Video Games and Violence
Tasks
TASK DETAILS
You are going to create a slide show about the relationship between Video Games and Violence to present to your class.
You should use no more than five slides.
Your slide show will be assessed on:
• the ideas and information you include;
• the way you organise the information;
• the design of the presentation; and
• your use of the software features.
This is the big task for this module.
After this big task you will have one small task to complete but this should only take one minute.
You should spend most of your remaining time on this big task.
Before you begin this task you will watch a demonstration of how to do it.
Time remaining 24 minute(s)
Click on 'I've finished' to watch the demonstration.
Click here to review details
I've finished



(Source: Australian MCEECDYA, 2008)

Sample Long Scenario

Table 4.3 below shows an example of a shell for a long scenario for grade 8 that addresses the major assessment areas of Design and Systems, and Information and Communication Technology in the context of planning school bus routes.

Table 4.3 Sample of a completed shell for a long scenario at grade 8

Grade	8
Major Assessment Areas	Design and Systems Information and Communication Technology
Context	School bus routes
Problem	Gather information, describe ways to make bus routes more efficient, create a report and presentation to the school board
Available Resources and Information	Map with bus stops, traffic data, distance, and time
Tools Used	Spreadsheet, Presentation Software, Maps, Geographic Information System (GIS)
Practices	Understanding Technological Principles Developing Solutions and Achieving Goals
Assessment Targets	D.8.8: Carry out a design process to solve a moderately difficult problem by identifying criteria and constraints, determining how they will affect the solution, researching and generating ideas, and using trade-offs to choose between alternative solutions. I.8.8: Use digital tools to gather and display data in order to test hypotheses of moderate complexity in various subject areas. Draw and report conclusions consistent with observations. I.8.9: Use a digital model of a system to conduct a simulation. Explain how changes in the model result in different outcomes.

Sample Items for the Long Scenario Example

The following set of sample items illustrate how, within the long scenario, students might use an interactive map to plan bus routes. The item sequence provides scaffolding for the interface by gradually increasing the number of options. The items increase in cognitive complexity, from more concrete (bus stops marked on the map) to more abstract (the effect of traffic on travel time) and from a focus only on the components in a system (one route with several stops) to interactions between components (the bus and other traffic) to the design of a system (with multiple components and interactions).

This set of items would be part of a scenario that might also include organizing data using a spreadsheet and presenting data and maps using a slide show.

In the first item, students use the map to create a bus route. They adjust the route to include several bus stops. The students can also adjust the route to make the total distance for the route as short as possible. The distance is automatically calculated. Evidence of mastery of the relevant targets may include connecting all seven stops, using fewer moves to create the bus route, and changing the route to make it shorter.

1. You need to draw a new bus route.
   - The route must go to each of the seven bus stops
   - The route must end at the school

   Try making your route as short as possible.
   When you are done, click “SAVE ROUTE.”

(Map courtesy of Atlanta Public Schools)

In this example, the student has set the start and end points for the bus route. The interface generates a possible route. Only three stops are included in the route. The student must drag the route to other streets until it includes all seven stops.

In the second item, students are given a different route and asked to adjust the route to make the total time as short as possible, using traffic information. There is a trade-off between the distance and time for the route.

2. Bus route 92 is taking too long. The bus gets stuck in traffic.

Change the bus route so that it will take as little time as possible.
When you are done, click "SAVE ROUTE"

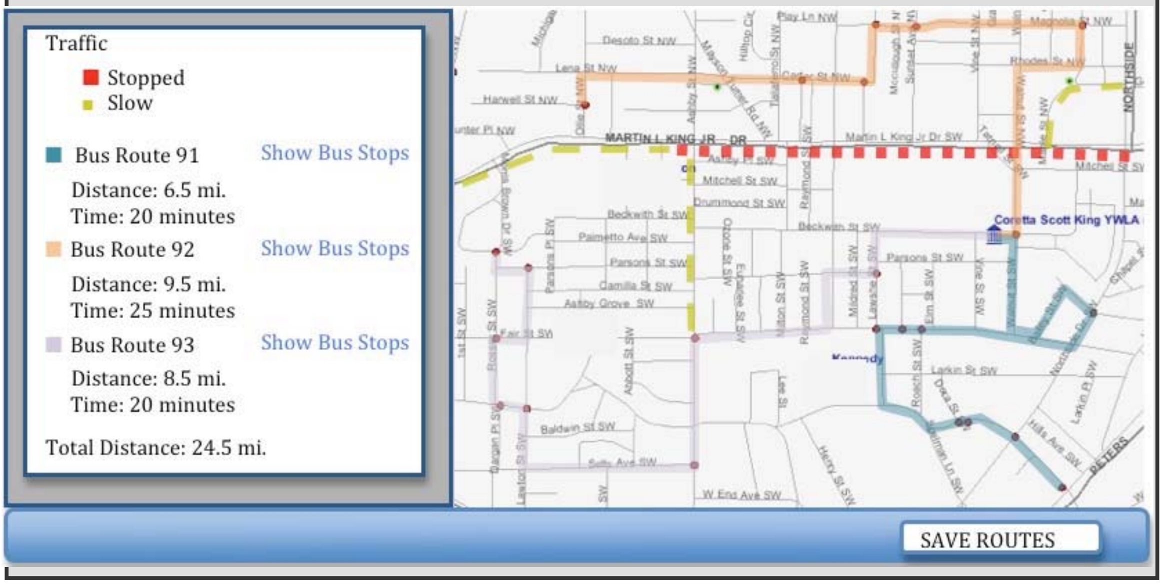
(Map courtesy of Atlanta Public Schools)

In this example, the student is given a route that includes two busy streets. The route takes 25 minutes. The student must drag the route to make it take less time. An additional item could be inserted here that asks students to explain the changes they made, testing their understanding of the trade-off between distance and time.

In the third item, students are given three routes and asked to make the system as efficient as possible, considering travel times for each route and total distance for all the routes. Students are allowed to change the starting point for each route and to select which routes make which stop. Students can show and hide the bus stops for each route.

3. You need to draw three bus routes.
    - The routes must go to all of the bus stops
    - The routes must end at the school

  Try making each route take as little time as possible.
  Try making the total distance as short as possible.
  When you are done, click "SAVE ROUTES."



(Map courtesy of Atlanta Public Schools)

In this example, the student has designed a system that meets all the requirements. Many different versions of the system could be designed that would also meet all the requirements, however, some would be more efficient than others. The student would use these data and the map in the tasks that would follow in the scenario.

Discrete Item Development

Following are examples of selected and constructed response items that might be developed for administration in discrete item blocks.

The following selected response item illustrates how an item for grade 4 might be developed based upon the idea that, given a specific issue that is relevant to a fourth grade student, the student could be asked to choose the search terms that will provide the most useful results.

Grade 4
I.4.B Information Research (practice: Developing Solutions and Achieving Goals)
I.4.5 Use digital and network tools and media resources to collect, organize, and display data in order to answer questions and solve problems.

Martin is in 4th grade at Jefferson Elementary. Next year he will be going to a different school, Franklin Elementary. He is looking at the school's website to find out what school will be like next year, shown below.

(Source: http://franklin.bsd.k12.ca.us)

Which words would be **best** for searching his school's website?

A. new students*
B. important dates
C. elementary schools
D. Franklin elementary

In this item, the context establishes a need to gather information, focusing on an early step in the practice of developing solutions and achieving goals. The issue, a student planning to attend a new school, is relevant to 4th grade students, as most have either attended more than one school, or have a classmate who was at one time new to the students' school. Only the correct answer directly addresses the central idea of this issue, being a new student, and is therefore best for searching the school's website. Students who understand that searching for "new students" means searching for pages with information for new students are more likely to answer correctly. The other options are either tangentially related to the issue or include unnecessary terms, given that the student has already accessed the school's website and is searching within it.

The next example at Grade 8 shows how a constructed response item could be developed in which a student is asked to communicate with a virtual collaborator to evaluate changes to the design of a school kitchen.

Grade 8
D.8.B Engineering Design (Practice: Communicating and collaborating)
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.

The picture below shows a school kitchen. You can click on any of the people to see how they work in the kitchen.

(Source: www.safework.sa.gov.au/contentPages/EducationAndTraining/ActivitiesAndTests/VirtualKitchen/vkitchenframe.htm)

[Note: This interactive virtual kitchen features animations that show the following:
- Using the on/off switch to start and stop a large mixer.
- Using a control knob on the back of a gas stove to increase the flame below a pot of water.
- Using an oven by setting analog controls for time and temperature]

You are going to work with another student, Kenji, to find ways to make the kitchen more efficient. Click on the picture of Kenji to hear his ideas about how to make the kitchen more efficient.

[Note: When students mouse over each tool, an image of Kenji appears in a pop-up window. Clicking on Kenji plays an audio clip and displays the text that is being read. Kenji's ideas are: Put a timer on the mixer. Move the control knobs from the back of the stove to the front. Replace the dials on the oven with buttons and a digital display.]

Pick one of Kenji's ideas. Tell him one advantage and one disadvantage of that idea.

This item focuses on identifying the benefits and possible unintended consequence of a design change in the context of communicating with a collaborator. The stimulus described would provide access to a rich source of information within the timeframe expected for a discrete item. The use of simple animations within a static image minimizes the development cost while providing many of the same affordances of more complex stimuli that might be needed in other contexts.

The item examples provided above are included in a more comprehensive set that are contained in Appendix I. Also, examples of several existing interactive items are included on a disk that accompanies these Specifications.

Cross-Checking with Other NAEP Content Areas

As can be seen from the scenario and discrete item examples in this chapter and in Appendix I, the tasks and items are set in different content areas. Assessment developers will need to ensure that any special content knowledge needed to respond to a question is provided in the item. Assessment developers will also need to ensure that scenarios and items that call upon skills from other subject areas such as mathematics, science or history/social studies do not go further than the expectations for that grade level. Most issues of grade appropriateness will be determined at the task and item level when these tasks and items are designed. For example, if a scenario were created to assess target T.8.7 of Technology and Society, in which students were asked to compare the environmental effects of two technologies a few cross checks would be needed. First, the developer would need to check that the information about environmental effects that is required to respond to the items is presented in the scenario. Also, if there are to be some quantitative representations of effects, the developer would check that the types of tables or graphs are age appropriate. Finally, the developer would ensure that any mathematics required is at a level approximately one to two grade levels below the technology and engineering assessment grade level so as not to confound technology and engineering achievement with mathematics achievement.

Similarly, assessment developers will need to check on the age appropriate levels of reading material (including vocabulary and terminology) and required writing structures (arguments, stories, essays, short explanations) and complexities. Item reading level should be below grade level so as not to confound the technology and engineering achievement being measured with reading ability. Therefore, although the term "hypothesis" in the grade 4 target I.4.8 refers to a type of investigation conducted by 4th graders and is a term used in many states’ science standards, test developers are not required to use the term itself, but are guided by the target to design some grade 4 scenarios in which a simple hypothesis or question is tested using digital tools in various subject areas, including, but not limited to science. Some questions could be science related, e.g., summarizing data in a bar graph on plant growth simulated under different sunlight conditions, or could involve investigating a question in language arts or social science, e.g., examining whether web pages with colored or moving graphics are more visited than those with only text. Item review teams with experience and expertise at the grade levels should further screen for age appropriate content and representations.

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 that it would take to administer all available assessment blocks (see Figure 3), which is the equivalent of approximately 5 hours of test time. Many students will be in the sample population during each administration of the test, but each of these students will spend approximately 50 minutes on the assessment tasks, so there must be a plan for distributing each assessment block to many students. Figure 3 also shows a simple example of how assessment types might be grouped together.

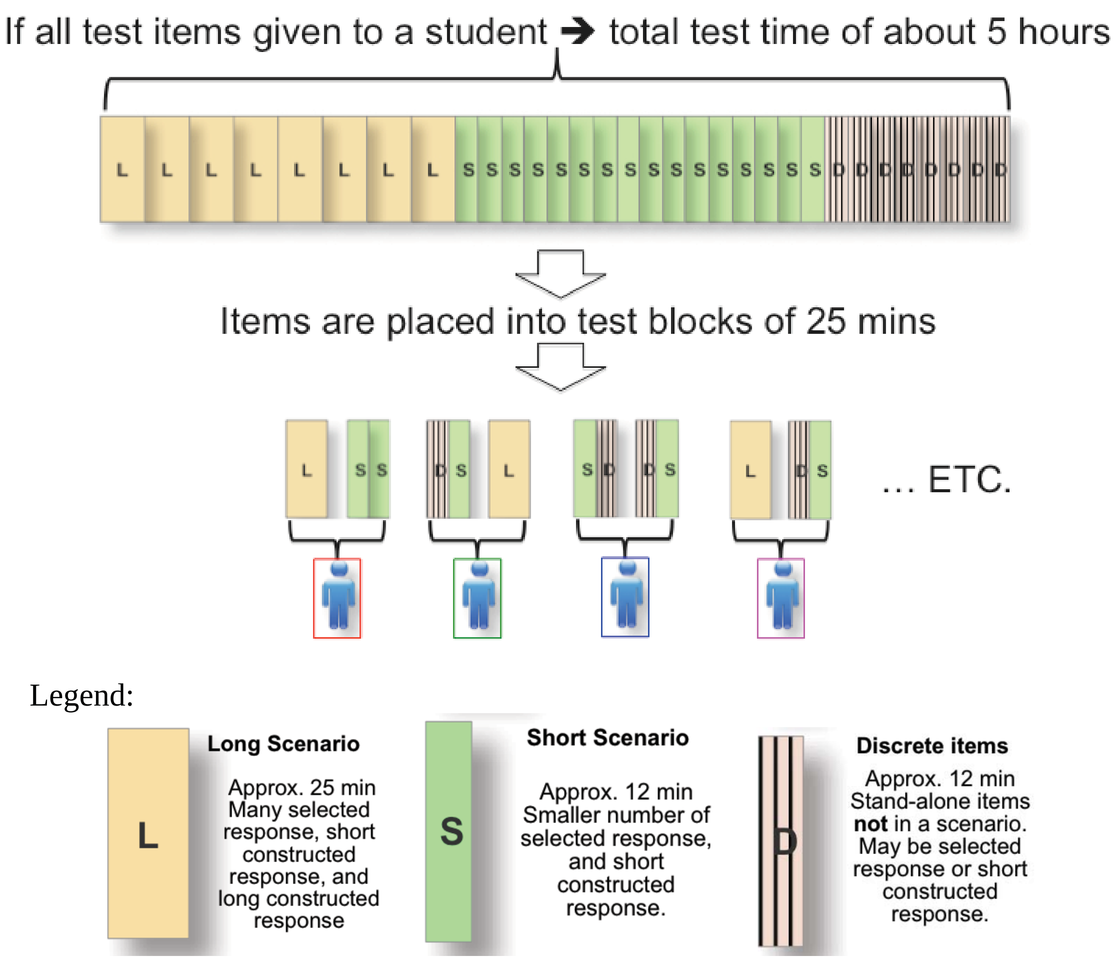


Figure 3 – Potential Balance of Total Test Time

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

- Balance by Major Assessment Area
    - Technology and Society
    - Design and Systems
    - Information and Communication Technology
- Balance by Practice
    - Understanding Technological Principles
    - Developing Solutions and Achieving Goals
    - Communicating and Collaborating
- Balance by Set Type
    - Long scenarios
    - Short scenarios
    - Discrete items sets
- Balance by Response Type
    - Selected response
    - 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 Table 4.4—would be allocated. Since a student is assigned to take only one of the groups of item sets shown in Table 4.4, the percentages do not necessarily represent the distribution of time in any single student's test session. It should also be noted that the percentage of testing time distributions shown in tables 4.4 through 4.7 are to be regarded as targets, and it is understood that percentages in the actual assessment may vary slightly from the target percentages.

The balances shown in the following tables 4.4 through 4.7 were determined after careful consideration and deliberation by both the Planning Committee and the Steering Committee members. They reflect the expert judgment of the committees after they took into account how the knowledge and skills in the area of Technology and Engineering Literacy are taught at different grade levels and how they develop over time. The percentages shown in the tables were derived from a process in which Planning Committee members made individual judgments, the group results were tabulated, and then discussion followed to come to a consensus that is represented in tables 4.4 through 4.7.

Assessment Balance by Major Assessment Area

Table 4.4 shows the balance by major assessment area at each of the three grade levels. At fourth grade there is an emphasis on ICT because the focus of technology and engineering 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 ICT than in the early grades. At twelfth grade the balance is slightly weighted to Design and Systems and to ICT.

Table 4.4 Assessment balance by major assessment areas and grades

Grade / **Major Assessment Area**	**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 Practice

The balance of the assessment by cross-cutting practices across the three grades levels is shown in Table 4.5. At all grades the balance of total test time is as follows:

- Understanding Technological Principles – 30%
- Developing Solutions and Achieving Goals – 40%
- Communicating and Collaborating – 30%

The rationale for a slight emphasis on the practice of Developing Solutions and Achieving Goals is that it is important for students to be able to use their knowledge of technological principles in developing solutions to problems.

Table 4.5 Assessment balance by practices and grades

Grade / Practice	Grade 4 (% total test time)	Grade 8 (% total test time)	Grade 12 (% total test time)
Understanding Technological Principles	30	30	30
Developing Solutions and Achieving Goals	40	40	40
Collaborating and Communicating	30	30	30

Assessment Balance by Set Type

In addition to ensuring a balance across the content of the assessment, Table 4.6 specifies how the total amount of testing time should be balanced across the three types of assessment sets—long scenario, short scenario, and discrete item sets. There is an emphasis on the scenarios because they allow for a wide range of interactive tasks that are well suited to assessing the types of practices that students need to apply in practical investigations. The twenty percent of discrete items allow for more independent testing of knowledge and skills that help to maintain test reliability.

Table 4.6 Assessment balance by set types and grades

Grade / Set Type	Grade 4 (% total test time)	Grade 8 (% total test time)	Grade 12 (% total test time)
Long Scenarios (Approx. 25 mins)	40	40	40
Short Scenarios (Approx. 12-15 mins)	40	40	40
Discrete items (Approx. 1-2 mins per item; approx. 12-15 mins per block)	20	20	20

Assessment Balance by Response Type

Table 4.7 specifies the balance of assessment response types across the total testing time. Across all grade levels, there will be an emphasis on constructed response items because the more complex tasks involved in scenarios demand that students are involved in activities that create products rather than simply selecting among choices of responses. Since the balance of types of assessment types specified in table 4.6 is weighted toward scenarios, there is a corresponding weighting toward constructed responses, although selected responses also form an important part of the assessment.

Table 4.7 Assessment balance by response types and grades

Grade / Response Type	Grade 4 (% total test time)	Grade 8 (% total test time)	Grade 12 (% total test time)
Selected Response	40	40	40
Constructed Response	60	60	60

CHAPTER FIVE: ASSESSMENT DESIGN AND STUDENT DIVERSITY

Students should have the opportunity to demonstrate their knowledge of the concepts and ideas that the NAEP Technology and Engineering Literacy Assessment is intended to measure. The assessment needs to be responsive to the challenges that stem from an increasingly diverse student population in the nation, the inclusion of all types of students in the general curriculum, and an increased emphasis and commitment to serve and be accountable for all students. NAEP should strive to develop 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 the NAEP Technology and Engineering Literacy Assessment will be computer-delivered and will contain a large proportion of scenario-based assessment items, great attention needs to be paid to ensuring that the assessments are valid and accessible to a wide range of students. Two types of populations need to be considered in order to properly address student diversity in the design of the assessment, English language learners—students who are developing English as their second language—and students with disabilities. Both populations are tremendously heterogeneous. The former, because of the wide range of students’ first languages, cultural influences, and stages in English development; the latter, because of the wide range of disabilities—from physical to sensory to cognitive. Whereas both populations may have common sets of needs, some design issues may be particularly relevant to one or the other. Both populations should be considered carefully in the design of the NAEP Technology and Engineering Literacy Assessment.

In order to effectively include English language learners and students with disabilities in the technology and engineering literacy assessments, three areas that need to be addressed include the participation of students in the pilot stages of test development and the use of testing accommodations.

The purpose of this chapter in the specifications is to provide a more detailed discussion of the issues that are raised in the final section of Chapter Four of the NAEP Technology and Engineering Literacy Assessment Framework concerning how the assessment should be designed to ensure the greatest level of access. In the first section, guidelines are given about the design of the assessment delivery system. In the second section, the general principles of universal design that apply to a complex computer based assessment are outlined and discussed. In the third section, the particular accommodations needs of students with physical, sensory, cognitive, and other disabilities are described, and strategies are outlined for ensuring inclusion of those students in the assessment. In the fourth section, the accommodations required by students who are English language learners are discussed along with recommendations for assessment development that ensures inclusion of such students. The fifth section describes how a development process can ensure that the assessment meets its targets for optimal accessibility for students and the fullest levels of inclusion of students in the sample selected to take the Technology and Engineering Literacy Assessment.

The Assessment Delivery System

For this Technology and Engineering Literacy Assessment, the computer delivery system needs to be designed to administer the complex assessment types that are described in these specifications, and it is recommended that a system be designed specifically for this purpose. There is danger in trying to repurpose an existing assessment delivery system as the design of the assessment tasks would have to be constrained in ways that could prevent them from operating and being scored as described in these specifications. Several constraints in current systems can limit the design of tasks. Such constraints include:

- *Inability to present tasks that use multimedia* – Restrictions on the use of video, audio or animations would constrain assessment designs.
- *Inability to capture diverse response types* – Capturing responses only using radio buttons or checkboxes would preclude capturing information about student actions, such as selection of tools. It would also limit the range of student actions that could be observed. For example, students would not be able to draw arrows or drag and drop to indicate their responses to an item
- *Inability to save and use student responses in ongoing tasks* – Restrictions in the ability to capture, for example, the values that a student enters in a table on one screen, and present those saved values in a latter part of the task where the student needs to refer to them would limit the ability to measure certain skills.
- *Constraints on operational screen area* – the pixel size of the window in which the assessment must run can constrain the level of detail that might be presented in a task, especially where several sources of information or virtual tools need to be present simultaneously.

In addition to the constraints that might exist on the presentation of assessment tasks, there may also be barriers to schools participating in the assessment if the administration system imposes technical restrictions. Examples of assessment system constraints that may limit the participation of schools:

- *Platform restrictions* – If the assessments will run only on a particular computer operating system (e.g., PC or Mac) it may be problematic for schools.
- *Software installations on school computers* – The loading of software on school computers can be challenging because of restrictions imposed by schools or di*stricts, and compatib*ility with existing software on the machine.
- *Web browser limitations* – Although software that runs via a web browser may get around the issues with having to load software on a school computer, if it does not run on all common browsers, or only the latest version, or only with particular plug-ins, this can restrict the ability to run the assessment.
- *Bandwidth requirements* – For web-based software that is running assessment tasks that use graphics and other rich multimedia, there can be problems with download speeds in school settings.
- *Firewalls and content filters* – Firewalls and content filters will prevent unknown downloads of software or contact with unknown websites, and settings may have to be

changed to allow the assessment administration software or websites to be accessed from school computers.

However, if NAEP does supply laptops, as was done for the 2009 NAEP Science Assessment and as planned for the 2011 NAEP Writing Assessment, then many of the deployment issues listed here are eliminated.

Accessibility of the Assessment

Students will be randomly selected to participate in the Technology and Engineering Literacy Assessment. Across this sample, students will have a range of experience with computers, and some will need particular accommodations to be able to access the assessment, to be able to respond, and to show what they know and can do in the topics covered by the Technology and Engineering Literacy Assessment. The accessibility of the assessment will be greatly improved through adherence to good design principles, and through the involvement of students, educators, and other experts in the development and testing of assessment delivery systems and assessment items right from the start of the assessment development process, rather than addressing issues of accessibility, usage and accommodations only near the end of the process.

Overview of the Concept of Universal Design

The items in the NAEP Technology and Engineering Literacy Assessment that make use of the multimedia capabilities of the computer offer a chance to more easily reach a wide range of students than traditional paper-and-pencil items allow to reach. Universal design is a concept that started in architecture and has been applied to assessment by identifying the relevant essential elements for assessment (Thompson, Thurlow, & Malouf, 2004). Since its early explication, the concept has been applied to instruction as universal design for learning (UDL) (Orkwis & McLane, 1998; Rose & Meyer, 2002). At the time of the writing of the framework and specifications, NAEP is considering how the principles of universal design might be applied in its assessments, but no policy has yet been adopted.

The Universal Design for Computer-Based Testing (UD-CBT) framework and a detailed set of UD-CBT guidelines (Dolan et al., 2007) specifically address the design of novel computer-delivered assessments such as the one that will be developed for the NAEP Technology and Engineering Literacy Framework. The UD-CBT represents, at the time of publication of the NAEP Technology and Engineering Literacy Framework, a useful guideline for developing interactive scenario-based assessments. However, developers of the assessment will need to pay attention to developments in the field as a greater number of innovative assessments are developed, and more information is available about how to apply the principles of universal design to them. This section draws attention to parts of the UD-CBT that could be particularly relevant in the development of the NAEP Technology and Engineering Literacy Assessment.

Rationale for Maximizing Accessibility on the Assessment

From a test developer's point of view, a major purpose of applying Universal Design to an assessment is to ensure that students taking the assessment need only apply the knowledge and skills that the developer intended to be measured, and to minimize the need for other skills required by the tasks and items. In educational measurement terminology, the aim is to minimize construct irrelevant variance. For example, if a computer-based task that focuses on engineering design includes complex navigation and requires students to interpret a complex interface in order to respond, then the assessment is not only measuring the student's knowledge of engineering design, but also the ability to understand a poorly designed interface, which is not part of the skill being tested.

In the Technology and Engineering Literacy Assessment there will be a tension between the complexity of the scenarios and the need to minimize construct irrelevant variance. The assessment tasks will need to be complex enough to allow students to show how they can solve problems, use virtual tools, and take actions that reveal what they know and can do, but should not, by virtue of their complexity, require students to apply a set of skills that are not directly part of the practices for technology and engineering literacy being measured.

Fortunately, the UD-CBT offers a comprehensive set of guidelines that will be helpful for the assessment developers to consider. It addresses three major areas: test delivery considerations, item content and delivery considerations, and component content and delivery considerations, each of which is discussed in the following sections. Within those three areas, the UD-CBT considers six types of processing that a student applies in understanding and responding to an item: perceptual, linguistic, cognitive, motoric, executive, and affective processing.

Of the UD-CBT, the section on multistage/multipart items is particularly relevant to the design of long and short scenarios in which students will engage in multiple actions and make multiple responses over a period of time. This will involve a student navigating from screen to screen to progress through a series of subtasks. It is possible that in some instances students' progression is best restricted to forward direction only as they move from subtask to subtask, but in other scenarios, part of the skill being measured will be students' abilities to navigate back and forth in the scenario.

Test Delivery Considerations

In computer-based assessments using scenario based tasks and items, there is a strong relationship between the assessment delivery system and the content of the assessment. Design decisions in one can greatly influence the design of the other, so it is important that the design of both be considered from the outset. The first section of this chapter sounded some cautions about the design of the assessment delivery system in general, and this section offers some more guidance from the point of view of universal design.

The computer-based assessment delivery system should avoid construct irrelevant variance due to adding a level of complexity on top of the assessments themselves that would add cognitive load to the student as they perform assessment tasks. The section in the UD-CBT on Test

Delivery Considerations provides more detailed guidance about things to consider in the design of the delivery system in order to minimize construct irrelevant variance. The UD-CBT recommends developing a standardized user interface design that provides a set of user tools that are available across the assessment content areas, including sequential item-to-item navigation and an interactive view that allows students to see where they are in the assessment sequence, return to previously seen items that they have flagged, or move to any item. Within the scenario tasks, there should be similar navigation that allows a student to move between items within the scenario. There should be a way for a student to undo an action that was unintended and to revise or reset a constructed response item answer as appropriate.

The layout of tasks and items and the location of tools on the screen should be consistent throughout, and assessment task and item developers should work within the predetermined screen wireframes that represent the layout. Specifications need to be developed for how stimulus materials are presented, and also for how interactive components are presented and function.

For functions that allow students to make notes, draft responses, make calculations, etc. in the process of making their final response, specifications need to be developed to define how those tools will be accessed and when and where they will be visible. Other tools that are more central to the assessment response also need to be carefully designed.

Assessment item writers and programmers need to be provided with all specifications, wireframes and style sheets to ensure that designed tasks and items are consistent. In general, the development needs to meet current best practices for accessible user interfaces. Especially important for providing accommodations for students with disabilities, which are discussed in more detail later, the developer needs to ensure that operating system level accessibility features on the computers that are used by students (such as screen enlargement) to take the assessment are enabled, or that equivalent or better features are provided within the assessment delivery system.

Item Content and Delivery Considerations

The UD-CBT section on item content and delivery considerations addresses issues that are relevant to ensuring that assessment items actually test the skills and knowledge they were intended to measure. The section presents principles that are essential to design good assessments of any sort, but some of the principles have particular relevance for the Technology and Engineering Literacy Assessment because of the nature of the complex tasks in which students will engage within the computer-based environment.

Attention should be paid to the realism of any virtual environments or tools intended to represent those existing in the real world, minimizing the need for students to interpret obscure representations when answering items. A balance needs to be found between providing tools that are like those in the real world, which perform the functions needed for the task, but are not so complex that a student might get lost if they are not familiar with that particular version of the tool. For example, if a database tool is to be included for a task, it should have the basic functions that might be found in common software, but it would not be exactly like a particular brand of database software.

Another topic covered in the UD-CBT that may be more challenging to judge in the design of complex assessments is the appropriate time and task load. In a multi-step task where students respond to several items in different ways, it would be easy to end up with a task that takes longer to complete than intended. In contrast, sometimes a developer underestimates the time that it might take to complete a task. As recommended elsewhere in the specifications, judgments of time and load can be obtained through usability testing with students during the design process.

One aspect not discussed directly in the UD-CBT but worth considering, is the range of students' abilities to type on a keyboard, which will vary across grade levels assessed in the NAEP Technology and Engineering Literacy Assessment because of physical differences in the size of their hands (Waner, Behymer, & McCrary, 1992) and variations in their level of keyboarding skills due to opportunity to learn those skills (Fleming, 2002). Students at grade 4 may lack some of the keyboard skills to efficiently type a written response. So, the design of items should minimize the amount of typed input at the fourth grade level and that input should be mainly via the mouse or other simple keyboard commands, such as the directional arrow keys and the "enter" button. Although it is more reasonable for eighth and twelfth grade students to type written responses, to maintain high levels of accessibility to the assessment, the simplest and least cognitively demanding input method should be used. Even accuracy in the use of the mouse is dependent on age and the size of the "target" that children are expected to click on (Hourcade, Bederson, Druin, & Guimbretière, 2004). Paying attention to such differences in the design stages will help to ensure that the tasks measure the relevant technology and engineering literacy performance expectations and that students are not hindered in their responses because they lack computer skills that are unrelated to what is being assessed.

Component Content and Delivery Considerations

The UD-CBT contains a comprehensive account of considerations for the design of the content of the assessment tasks and items in a computer-based assessment. It covers all major formats of task and item components, including text, images, audio, tables and graphs, mathematical and scientific notation, video/animation, response options, active objects and links, constructed responses (text and math) and multistage/multipart items. While all of these are relevant to the Technology and Engineering Literacy Assessment to a greater or lesser degree, the multistage/multipart items section will be particularly relevant for the design of the long and short scenarios.

It is not necessary to repeat here all of the detailed advice contained in the UD-CBT, but there are several things to add about the design of the scenario-based tasks and items. In choosing the dynamic tasks for students to complete in the scenarios and the items they contain, care should be taken to ensure that the dynamic or interactive features included are truly required for the task and that they align to the content targets being assessed. Also, while it is desirable to have students do tasks that are like real world tasks, for the purpose of the assessment if a simpler task allows the same information to be measured, use the simpler task (Mislevy & Gitomer, 1996).

Even when complexity is necessary to measure the knowledge and skills effectively, it is a good idea to gradually increase the complexity of interaction required in the task. If necessary, provide some scaffolding for the task initially, and then gradually remove the scaffolding.

Students with Disabilities: Assessment Issues and Recommendations

NAEP strives to assess all students selected by its sampling process. Rigorous efforts are made to minimize the number of students with disabilities excluded from NAEP assessments. NAEP is committed to including 95 percent of all students sampled. Among students with disabilities the goal is 85 percent inclusion. 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, 2005, Current Policy section, ¶ 4).

Students with disabilities should participate in the National Assessment with or without allowable accommodations, as needed. Allowable accommodations are any changes from standard test administration procedures, needed to provide fair access by students with disabilities that do not alter the constructs being measured and produce valid results. In cases where non-standard procedures are permitted on state tests but not allowed on NAEP, students will be urged to take NAEP without them, but these students may use other allowable accommodations that they need.

The computer-based Technology and Engineering Literacy Assessment will rely upon the delivery of tasks and items that make extensive use of graphical and animated materials, and multiple formats for students to respond. To meet the commitment to assess all students, it will be necessary for the assessment delivery system to include tools, such as screen magnification or text-to-speech options, that can provide the sort of accommodations that students with disabilities need. In fact, the computer delivery system may be able to standardize the provision of accommodations that allow students with disabilities to participate in the assessment and thus improve access. On the other hand, the media rich, computer-based assessment tasks may present even more challenges than would have occurred in a paper-based test for accommodating students with certain physical disabilities such as limited vision, hearing, or physical dexterity. To the extent possible, the assessment tasks and items should be designed in such a way as to allow permissible accommodations.

Typical NAEP Accommodations for Students with Disabilities

Accommodations needed by students with disabilities may be incorporated into the assessment delivery system. However, software and devices already exist for students with disabilities to use computers in general. A balance will need to be struck between incorporating accommodations versus ensuring that the assessment system is compatible with existing solutions; assessment developers should consider the cost of developing built-in accommodations against the frequency with which it is expected that they will be needed. The typical accommodations provided by NAEP for students with disabilities fall into five categories: presentation, response, setting, timing, and other accommodations. The following sections discuss considerations in providing accommodations in the various categories for the Technology and Engineering Literacy Assessment.

Presentation

Accommodations to the presentation will be particularly important to design for in the Technology and Engineering Literacy Assessment. Some accommodations, such as having the directions or other text read aloud, can easily be automated in a computer environment when the assessment developer plans for it. Text-to-speech software is improving; by the date that the assessment is first administered, it may be nearly indistinguishable from a human reader. Magnification of text and graphics is also easily achieved in computer-based assessment and can be built into the assessment delivery system. External screen magnification software may also be used; a drawback of current systems, such as accessibility features in computer operating systems, is to magnify the screen using a static image, which would not allow interaction with the assessment interface. A carefully designed screen magnifier built into the assessment system could allow magnification and interactivity simultaneously. Signing of directions is currently provided in some NAEP assessments, but would be challenging to provide for the more complex tasks in the Technology and Engineering Literacy Assessment. A Braille version of the assessment may not be possible at all.

Response

The assessment delivery system should be designed to allow students to respond in multiple ways. Developers need to make sure that the assessment delivery system is compatible with common devices that students with disabilities use to access computer software. There will, however, likely be some accommodations that are currently provided in NAEP paper and pencil test formats, such as allowing a student to point, to sign, verbalize their response, or type a response using a Braille typewriter, that would have to be provided outside of the computer-based environment.

Setting

The typical accommodations of the setting for the assessment, such as providing a small group, 1-on-1, a separate study carrel, preferred seating, having the test administered by a familiar person, etc. should all still be possible with a computer-based administration.

Timing

Typical accommodations for timing include allowing extra time, providing breaks during testing, or completing the assessment in more than one session. A simple feature should be added to the assessment system to provide extra time to complete the assessment. Mechanisms for saving incomplete assessments and for returning to the assessment at appropriate points should be added to provide the capability to take breaks or to complete the assessment in several separate sessions. All students, including students with disabilities, need these features to allow for unplanned interruptions to the assessment when, for example, the power to the computer is accidentally turned off while a student is taking the assessment.

Other Accommodations

The types of accommodations provided under this category for text-based items and response formats have in the past included such things as allowing a student to use a dictionary, thesaurus, or spelling and grammar-checking software or devices. Such accommodations can be built into the assessment delivery system. Similarly, allowing a student to use a calculator or arithmetic tables for computation tasks is easy to provide on a computer. Providing a talking or Braille calculator, abacus, or graph paper however, might have to be done outside of the computer environment.

English Language Learners: Assessment Issues and Recommendations

NAEP also makes great efforts to include students who are English language learners (ELLs) in NAEP assessments. NAEP is committed to the goal of 85 percent inclusion for ELLs. The term “inclusion” refers to testing English language learners (ELLs) along with their native English speaking counterparts in large-scale assessment. Underlying the notion of inclusion is the assumption that appropriate actions can be taken to ensure that students’ performances on tests of constructs other than language accurately represent their levels of competencies in these constructs, rather than their proficiencies in the language of the test.

In order to effectively minimize the influence of language factors on student performance, test developers should understand the term “inclusion” as something that takes place throughout the entire process of testing, not at its end. Thus, while necessary, the use of NAEP-authorized testing accommodations is not sufficient to ensure fair and valid testing. Other, important actions need to take place in the ways in which student populations are specified, the process of test development, and the kinds of generalizations of testing data.

Ensuring fair and valid testing for ELLs begins with properly addressing the characteristics of this population. Not only is this group large, with about 10% of the total student enrollment in public schools in the U.S. (see Kindler, 2002); it is also tremendously heterogeneous. ELLs can be thought of as bilingual individuals who have different sets of strengths and weaknesses in English and in their native languages (Bialystok, 2001). “Bilingual” is a very broad concept that includes many different patterns of dominance of first language or second language across language modes (listening, speaking, reading, writing) (Grosjean, 1989). These different patterns are due to formal schooling, migration histories, family, culture, and many more factors (Cummins, 2001).

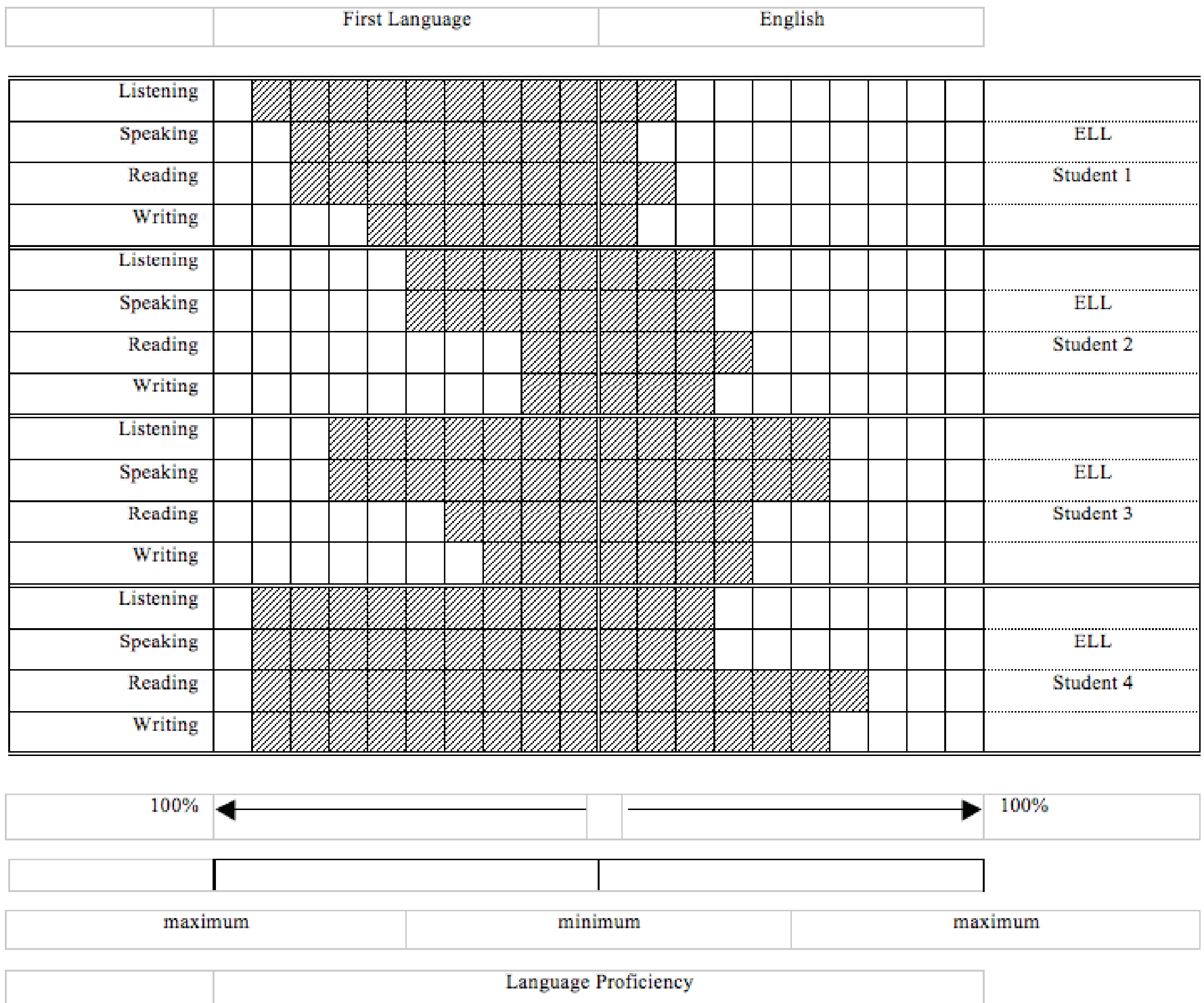


Figure 4 – Diverse Language Proficiency Patterns: Linguagrams of Four Hypothetical English Language Learners (Source: Solano-Flores & Li, 2008)

The linguistic heterogeneity of ELLs is illustrated in the linguagram shown in Figure 4 (Solano-Flores & Li, 2008), which graphically represents the proficiency of four hypothetical ELL students in the listening, speaking, reading, and writing modes in both English and their native languages. As the figure shows, each student has a unique pattern of language dominance.

Test Translation

Administration of the assessment in the ELLs' native language should be considered as an option only when these students have received instruction on the content of the assessment in their native language.

If the assessment is to be administered in the ELLs' native language, two models of development can be considered, simultaneous and sequential (Solano-Flores, in press a, b). In the simultaneous model the English version and the ELLs native-language version of the assessment are developed concurrently; any modification in one language version of the assessment must result in a corresponding change in the other version. Although effective, this model requires the participation of bilingual teams during the entire process of development and may not be practical when more than one language version, other than English, is to be created.

In the sequential model, the assessment is translated after it has been developed in English. The complexity of translation should not be underestimated. The use of one translator and the use of back translation as a translation verification procedure should be discouraged, as there is evidence of the limitations of such approaches. A more effective approach is based on the use of translation and translation review teams composed of certified translators, specialists in the corresponding content area, and teachers.

As with the process of test development in the original language, the translation of an assessment should be done iteratively. In this iterative process, that the translation is tried-out with pilot students and refined based on information collected from them. Test developers should ensure that they allocate sufficient time for test translation and at least two translation review iterations (Solano-Flores, Backhoff, & Contreras-Niño, 2009).

Testing Accommodations for ELLs

NAEP authorizes the use of certain accommodations in the testing of ELLs. However, without high quality and consistent implementation, there may be a limit to the ways in which testing accommodations can be provided to ELLs. For example, many testing accommodations assume certain linguistic skills among the educators who provide them. Others can be interpreted or implemented in multiple ways. The use of computers in the administration offers the opportunity to provide a standardized set of accommodations through the use of audio files for reading of text in a student’s native language, or the reading aloud of the text in English.

Test developers should ensure that, as a part of the process of test development, they pilot test the tasks with ELLs who are and are not given those testing accommodations. The intent should be to gather information on the issues that may hamper the proper implementation of the accommodations and determine when it is and when it is not appropriate to provide them.

Scoring of ELL Student Responses

Even if the assessment is to be administered only in English, the pool of professionals used to score the students’ responses should reflect the linguistic diversity of this country. More specifically, bilingual individuals should be properly represented among the professionals hired as raters of open-ended responses.

Linguistic Features that May Influence the Scoring of ELL Student Responses

1. Code-switching—use of both the student's native language and English, ranging from the insertion of some words from the native language to the use of the two languages in the same sentence without violating the syntactical rules of either one of the languages (see Romaine, 1995)
2. Use of native language phonetics in attempting to write English or beginning-stage English phonetic spelling (e.g., *de ticher sed*—"the teacher said")
3. Use of writing conventions from the native language (e.g., *today is monday*—the names of the weekdays are not capitalized in standard Spanish)
4. Use of technical notation conventions from the student's culture (e.g., $25,00 to express twenty-five dollars)
5. Imprecise use of words (e.g., *I called with him*—"I spoke with him")
6. Unusual sentence structures (e.g., *I don't know what is the response*)
7. Unusual discourse structure (e.g., lack of a topic sentence at the beginning of a paragraph, which may reflect the discursive style that is acceptable in the student's formal written language)
8. Over-reliance on non-verbal forms of communication (such as charts or pictures) with limited writing
9. Others, including transposition of words (e.g., *the cat black*), and omission of tense markers (e.g., *Yesterday he learn at lot*), articles (*I didn't see it in notebook)*, plurals (*the horse are gone*), prepositions (e.g., *explain me what you said*), or other words

(Source: National Assessment Governing Board, 2008a)

There is consensus that being bilingual helps teachers to better interpret ELL students' written responses, even if they are tested only in English. The reason is that bilingual teachers can potentially recognize students' first language influences in written responses and thus infer their students' interpretation of the test items and the intended meaning of their students' responses.

The scorer training materials, including benchmark student responses, should include responses given by ELL students. These materials and sample responses should address issues such as those shown in the text box above.

Test Development Processes

The test development cycles for complex interactive assessments need to be different from those that are used for paper-based assessments, because the design of the assessment delivery system and the interactions that students have with the interface introduce many more things that could increase construct irrelevant variance. The main difference between typical development processes and the new processes needed for the Technology and Engineering Literacy Assessment is that computer-based assessments with complex tasks and items need to go through multiple stages of tryout first with development team members and then with students. These processes and stages are described below.

Test Development Teams

In addition to content area experts and teachers of the content assessed, assessment development teams should include experts in psychometrics, design of interactive educational computer environments, teaching ELLs, and educating students with disabilities. These additional groups of experts are discussed below.

Psychometricians

All assessment development should include psychometricians who are trained in the ways of measuring and reporting on student performance; the computer-based nature of the Technology and Engineering Literacy Assessment and its strong emphasis on complex tasks will require that the psychometricians on the team have particular expertise in those aspects.

Experts in Computer-Based Educational Environments

Typical types of expertise that are required in developing complex computer-based assessments include computer interface and interaction designers, artists, animators, and programmers. These experts should be involved early in the process because the design of the content of tasks and items is inseparable from the ways that they are presented to students on screen and the methods that students will use to respond. In the latter stages of development, team members will need to include software quality assurance experts to ensure that the system works as designed.

Experts in Teaching ELLs

This category includes bilingual educators who teach ELLs and professionals from the fields of linguistics and cultural anthropology and educators who teach students with disabilities and professionals in the field of special education. These professionals bring to the process valuable practical knowledge of the characteristics of ELL students and the complex interaction of language and culture. While assessments go through some sort of review intended to address issues of language and culture, the importance of involving these professionals in all stages of the process of assessment development cannot be emphasized enough. They should be involved in the process of assessment development from its early stages, even if the assessment is to be administered only in English.

Experts in Teaching Students with Disabilities

Teachers who specialize in teaching students with disabilities and experts knowledgeable about the particular aspects of universal design for students with disabilities using computer software will be able to ensure that the assessment delivery system and the designs of the tasks and items allow for inclusion of students with disabilities.

Test Development Processes

Test development processes for the Technology and Engineering Literacy Assessment will require two types of tryouts, the first round within the development team described above, and the second round with students in the target population for the assessment.

Tryouts within the Development Team

There are two reasons for tryouts of assessment tasks and items within the development team. First, it is hard for content experts and teachers to envision the fully interactive tasks without seeing shells that describe the tasks and items and prototypes that illustrate the assessment activities that students will experience. The use of paper or electronic prototypes that represent the essential interactive elements of a scenario allow the team to experience mockups that will quickly reveal how the task might function and how the interface might need to be designed. Second, through prototyping and review cycles, a better quality assessment task can be designed before high costs are incurred in having computer programmers code the tasks for the computer.

Tryouts with Students in the Target Populations

As part of the process of assessment development, several try-out iterations need to take place in which students are given pilot versions of tasks with the purpose of examining how they interpret and respond to them. This information is obtained through cognitive labs in which students describe their thinking as they solve the problems, and based on the analysis of their written responses. This information is valuable because allows test developers to identify those aspects in which the tasks need improvement, among other things, so that the majority of the students can understand them in the ways in which test developers intend. It also provides a measure of the content validity because it reveals how students are reasoning about the task and whether they are applying the sorts of knowledge and skills that the test developers intended the item to tap into.

ELL Student Participation Throughout Assessment Development

A great number of the changes to assessment tasks are changes in which tasks are worded. Wording is relevant for both ELL and non-ELL students and is critical to proper understanding of the tasks. The ways in which tasks are interpreted may vary across students with different first language backgrounds. Because of this heterogeneity, it is extremely important to ensure that appropriate samples of ELLs participate in all pilot stages of the process of assessment development. A misconception about ELLs is that, because of a limited capacity to communicate in English, little information can be obtained on the ways in which they interpret tasks administered in English. However, many ELLs have the minimum level of basic communication skills in English that would allow test developers to obtain rich information from them.

Representation of ELLs in Samples

The samples of ELLs in the assessment development tryouts should, as far as possible, reflect the proportions of ELLs in the target student population and the linguistic diversity of ELLs.

Language proficiency is difficult to capture in a single test. As a result of this complexity, diagnostic tests of English proficiency and tests of reading or writing proficiency in English may render inconsistent rank-orderings and classifications of students (see García, McKoon, & August, 2006). In addition, the criteria used to classify ELL students vary across states. As a consequence, labels such as “limited English proficient” provide little information about the characteristics of ELLs and may mislead test developers’ actions if additional information on the students’ language proficiency is not available. If possible, ELL students who participate in the process of assessment development should be identified based on multiple measures of language proficiency and other demographic information. This information should allow test developers to draw appropriate samples of ELLs to be included in the process of test development. For example, the ELL individuals included in the process should, as far as possible, represent different levels of English proficiency, different broad linguistic groups (i.e., native speakers of different languages), different socio-economic status levels, different places of origin, and different ethnicities.

Participation of Students with Disabilities in Assessment Development

Students with disabilities should be included in the tryout of the assessment tasks and items. In addition to providing the usual feedback on the content of the pilot versions of the assessment tasks and items, they will be able to provide feedback to test developers on how accessible they are and what modifications might enhance access.

Testing Usability in Schools

In addition to the one-on-one student tryouts in the cognitive interviews, when revised versions of the assessment tasks and items are ready, they should be pilot tested in school settings with samples of students from the target populations. This will provide valuable data for psychometric analyses of the items, but will also provide a realistic test of the assessment administration system. This will highlight any deployment problems that might occur in having to access the assessment tasks and items via the widely-varied platforms, operating systems, processor speeds, and software found in educational settings assuming NAEP will not provide the hardware and software to schools for the assessment. If NAEP does supply laptops, as was done for the 2009 NAEP Science Assessment and as planned for the 2011 NAEP Writing Assessment, then many deployment issues are eliminated. Also, given that the format of the NAEP Technology and Engineering Literacy Assessment is likely to be unfamiliar to most students, students should be given an opportunity to view a demonstration of how to respond to such tasks and items and given the opportunity to practice with a sample item prior to engaging with the pilot test items.

CHAPTER SIX: SCORING AND REPORTING

Introduction

The purpose of this chapter is to provide guidance on how the NAEP Technology and Engineering Literacy Assessment will be scored and the results reported. The assessment will first be administered in 2014. Key sections of the chapter are as follows:

- Overview of the Scoring Processes;
- Measurement Methods;
- How NAEP Results are Reported;
- Reporting Scale Scores and Achievement Levels;
- Reporting Background Variables; and
- Uses of NAEP Reporting.

Overview of the Scoring Processes

Scoring and reporting in the NAEP Technology and Engineering Literacy Assessment will necessarily require the application of measurement processes and methods that have not been a common part of previous NAEP assessments. The closest example of this type of assessment is the development and administration in 2009 of a set of interactive computer tasks as a part of the NAEP Science Assessment.

Before discussing in more detail the types of scoring processes that might be applicable in the NAEP Technology and Engineering Literacy Assessment, it is useful to consider at a general level of specificity the components of complex, computer-based assessments. A very useful framework for describing the scoring approach is the *Four-Process Architecture* proposed by Almond, Steinberg, and Mislevy (2003), which is shown in Figure 5.

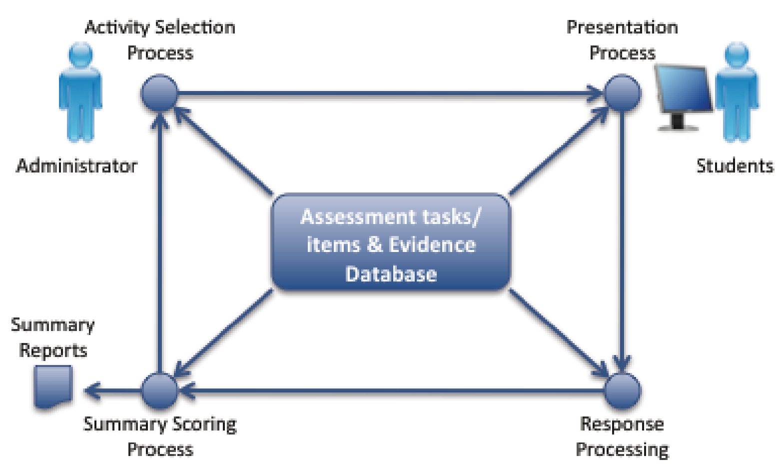


Figure 5 – The Four-Process Architecture (Adapted from Almond et al., 2003)

In Figure 5, the two key human players are the administrator and the student. In the case of the NAEP Technology and Engineering Literacy Assessment, the administrators are the contractors charged by NCES with the tasks of developing and administering the assessment. The administrator is the starting point for the assessment process and determines the choices made in the assessment system. The other players in the system are the students who take the NAEP Technology and Engineering Literacy Assessment at grades 4, 8, and 12. They interact with the various tasks and items that are presented to them via the Presentation Process.

At the center of Figure 5 is a database that contains information on the various assessment tasks and items, the item response types, response processing information, and weightings for responses. This information may be called upon in the Activity Selection Process as a scenario-based task is specified for presentation and response processing. The evidence from all of a student's interactions with a particular task and set of items are processed and sent to the next step in the cycle, the Summary Scoring Process, described in the next section.

The following sections give specifications relevant to each of the four processes of the assessment cycle shown in Figure 5.

Activity Selection Process

The Activity Selection Process is the process responsible for the selection and sequencing of tasks from the assessment tasks and items, and the evidence database represented in the center of Figure 5. The database will comprise the long and short scenarios, and the discrete items, examples of which are given in Chapter Three.

Presentation Process

The presentation process is responsible for presenting the assessment tasks and items to the students via computers connected to the Internet. The presentation must be accessible from different hardware platforms (PC and Mac) using a range of common web-browsing software (e.g., Microsoft Internet Explorer, Safari, Mozilla Firefox). Any software plug-ins needed to run the presentation of the assessment must be freely available to schools. The presentation process should run smoothly at download speeds typical of common broadband Internet access in schools. Access to the presentation process will be secured by usernames and passwords. All data transactions should be secure. If NAEP does supply laptops, as was done for the 2009 NAEP Science Assessment and as planned for the 2011 NAEP Writing Assessment, then many deployment issues are eliminated.

To maximize the use of tasks and items in the database, it is envisioned that components of the tasks items will be stored in separate data collections. For instance, separate components might include—but are not limited to—the following:

- The scenario context and problem statement
- Available background resources and information
- Component tasks and task blocks in the scenario
- Variable programmed objects in the scenario

- Values of objects in the scenario
- Assessment tasks and items
- Response tools

The selection process (predetermined by the administrator in advance of the assessment delivery) will determine how the appropriate components for a given task are assembled and presented to the student. As students interact with the tasks and items, their responses will be captured and sent as “work products” to the response processing part of the assessment sequence. Response processing is described in the following section.

Response Processing

The actions and inputs that students make in response to the tasks and items in the presentation process are gathered as work products particular to the different elements of each task. These work products are, at this stage, just raw data that must be processed before they can be scored in the next stage of the assessment cycle. The response processing identifies the essential features of the response that provide evidence about the student’s current knowledge, skills, and capabilities for identified targets.

In the NAEP Technology and Engineering Literacy assessment system, there will be several different work products generated. First, the student’s interaction with the tasks and tools in the scenarios will produce student actions that are observable evidence of the knowledge and skills to be measured. For example, in a design task, the choice of tools to accomplish the task, how the tools were used, and the design outcome all might provide measurable responses.

Other work products will come from the items that students answer during their construction of responses in the scenarios or in the discrete items. These questions may be selected-response questions or constructed-response questions.

Work products will be processed in a variety of ways. For some work products, meeting a greater number of criteria might indicate higher achievement. However, greater values in the raw data will not always translate into higher scores. For example, a task may require students to test a system and make changes. Less knowledgeable students may test the system only once, failing to identify the optimal settings for the system. Slightly higher achieving students may use trial and error, testing the system many times in a non-systematic way. The highest achieving students may use a more efficient method of testing. These students' responses would indicate higher achievement than students who had both fewer and greater numbers of tests. Thus, there needs to be some processing of the response data in order to convert them to a form that is interpretable as part of the summary scoring (discussed in the next subsection).

A potential—but not necessarily the only—way of scoring actions and combining them into an interpretable single score is “bundling” (Timms, 2005). For example, Table 6.1 shows how, on a series of four measurable actions in a simulation, different students might get the same raw score. The first column shows the actions upon which the students were judged. The four right-hand columns labeled Student A through Student D show the dichotomous scores allocated for completing each action successfully (1) or not (0). Note that the total score for each student is the same (3) but that each obtained his or her score in a different way. Suppose it is of interest to see whether students can select and use tools and that to score highly on this task, students should do both correctly. This means that it would be preferable to give students C and D a higher score than students A and B. A "bundled" score for these scoring patterns is shown in the bottom row of the table. Students C and D are given four points, while students A and B get only three points.

Table 6.1 Example of bundling student scores

Action	Student A	Student B	Student C	Student D
Selected correct tools	0	1	1	1
Used tools correctly	1	0	1	1
Ran sufficient tests	1	1	0	1
Accurately recorded data	1	1	1	0
Total raw score	3	3	3	3
Bundled score	**3**	**3**	**4**	**4**

Processing of selected-responses is also necessary. Some may simply generate dichotomous scores where there are correct (1) and incorrect (0) options; however, there may be situations where one selection is optimal, and other selections generate partial scores.

It is recommended that the computer-based system be used to score constructed-responses as often as possible. Constructed-responses will be short answers that a student types into the computer. Response processing of the text of a student's short written response will be handled by such technology as natural language processing to categorize responses according to level. Such technologies generally require that the system be "trained" by scoring a few hundred student responses with previously known scores (obtained by human scoring). Occasional checks by human scorers of subsequent computer scoring of assessment task responses also should be instituted.

Summary Scoring Process

The summary scoring process forms the second stage of the scoring. It accumulates the evidence that is generated from the response processing stage to update the Scoring Record, which represents the interpretations about the student's knowledge and skills measured in the NAEP Technology and Engineering Literacy Assessment.

The NAEP Technology and Engineering Literacy Assessment is likely to adopt a student model for overall mastery (Almond et al., 2003) in which there is a single (continuous) student model variable that indicates the student's achievement level (Basic, Proficient, or Advanced) in Technology and Engineering Literacy. The measurement model will need to handle the accumulation of multiple sources of evidence gathered from across the tasks and items and produce a summary score on the NAEP achievement scale. Potential measurement models are discussed in the next section.

Measurement Methods

The field of educational psychometrics has grown up around the types of responses that are typical in paper-based, large-scale assessments: primarily multiple-choice and written response items. Over the years, the methods of analyzing these types of student responses have become increasingly sophisticated, progressing from Classical Test Theory to Item Response Theory methods that can model different dimensions of students' responses and even dynamically adapt the assessment to the achievement of the student as the student is being assessed. In the types of computer-based tasks and items that will be administered in the NAEP Technology and Engineering Literacy Assessment, the ways in which a student can respond in an assessment task or item are greatly expanded. As discussed in Chapter Three, the old ways of describing response types as, for example, multiple-choice or written response, are too limiting and new ways of thinking about response types need to be defined. The measurement methods for modeling the responses and interpreting them on the NAEP scales need to reflect those complexities.

Assessment developers are encouraged to consider a wide range of measurement methods in deciding on the best approach to scoring the responses that will be obtained in the NAEP Technology and Engineering Literacy Assessment. The following subsections discuss some particular methods that might be useful, but developers should keep abreast of how similar assessments and eLearning systems are solving such issues and choose the most appropriate method(s) to fit the goals and purposes of NAEP.

Limitations of Classical Test Theory and Item Response Theory

The complex tasks in the NAEP Technology and Engineering Literacy Assessment cannot easily be modeled using just Classical Test Theory (CTT) and Item Response Theory (IRT), the methods most commonly used in educational testing. To understand why this is the case, it is helpful to refer to the definition of "complex tasks" in computer-based testing that was proposed by Williamson et al. (Williamson, Bejar, & Mislevy, 2006), which lists four characteristics of complex tasks.

The first characteristic is that the completion of the task requires the student to undergo multiple, non-trivial, domain-relevant steps or cognitive processes. This is true of the tasks and items in the NAEP Technology and Engineering Literacy Assessment.

The second characteristic of complex tasks is that multiple elements, or features, of each task performance are captured and considered in the determination of summaries of performance. A wide range of student responses and actions will be captured in the scenarios and discrete items of the NAEP Technology and Engineering Literacy Assessment.

The third characteristic of complex tasks is that there is a high degree of potential variability in the data vectors for each task, reflecting relatively unconstrained generation of work products. An example of this in the performance of complex tasks in scenarios is when the time taken by a student to perform a task is used as a variable measurement. Unlike traditional measures that have a linear pattern in which more of something is better, time does not necessarily follow that pattern. A student who completes a task quickly might be a high performer who possesses the knowledge and skill required for the task, or he might be a low performer who responds quickly in order to move on in the overall assessment. A student who takes a long time performing the task might be skilled in the task, but proceeds thoughtfully and carefully, or he or she may be unskilled and lingers because of confusion. Without being considered in conjunction with additional variables about task performance, time is not an easy variable to interpret.

The fourth characteristic in the Williamson et al. definition of complex tasks is that the evaluation of the adequacy of task solutions requires the task features to be considered as an interdependent set, for which assumptions of conditional independence typically do not hold. There will be a tension between validity and reliability in the NAEP Technology and Engineering Literacy Assessment: because of their complexity and the longer time that students spend on the tasks, the scenarios can mirror practical tasks and thereby provide greater validity to the assessment. At the same time, however, the use of these complex tasks reduces the number of measures that can be included in any one test and causes many of the measures to be interdependent because they are related to the same scenario, thereby reducing the reliability. While some independence can be achieved by segmenting tasks within the scenarios, interdependence is difficult to avoid.

The Need for an Increased Range of Psychometric Methods

The NAEP Technology and Engineering Literacy Assessment will contain scenarios that lead to diverse sequences of tasks and items, producing multiple measures, often gathered simultaneously, that require metrics not usually found in standard assessments. The multidimensional nature of assessment in the NAEP Technology and Engineering Literacy Assessment will make Classical Test Theory unsuitable as a measurement method because it cannot model different dimensions of a performance simultaneously. Measurement in complex tasks involves interpreting patterns of behavior across one or more tasks. So, the types of measurement methods that better lend themselves to the NAEP Technology and Engineering Literacy Assessment are probability-based methods (like Item Response Theory and Bayes Nets) that can handle uncertainty about the current state of the learner over time, can provide immediate evidence processing during tasks (e.g., rule-based methods like decision trees), and are able to model patterns of student behavior (e.g., Artificial Neural Networks and Bayes Nets). These methods are discussed next.

Discussion of Potential Measurement Models for the NAEP Technology and Engineering Literacy Assessment

The following methods have been used in complex assessments, or in related work in intelligent tutoring. Each is explained briefly and citations are given for relevant work that has used them. This list is not intended to be exhaustive, nor is it intended to provide detailed explanations of the methods.

Item Response Theory (IRT) — Item response models such as the Rasch model have the advantage that they place estimates of student capability and item difficulty on the same linear scale, measured in logits (a log of the odds scale), a property that has been used in an intelligent tutoring system (Timms, 2007). IRT can also represent multiple dimensions from tasks and items. IRT is also useful for analyzing existing response data to obtain estimates of prior probabilities that can be used in Bayes Nets and has been used in conjunction with Artificial Neural Networks (Cooper & Stevens, 2008). NAEP currently uses the three parameter IRT model.

Bayes Nets — A Bayesian network is a probabilistic graphical model that represents a set of random variables and their conditional independencies via a directed acyclic graph. A directed acyclic graph is formed by a collection of nodes and directed edges (links between the nodes). Directed acyclic graphs may be used to model processes in which information flows in a consistent direction through a network of processors. In the Bayes Net, nodes represent random variables and the edges encode the conditional dependencies between the variables. Across a series of nodes and edges a joint probability distribution can be specified over a set of discrete random variables. Figure 6 shows an example of a fragment of a Bayes Net used in the scoring of the ecosystems benchmark assessments in SimScientists (Quellmalz, Timms, & Buckley, in press). It shows how nodes in the network representing data gathered from student actions in the assessment (the lower two rows) provide information to assess the top level variables of content knowledge and science inquiry skills represented in the upper two rows.

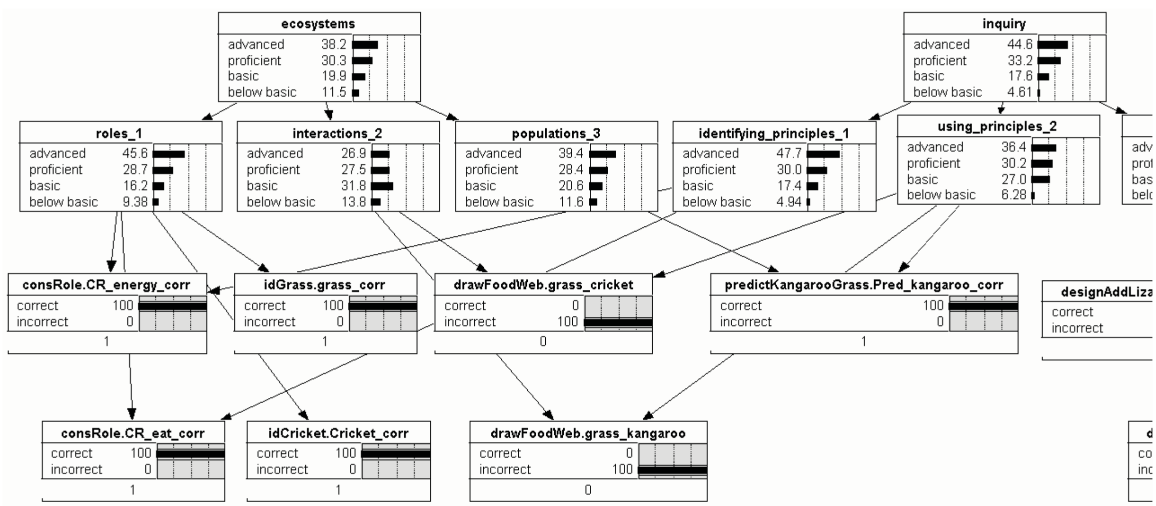


Figure 6 – Fragment of a Bayes Net from the SimScientists Ecosystems Benchmark Assessment (Source: Quellmalz et al., in press)

Values for the edges are encoded, but not visible in this view. Data are gathered from student interactions within the scenario or task and passed to the Bayes Net, where algorithms are then applied using software such as Netica. These algorithms produce estimates of probability that can be used to infer whether students possess the knowledge or skill represented via the nodes. In recent years, Bayesian networks have been widely used in intelligent tutoring systems; their use in systems for assessment is growing. Martin and VanLehn (1995) and Mislevy and Gitomer (1996) studied the applications of Bayesian networks for student assessment. Mislevy has continued this work with Behrens in the NetPass program which assesses examinees' capability to design and troubleshoot computer networks (Behrens, Frezzo, Mislevy, Kroopnick, & Wise, 2008). Conati, Gertner, and Van Lehn (2002) applied Bayesian networks to both assessing students' capability and recognizing students' intentions. Some organizations conducting

research in educational assessment are currently developing Bayes Net system within simulation-based assessment (Quellmalz et al., in press).
Artificial Neural Networks — An Artificial Neural Network (ANN) is an adaptive, most often nonlinear system that learns to perform a function (an input/output map) from data. In a “supervised” ANN, the system parameters are developed in a training phase during which the system is calibrated using sample data that has already been scored. The ANN is built using a systematic step-by-step procedure to optimize a performance criterion or to follow some implicit internal constraint, commonly referred to as the learning rule. After the training phase, the Artificial Neural Network parameters are fixed and the system is deployed to solve the problem at hand (the testing phase). ANN models achieve good performance via massively parallel nets composed of non-linear computational elements, sometimes referred to as units or neurons. Each neuron has an activation level, represented as a number, and each connection between neurons has a weight, also represented by a number. These resemble the firing rate of a biological neuron and the strength of a synapse (connection between two neurons) in the brain. A neuron's activation depends on the activations of the neurons connected to it and the interconnection weights. Neurons are often arranged into layers. Input layer neurons have their activations set externally. ANNs have been widely used in intelligent systems, especially those in which the system needs to learn from data. In education, an example of the use of ANNs is in the work of Stevens through a series of projects in IMMEX (Interactive MultiMedia Exercises). A recent article (Cooper & Stevens, 2008) describes the use of ANNs to assess student metacognition in problem-solving in chemistry. In addition to the ANN, IMMEX uses Hidden Markov Models to cluster a large number of performances in a predetermined number of strategies (called states) and uses IRT to model the student capability, or level of difficulty that the student has been able to reach in the problem set.

Rule-based methods — For immediate assessment of student actions, rule-based methods that are simpler than the other methods discussed above can be appropriate. Rule based methods are ones that employ some logic method to decide how to interpret a student action. A simple example would be posing a multiple-choice question in which the distractors (wrong answer choices) were derived from known misconceptions in the content being assessed. The student’s incorrect response could then be diagnosed and immediate action can be taken, such as selecting another item. This type of diagnosis is the basis of the work of Minstrell and Kraus in their work with the DIAGNOSER software that assesses students in science and diagnoses their understanding and misconceptions (Minstrell & Kraus, 2007). An example of a more complex rule-based method is the decision tree, which applies a logic chain to categorize the student response. The logic chain is represented in a diagram with logic gates that direct the program to implement one of two choices depending on whether the logic test is true or false. Rule based methods are used in the SimScientists project to assess student misconceptions and generate feedback (Quellmalz et al., in press).

How NAEP Results are Reported

The National Assessment of Educational Progress provides the only nationally representative report on student achievement in a variety of subjects. The primary means for public release of NAEP results is a printed summary report known as The Nation’s Report Card. This report is also available on a dedicated website: http://nationsreportcard.gov. Both resources provide detailed information on the nature of the assessment, the demographics of the students who participate, and the assessment results.

The Nation's Report Card includes information on the performance of various subgroups of students at the national level. Subgroups for NAEP include:

- Gender;
- Race/ethnicity;
- Eligibility for free/reduced-price lunch;
- Students with disabilities; and
- English language learners.

Detailed data on NAEP results, demographic variables, and subject-specific background information are available via the NAEP Data Explorer on the website. Additional restricted data are available for scholarly research, subject to National Center for Education Statistics (NCES) licensing procedures.

The Nation's Report Card provides results on the performance of students in public schools in various states as well as in the NAEP Trial Urban Districts. The Trial Urban District Assessment was initiated in 2002 to report on the achievement of public school students in large urban districts. The NAEP Technology and Engineering Literacy Assessment will not be administered as part of the Trial Urban District Assessment program. Results will be reported only at the national level.

Reporting Scale Scores and Achievement Levels

Results of the NAEP Technology and Engineering Literacy Assessment will be reported in terms of percentages of students who attain each of the three achievement levels, Basic, Proficient, and Advanced, discussed below. The NAEP Technology and Engineering Literacy Assessment is an assessment of overall achievement, not a tool for diagnosing the needs of individuals or groups of students. Reported scores are always at the aggregate level. By law and by design, scores are not produced for individual schools or students. Results will be reported for the nation as a whole as well as for regions of the nation. The NAEP Technology and Engineering Literacy Assessment will not provide results for individual states, since the student samples will be drawn to report at the national level only.

The project committees have recommended that the results of the assessment be reported in terms of three subscores, each of them reflecting performance in one of the three main areas of technology and engineering literacy: Technology and Society, Design and Systems, and Information and Communication Technology. An overall composite score will also be reported. At this time technology instruction in most K-12 schools focuses on one or another of the three areas rather than a fusion of the three, so a composite score can be expected to have less relevance than the scores from the three areas.

Reporting on achievement levels is the primary way in which NAEP results reach the general public and policymakers. Achievement level results indicate the degree to which student performance meets the standards set for what students *should know and be able to do* at the *Basic, Proficient,* and *Advanced* levels. Definitions of achievement levels articulate expectations of performance at each grade level. They are reported as percentages of students within each achievement level range, as well as the percentage of students at or above the *Basic* and at or above *Proficient* ranges. Results for students not reaching the *Basic* achievement level are reported as below *Basic*. Results are also reported for subgroups of students using demographic data and background variables specific to the NAEP Technology and Engineering Literacy Assessment. An individual student's performance cannot be reported based on NAEP results.

Table 6.2 displays the Governing Board's generic policy definitions for *Basic, Proficient,* and *Advanced* achievement that pertain to all NAEP subjects and grades.

Table 6.2 Generic achievement level policy definitions for NAEP

Achievement Level	Definition
Advanced	This level signifies superior performance.
Proficient	This level 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.
Basic	This level denotes partial mastery of prerequisite knowledge and skills that are fundamental for proficient work at each grade.

There are three components to the NAEP achievement levels:

- Achievement level definitions;
- Cut scores; and
- Examples of students' responses.

Achievement Level Definitions

Since 1990, the Governing Board has used student achievement levels for reporting results on NAEP assessments. The achievement levels represent an informed judgment of "how good is good enough" in the various subjects that are assessed. Generic policy definitions for achievement at the Basic, Proficient, and Advanced levels describe in very general terms what students at each grade level should know and be able to do on the assessment. Technology and Engineering Literacy achievement levels specific to the 2014 NAEP Technology and Engineering Literacy Framework and Assessment Specifications will be developed to elaborate the generic policy definitions of Basic, Proficient, and Advanced achievement for NAEP assessments. Preliminary achievement level definitions have been developed for each of the three areas to be reported separately in the assessment and they will be used to guide item development and initial stages of standard setting for the 2014 NAEP Technology and Engineering Literacy Assessment. (See Appendix H for these preliminary definitions.)

The preliminary achievement level definitions will be revised when actual student responses have been collected and analyzed. The Governing Board will convene panels of experts to examine the preliminary achievement level definitions and to recommend final achievement level definitions for each grade level. A broadly representative panel of exceptional teachers, educators, and professionals will then be convened to engage in a standard setting process to determine the cut scores that correspond to these achievement level definitions. The panelists will be trained and will engage in a series of discussions designed to ensure informed judgments about mapping cut scores to the assessment.

Cut Scores

Cut scores, the second component of reporting on achievement levels, represent the minimum score required for performance at each NAEP achievement level. Cut scores are reported along with the percentage of students who scored at or above the cut score. As described in Chapter Four, the assessment design for the 2014 NAEP Technology and Engineering Literacy Assessment incorporates scores from selected responses, written responses, as well as measures of the patterns of action a student takes in problem solving. Selected responses in which there is a single best answer will be scored as correct or not and written responses will be scored using a rubric that rewards answers according to their match to descriptions in the rubric. The pattern-tracking will be evaluated by comparing the pattern of action against a set of possible patterns, and students will get more credit for a course of action that is optimal than for alternative patterns of action. Scores can then be combined to produce overall scores so that cut score decisions can be made.

Examples of Students' Responses

The third component of achievement level reporting includes examples of student responses on released tasks from the NAEP Technology and Engineering Literacy Assessment. These examples provide illustrations of student skills within each level of achievement for each of the three areas and will be developed after the first administration of the assessment. Example responses will be annotated to explain the score for the response.

Reporting Background Variables

Background data on students, teachers, and schools are needed to fulfill the statutory requirement that NAEP include information, whenever feasible, for groups identified in the first section of this chapter (e.g., gender, race/ethnicity). Therefore, students, teachers, and school administrators participating in NAEP are asked to respond to questionnaires designed to gather demographic information. Information is also gathered from non-NAEP sources, such as state, district, or school records. For the 2014 NAEP Technology and Engineering Literacy Assessment, only student and school information will be collected since many students will not have taken a separate course in technology and engineering literacy taught by a specific teacher.

In addition to demographic information, background questionnaires include questions about variables related to opportunities to learn and achievement in technology and engineering literacy. The variables are selected to be of topical interest, to be timely, and to be directly related to academic achievement and current trends and issues in technology and engineering literacy. Questions do not solicit information about personal topics or information irrelevant to the collection of data on technology and engineering literacy achievement.

The important components of NAEP reporting are summarized in Table 6.3. Recommendations for background variables for the 2014 NAEP Technology and Engineering Literacy Assessment are presented in the separate background variables document.

Table 6.3 Summary of NAEP reporting components

		Key Characteristics
Components of NAEP Reporting	**How Information is Reported**	Elements released to the public include: • Printed summary report known as The Nation's Report Card • Dedicated website: http://nationsreportcard.gov • Performance of various subgroups at the national level published in print and online
	What is Reported	NAEP data are reported by: • Percentage of students attaining achievement levels • Scale scores • Sample responses to illustrate achievement level definitions
	What Information is Gathered	Types of background variables distributed to students and schools: • These are presented in the separate background variables document.

Uses of NAEP Reporting

The information available from results of the probe for the 2014 NAEP Technology and Engineering Literacy Assessment will provide important data that can be used throughout the tenure of the framework and specifications. The results of the probe will begin the trend line for the new assessment, and policymakers, educators, and the public can use data from the assessments as a tool for monitoring certain aspects of student achievement in technology and engineering literacy over time. NAEP reports from any subsequent administrations of the assessment will compare student performance in the three areas of Technology and Society, Design and Systems, and ICT among groups of students within the same grade. Long-term achievement trends (e.g., the comparison of score performance to previous administrations) can also be reported starting with the second administration.

The scores from the assessment will be of value and interest not just to technology and engineering teachers but to a broad range of educators. As discussed earlier, many different types of teachers are involved in teaching their students about technology and its applications in grades K-12, from those specializing in science, math, and engineering, to those teaching social sciences, humanities, and the arts as well as members of cross-disciplinary teams.

Because the NAEP Technology and Engineering Literacy Assessment will measure some technology and engineering literacy experiences but not all, there will be limitations to the range and scope of information it can produce. NAEP publishes data on student performance in relation to various achievement levels and demographic subgroups; the information reported does not evaluate results or provide conclusive statements about the level of achievement among the nation’s K-12 students. Furthermore, the NAEP Technology and Engineering Literacy Assessment is not designed to inform instruction—to guide how technology and engineering literacy is taught—but only to measure the performance of a representative sample of the American student population at the designated grade within the assessment context outlined in this framework and specifications.

APPENDICES

Appendix A: NAEP Technology and Engineering Literacy Project Committees and Staff

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Appendix B: Glossary of Acronyms, Words, and Terms Used in the Framework and Specifications

The glossary is divided into five sections. The first section presents acronyms used in the framework and specifications, followed by sections on basic framework and specifications terminology, assessment terms, and terms related to education content and pedagogy. The final section presents terms specific to the three major assessment areas of Technology and Engineering Literacy: Technology and Society, Design and Systems, and Information and Communication Technology. Relevant terms and definitions from each area are included, and they are defined within the context of the framework and specifications.

Acronyms for Associations, Educational Organizations, or Reports

AAAS	American Association for the Advancement of Science
CCSSO	Council of Chief State School Officers
IBA	International Baccalaureate Association
ISTE	International Society for Technology in Education
ITEEA	International Technology and Engineering Educators Association
NAE	National Academy of Engineering
NAEP	National Assessment of Educational Progress
NCES	National Center for Education Statistics
NETS•S	National Educational Technology Standards for Students
NRC	National Research Council
NSTA	National Science Teachers Association
OECD	Organisation for Economic Co-operation and Development
PISA	Programme for International Student Assessment
SETDA	State Educational Technology Directors Association
STEM	Science, Technology, Engineering, and Mathematics
TIMSS	Third International Mathematics and Science Study

Basic Framework and Specifications Terminology

Technology	Any modification of the natural or designed world done to fulfill human needs or desires.
Engineering	A systematic and often iterative approach to designing objects, processes, and systems to meet human needs and wants.
Technology and engineering literacy	Capacity to use, understand, and evaluate technology as well as to understand technological principles and strategies needed to develop solutions and achieve goals. It encompasses the three areas of Technology and Society, Design and Systems, and Information and Communication Technology.
Educational technology	Various types of equipment, tools, and processes used as aids in teaching and learning.

Technology educators	All those whose teaching responsibilities include imparting the knowledge, capabilities, and skills described in this framework and specifications.
Technology education	The knowledge and skills taught to students in the three areas of Technology and Society, Design and Systems, and Information and Communication Technology.
Framework	A NAEP framework is a document that defines the parameters of a NAEP assessment. It guides the test makers in developing an assessment.
Technological processes	Procedures using technological knowledge, tools, and skills to develop solutions and achieve goals.
Technological principles	Sets of foundational and fundamental assumptions that underlie each of the three areas of technology and engineering literacy defined in this framework and specifications.
Technological practices	Types of thinking and reasoning that students are expected to demonstrate when responding to an assessment item. The framework and specifications specify three practices: understanding technological principles; developing solutions and achieving goals; and communicating and collaboration.

Assessment Terms

Advanced achievement level	The highest of NAEP’s three levels of performance. This level signifies superior performance.
Assessment areas or targets	The three assessment foci of this framework and specifications on technological literary: Technology and Society, Design and Systems, and Information and Communication Technology.
Assessment balance	Appropriate distribution of items according to major assessment area, technological practice, assessment set type, and response type.
Assessment specifications	Assessment requirements that framework developers give to test developers. These include, for example, the foci of the assessment, the number and types of items, the specific areas to be assessed, the accommodations for students with disabilities, etc.
Background variables	Demographic and contextual data related to the NAEP assessment gathered through questionnaires usually completed by school administrators, teachers, and students.

Basic achievement level	The lowest of NAEP's three levels of performance. This level denotes partial mastery of prerequisite knowledge and skills that are fundamental for proficient work at each grade.
Constructed response	Items in which the student "constructs" the response rather than choosing a response from a limited number of alternatives. Constructed responses may be short (students supply a word or short sentence) or extended (students complete a task).
Cut scores	The minimum score required for performance at each NAEP achievement level.
Discrete item set	A group of questions that include conventional selected response items and short constructed response items.
Item	A single question or set of instructions.
Item specifications	Assessment requirements that framework developers give to test developers, for example, the number and types of items to be included.
Probe (noun)	A smaller-scale, focused assessment on a timely topic that explores a particular question or issue and may be limited to particular grades.
Proficient achievement level	The middle of NAEP's three levels of performance. This level 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 practical situations, and analytical skills appropriate to the subject matter.
Response type	The activity an item asks a student to perform when responding. In this assessment there are three item response types: short constructed response, long constructed response, and selected response.
Scale scores	Scores that allow for comparison of students' performance on different administrations of a test. For example, students' scores might be converted to a score on a scale that ranges from 0 to 500 points.

Scenario-based assessment	In the context of this framework and specifications, scenarios are interactive computer tasks that constitute the bulk of the items. Scenarios may be short or long, depending on what they require the student to do.
Selected response	A type of item in which students read a question and choose the best answer from a set of options.
Universal design for assessment	Guidelines for ensuring that the largest number of disabled students and English language learners participate in an assessment.

Education Content and Pedagogy

Academic problem	An assigned task that a teacher may give to a student.
Collaboration	To work together with other individuals. However, for this NAEP assessment, it will mean using contemporary technologies to work with virtual (computer-generated) individuals to solve problems or achieve goals.
Diffuse curriculum	Curriculum without a clear scope, sequence, and series of courses.
Disaggregation	Separation into component parts, such as the breaking down of achievement data by racial and ethnic subgroup.
Equity	Fair access to opportunities to learn that are based on need rather than on some arbitrary factor.
Fluency	A smooth and easy flow of knowledge and skills.
Habits of mind	Customary ways of thinking and acting.
Literacy	The capacity to use, understand, and evaluate a body of knowledge and skills as well as to apply concepts and processes to solve problems and reach one’s goals.
Sequential curriculum	Curriculum that has a scope, sequence, and a series of courses.

Area-Specific Terms

<u>Technology and Society</u>

Artifacts	Products and items that a society’s population develops, uses, and updates to meet needs and wants.

Human-made	Term describing an artifact that has been designed and developed by means that are outside the boundaries and capabilities of the natural world.
Modeling and simulation	Utilizing technology to analyze and test the possible effects, impacts, and trade-offs that are associated with a new technological innovation to evaluate efficiency, discover potential problems, and develop workable solutions.
Natural world	Plants, animals, water, and other organisms and elements that exist without contributions from humans.
Practical problem	A situation that a person may encounter in everyday life that requires a solution.
Product life cycle	The span of time that an artifact is commissioned to satisfy a societal need that can start from the point of design, manipulation of raw materials, and manufacturing processes, to eventual obsolescence and disposal.
Regulating technologies	Technological innovations that are responsible for contributing to the protection of natural resources in areas such as transportation, energy, and waste disposal.
Technological inequalities	Instances where countries and societies use antiquated technologies due to economic circumstances or cultural preferences.
Trade-off	A decision where complete awareness of both the advantages and disadvantages of the result are explored and the impacts of both are taken into consideration.

<u>Design and Systems</u>

Constraint	A boundary, limit, or restriction, such as time, money, or resources, in the requirements for a project.
Criteria	Characteristics (or specifications) of a successful solution, such as a desired function or a particular level of efficiency.
Engineering design method (Sometimes called technological design)	An iterative, systematic process for solving problems that involves creativity, experience, and accumulated disciplinary knowledge.

Life cycle	Important phases in the development of a system from initial concept through design, testing, use, and maintenance to retirement.
Optimization	Finding the best possible solution when some criterion or constraint is identified as the most important and others are given less weight.
Problem solving	The cognitive process of finding answers to questions and solutions to undesired situations.
Prototype	First version, or generation, of an entity created from a particular design plan using the engineering design method.
Requirements	Combination of criteria and constraints for a given project.
Reverse engineering	Disassembling an item in a systemic way to understand how it works, usually so it can be repaired, copied, or improved.
Systems thinking	Way of investigating or thinking about a system using a set of principles.
Troubleshooting	Systematic method of dealing with failures.

<u>Information and Communication Technology</u>

Digital assistants	Also called Personal Digital Assistants (PDAs), devices used as organizers to enter and store data such as addresses, expenses, or calendar items. Some are capable of being used as handheld computers and may also have Internet capabilities.
Digital models	An electronic representation of a system.
Digital tools	Any technology that stores and transmits data electronically.
Fair use	A condition under U.S. copyright law that permits limited use of copyrighted material without procuring permission from the copyright holder.
Geographical Information System	Any system that gathers, saves, evaluates, and presents data related to geographic locations. A common example is a Global Positioning System (GPS), used to obtain driving directions.
Information and Communication Technologies	Technologies used to access, gather, store, analyze, and report information.

Information (or digital) literacy	Skills needed to access, evaluate, and use information from a variety of sources.
Interactive whiteboards	An interactive display system that connects to a projector and a computer. Using special software, it is possible to project the computer’s desktop and then control the computer using a stylus, personal response system, or even a finger.
Media literacy	The capacity to access and evaluate messages created using a variety of media, such as advertisements, commercials, or speeches, etc. It also refers to the skills required to develop and communicate a message using media.
Media player	Software used on a computer to manage and play video or audio files or to view digital images. It can also be handheld hardware that provides the same functions and is also used to store files.
Mobile wireless devices	Small, lightweight hardware, often called handheld technology, that has the capability to connect wirelessly to the Internet. Examples include handheld computers, smart phones, and netbooks.
Wiki	A website that allows users to work collaboratively to view, edit, and add information. One of the best-known examples of this type of site is Wikipedia, a collaboratively written encyclopedia.

Appendix C: Steering Committee Guidelines*

December 18, 2008
Provisional Approval: September 16, 2009

Introduction

The Steering Committee Guidelines that follow are framed, in part, by the Issues and Recommendations paper prepared by Sharif Shakrani (Michigan State University) and Greg Pearson (National Academy of Engineering) for the National Assessment Governing Board. The guidelines were developed over a two-day period (December 17-18, 2008) by the Steering Committee for the 2012 National Assessment of Educational Progress (NAEP) Technological Literacy Assessment Project. The Steering Committee presented these guidelines to the Planning Committee in a joint session on December 18, 2008. The guidelines were revised and reorganized according to decisions made during the Steering Committee's meeting of March 11-12, 2009, and again shared with the Planning Committee. Additionally, the Steering Committee sought input from leaders in education, industry, business, engineering, research, and allied organizations [including the International Society for Technology in Education (ISTE), the International Technology and Engineering Educators Association (ITEEA), and the Partnership for 21st Century Skills]; feedback resulting from these reviews served further to refine the guidelines.

Suggested Definition for Technological Literacy

The Steering Committee has identified various elements that illustrate the knowledge, ways of thinking and acting, and capabilities that define technological literacy. Technological literacy, as viewed by the Steering Committee, is the capacity to use, understand, and evaluate technology as well as to understand technological principles and strategies needed to develop solutions and achieve goals. It encompasses the three areas of Technology and Society, Design and Systems, and Information and Communications Technology.

Recommended Grade Level to Be Assessed

The National Assessment Governing Board requested that the two committees recommend to the Board at what grade(s) the national probe should be conducted in 2012. Hence, the Steering and Planning Committees of the NAEP Technological Literacy Framework Development Project, in a joint session on March 11, 2009, discussed the matter. On the basis of this discussion, the two committees recommend to the Board that the proposed 2012 NAEP Technological Literacy probe be administered at grade 8. If funding is available for an additional probe, the committees recommend that it be given at grade 12. The lowest priority would be for a probe at grade 4. The rationale for choosing grade 8 included:

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*These Guidelines reflect the recommendations of the Steering Committee as of September, 2009, and do not include the change in title and year of the assessment approved by the National Assessment Governing Board in March, 2010.

- Students are cognitively mature and are more likely to have taken a technology-related course or curriculum units.
- This is the last grade before student dropout rates increase.
- Grade 8 is aligned with The Trends in International Mathematics and Science Study (TIMSS) and the Programme for International Student Assessment (PISA) assessments, allowing for more data analysis.
- Differences in performance by gender are less pronounced than at grade 12.
- There is more opportunity to measure impact from schooling than at grade 4.
- Students may be better equipped to take a computer-based test than at grade 4.
- Grade 8 is specifically targeted in No Child Left Behind, which requires that every student is technologically literate by the time the student finishes the eighth grade.

Guiding Principles

The assessment shall consist of technological content areas making up the scale scores to be reported and technological practices that characterize the field.

1. There are two content areas that must be assessed and where the data must be reported out as subscales:
   a. Design and Systems
   b. Information and Communication Technology (ICT)

If possible, the following area should be explored as a third content area of focus:
   c. Technology and Society

See the Addendum for examples of targets to be included in the three content areas.

2. Suggested technological practices are listed below:

   a. Understanding Technological Principles
   b. Developing Solutions and Achieving Goals
   c. Communicating and Collaborating

The relationships of these practices to the content areas and to each other are reflected in Figure B-1.

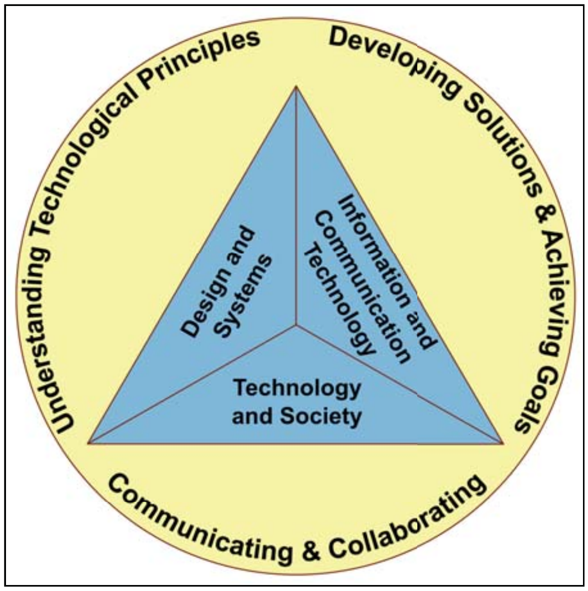


Figure B-1: The relationship between major assessment content areas (blue) and technological practices (yellow).

3. Content and context for the assessment should be informed by existing state standards and assessments, national [e.g., International Society for Technology in Education (ISTE), International Technology and Engineering Educators Association (ITEEA)] and international standards, and research (National Academy of Engineering, National Research Council). Examples from industry, federal agencies responsible for carrying out STEM-based research

[National Aeronautics and Space Administration (NASA), National Oceanic and Atmospheric Administration (NOAA), Department of Agriculture, National Science Foundation (NSF), Department of Energy, Department of Transportation, etc), and science and technology museums might also be collected for building assessment ideas.

4. The assessment should have tasks that are applied to real-world contexts and should be scaffolded to ensure that reliance on students' prior knowledge of specific technology systems will be minimized. The focus should be on concepts and not on specific vocational skills or technologies.

5. "Life situations" and local and contemporaneous conditions should be used as a way to confer relevance to each grade level. Content and context of the assessment items should have relevance and meaning to the learner. If possible, options should be generated in the assessment representing different situations to remove bias due to background of the student.

6. The Planning Committee must develop examples of items and tasks that measure only knowledge and practices that are assessable. The examples should not be limited, to multiple choice, but should illustrate, if possible, different styles and technological tools.

7. Considerable work has already been put into the development of state standards for technology, ICT fluency, and engineering. These existing state standards and assessments should inform the development of the NAEP framework, but should not limit the framework. The Planning Committee should consider differences in how technological literacy is defined and treated in state standards, whether as discrete standards or as part of core content standards, e.g. mathematics, science, and language arts. Attention should also be paid to the confusion around Educational Technology versus Technological Education. There are numerous studies that specify the nature of technological literacy within the standards of various states. States each have their own definition of technological literacy, which may vary from the definition used in the NAEP framework.

8. To avoid the potential problem of obsolescence, the 2012 Technological Literacy Assessment should focus on a broad base of knowledge and skills, not on specific technologies that may change. 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 will most likely be obsolete a decade from now.

9. The assessment should use innovative computer-based assessment strategies that are informed by research on learning and are related to the assessment target (e.g., problem solving). These strategies should also reflect existing state computer-based assessments and the computer-based assessment aspects of the 2009 NAEP Science Framework. To effectively integrate innovative computer-based assessment strategies in the NAEP Technological Literacy Framework, the Planning Committee and/or assessment developers need to know the affordances and constraints of various technologies, how particular ones could support assessment goals, and how to use them. Specific examples of tools available for assessment tasks include probeware, presentation software, authoring tools, electronic white boards, drawing software, and typing tutors.

10. Computer-based assessment strategies should be informed by what is known about all learners, including those with special needs (English language learners and students with disabilities). These strategies should also be informed by the ways students currently use computers to access, process, and utilize information (web 2.0, social networking, etc.). Effective assessment design incorporates current understandings on how people learn, how experts organize information, and the skills of effective learners. Development of the framework and item specifications should draw on expertise in engineering and technology to suggest types of problems that might be adapted to computer-based testing. The kinds of technological tools scientists and engineers use, such as simulations and visualizations, should be considered for use in the technological literacy assessment.

Addendum

The Steering Committee formulated the following list of targets they thought should be included in each of the content areas. Although they consider these sets of targets to be necessary, they agree that the specified targets may not be sufficient. In addition, the committee recognized that guidelines are normally “big ideas” and that this list contains detail in some areas and not in others. In the areas where detail appears, the committee considers these details sufficiently important to enumerate them for the Planning Committee’s consideration on individual targets.

Major Assessment Areas	Targets
Technology and Society	a. Where does technology come from? b. Why is it created? c. How is society affected by scientific and technological concepts and capabilities? d. How technology affects the environment and vice versa. e. Assessing consequences of technology (intended and unintended) f. Green technology g. Digital citizenship h. Safety i. Ethics j. Responsible use of technology
Design and Systems	a. Artifacts are the products of technological systems that meet a need or solve a problem b. Identifying the technological dimensions of an artifact c. Constraints d. Models (and their importance and limitations) e. Evaluation f. Efficiency g. Ethics h. Economy i. Trade-offs/cost, benefit j. Consequences k. Systems thinking
Information and Communication Technology (ICT)	a. Research and use of information b. Recognizing bias c. Extracting critical information d. Media literacy e. Use of digital information systems for innovation and creative expression f. Information/communication operations and concepts g. Use of ICT and learning technologies to learn new content and create knowledge (such as wikis, blogs, probeware, and other collaboration technologies) h. Data driven decision making i. Global awareness j. Ethics

Appendix D: Alignment Table – Comparing the NAEP Technology and Engineering Literacy Assessment Areas to U.S. Source Documents

2014 NAEP – Technology and Society	ISTE – National Education Technology Standards (2007)	ITEEA – Standards for Technological Literacy (2007)
Interaction of Technology and Humans	**Digital Citizenship:** Students understand human, cultural and societal issues related to technology and practice legal and ethical behavior **5.d.** Students exhibit leadership for digital citizenship.	**Standard 4:** Students will develop an understanding of the cultural, social, economic, and political effects of technology. **Standard 6:** Students will develop an understanding of the role of society in the development and use of technology. **Standard 7:** Students will develop an understanding of the influence of technology on history. **Standard 13:** Students will develop abilities to assess the impact of products and systems.
Effects of Technology on the Natural World		**Standard 5:** Students will develop an understanding of the effects of technology on the environment. **Standard 13:** Students will develop abilities to assess the impact of products and systems.
Effects of Technology on the World of Information and Knowledge	**5. Digital Citizenship:** **5.a**. Students advocate and practice safe, legal, and responsible use of information and technology. **5.b**. Students exhibit a positive attitude toward using technology that supports collaboration, learning, and productivity.	**Standard 13:** Students will develop abilities to assess the impact of products and systems.
Ethics, Equity, and Responsibility	**5. Digital Citizenship:** **5.a**. Students advocate and practice safe, legal, and responsible use of information and technology.	

2014 NAEP – Design and Systems	ISTE – National Education Technology Standards (2007)	ITEEA – Standards for Technological Literacy (2007)
Nature of Technology	**1. Creativity and Innovation:** **1.a.** Students apply existing knowledge to generate new ideas, products, or processes. **6. Technology Operations and Concepts:** **6.a.** Students understand and use technology systems.	**Standard 1:** Students will develop an understanding of the characteristics and scope of technology. **Standard 2:** Students will develop an understanding of the core concepts of technology. **Standard 3:** Students will develop an understanding of the relationships among technologies and the connections between technology and other fields of study.
Engineering Design	**1. Creativity and Innovation:** **1.a.** Students apply existing knowledge to generate new ideas, products, or processes. **1.c**. Students use models and simulations to explore complex systems and issues. **3. Research and Information Fluency** **3.a.** Students plan strategies to guide inquiry. **3.d.** Students process data and report results. **4. Critical Thinking, Problem Solving and Decision Making:** Students use critical thinking skills to plan and conduct research, manage projects, solve problems, and make informed decision using appropriate digital tools and resources.	**Standard 8:** Students will develop an understanding of the attributes of design. **Standard 9:** Students will develop an understanding of engineering design. **Standard 11:** Students will develop abilities to apply the design process.
Systems Thinking	**1. Creativity and Innovation:** **1.a.** Students apply existing knowledge to generate new ideas, products or processes. **6. Technology Operations and Concepts:** **6.a.** Students understand and use technology systems.	**Standard 13:** Students will develop abilities to assess the impact of products and systems.
Maintenance and Troubleshooting	**6. Technology Operations and Concepts:** **6.c**. Students troubleshoot systems and applications.	**Standard 10:** Students will develop an understanding of the role of troubleshooting, research and development, invention and innovation, and experimentation in problem solving. **Standard 12:** Students will develop abilities to use and maintain technological products and systems.

2014 NAEP – Information and Communication Technology (ICT)	ISTE – National Education Technology Standards (2007)	ITEEA – Standards for Technological Literacy (2007)
Construction and Exchange of Ideas and Solutions	**2. Communication and Collaboration:** Students use digital media and environments to communicate and work collaboratively, including at a distance to support individual learning and contribute to the learning of others.	
Information Research	**3. Research and Information Fluency:** Students apply digital tools to gather, evaluate, and use information.	
Investigation of Problems	**4. Critical Thinking, Problem Solving, and Decision Making:** Students use critical thinking skills to plan and conduct research, manage projects, solve problems, and make informed decisions using appropriate digital tools and resources.	**Standard 8:** Students will develop an understanding of the attributes of design. **Standard 9:** Students will develop an understanding of engineering design. **Standard 11:** Students will develop abilities to apply the design process.
Acknowledgement of Ideas and Information	**5. Digital Citizenship:** Students understand human, cultural, and societal issues related to technology and practice legal and ethical behavior.	
Selection and Use of Digital Tools	**6. Technology Operations and Concepts:** Students demonstrate a sound understanding of technology concepts, systems, and operations.	**Standard 17:** Students will develop an understanding of and be able to select and use information and communication technologies.

Appendix E: Alignment Table – Comparing the NAEP Technology and Engineering Literacy Assessment Areas to International Source Documents

2014 NAEP Technology and Society	International Baccalaureate Organization Middle Years Programme Technology (2006)	EU Key Competences for Lifelong Learning – A European Framework (2007)	UK Framework for Secondary ICT (2008)	PISA Framework for Assessment of ICT Literacy (2006)
Interaction of Technology and Humans	Students identify the problem to be solved.	Understanding the potential of IST to support creativity and innovation for personal fulfillment, social inclusion and employability Interest in using IST to broaden horizons by taking part in communities and networks for cultural, social and professional purposes.		
Effects of Technology on the Natural World	Students identify the problem to be solved.			
Effects of Technology on the World of Information and Knowledge				
Ethics, Equity, and Responsibility	During the course, students should: • carry out units of work in technology using materials and techniques safely and responsibly • provide evidence of personal engagement with the subject (motivation, independence, general positive attitude) when working in technology.	Positive attitude and sensitivity to safe and responsible use of the Internet, including privacy issues and cultural differences.		

2014 NAEP **Design and Systems**	**International Baccalaureate Organization Middle Years Programme Technology (2006)**	**EU Key Competences for Lifelong Learning – A European Framework (2007)**	**UK Framework for Secondary ICT (2008)**	**PISA Framework for Assessment of ICT Literacy (2006)**
Nature of Technology				
Engineering Design	Students formulate a design specification. Students design the product/solution. Students plan the product/solution. Students follow the plan. Students create the product/solution.		2 Developing ideas 2.2 Models and modelling 4 Evaluating 4.1 Evaluating work	
Maintenance and Troubleshooting				
Systems Thinking				

2014 NAEP **Information and Communication Technology (ICT)**	**International Baccalaureate Organization Middle Years Programme Technology (2006)**	**EU Key Competences for Lifelong Learning – A European Framework (2007)**	**UK Framework for Secondary ICT (2008)**	**PISA Framework for Assessment of ICT Literacy (2006)**
Construction and Exchange of Ideas and Solutions	During the course, students should work effectively as members of a team, collaborating, acknowledging and supporting the views of others.	Propensity to use IST to work autonomously and in teams; critical and reflective attitude in the assessment of available information. Ability to use appropriate aids (presentations, graphs, charts, maps) to produce, present or understand complex information.	3 Communicating information 3.1 Fitness for purpose 3.2 Refining and presenting information 3.3 Communicating	Processes - communicating with others
Information Research	Students should develop the design brief.	Ability to search, collect and process electronic information, data and concepts and to use them in a systematic way. Ability to access and search a website and to use Internet-based services such as discussion forums and e-mail.	1 Finding information 1.1 Using data and information sources 1.2 Searching and selecting 1.3 Organising and investigating	Processes - accessing information - managing information - integrating information - evaluating information - constructing new knowledge
Investigation of Problems		Ability to use IST to support critical thinking, creativity and innovation in different contexts at home, leisure and work.	2 Developing ideas 2.1 Analysing and automating processes 2.2 Models and modelling 2.3 Sequencing instructions	Context - ICT for personal use - ICT for public use - ICT for educational - ICT for occupational purposes
Acknowledgement of Ideas and Information	During the course, students should work effectively as members of a team, collaborating, acknowledging and supporting the views of others.	Basic understanding of the reliability and validity of the information available (accessibility/acceptability) and awareness of the need to respect ethical principles in the interactive use of IST.		
Selection and Use of Digital Tools		Understanding the main computer applications, including word processing, spreadsheets, databases, information storage and management. Awareness of the opportunities given by the use of Internet and communication via electronic media (e-mail, videoconferencing, other network tools); and the differences between the real and virtual world		Technology Environments - Web - desktop - e-learning environments.

Appendix F: Alignment Table – Comparing ICT Sub-Areas to the ISTE NETS•S and the Framework for 21st Century Learning

<table>
<tr><th colspan="3">A. Construction and Exchange of Ideas and Solutions</th></tr>
<tr><td colspan="3">Fourth-grade students should be able to collaborate and communicate by working with other members of a (virtual) 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 (virtual). 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.</td></tr>
<tr><th>Grade 4</th><th>Grade 8</th><th>Grade 12</th></tr>
<tr><td>Students know that:
I.4.1: People collaborating as a team can often produce a better product than people working alone. There are common digital tools that can be used to facilitate virtual or face-to-face collaboration.</td><td>Students know that:
I.8.1: Collaboration can take many forms. Pairs or teams of people can work together in the same space or at a distance, at the same time or at different times, and on creative projects or on technical tasks. Different communications technologies are used to support these different forms of collaboration.</td><td>Students know that:
I.12.1: Effective collaboration requires careful selection of team members, monitoring of progress, strategies for reaching agreement when there are opposing points of view, and iterative improvement of collaborative processes. Information and communication technologies can be used to record and share different viewpoints and to collect and tabulate the views of groups of people.</td></tr>
<tr><td>Students are able to:
I.4.2: Utilize input from (virtual, that is, computer-generated) collaborators and experts or sources in the decision-making process to design a product or presentation.</td><td>Students are able to:
I.8.2: Provide feedback to a (virtual) collaborator on a product or presentation, taking into account the other person’s goals and using constructive, rather than negative, criticism.</td><td>Students are able to:
I.12.2: Work through a simulation of a collaborative process. 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.</td></tr>
<tr><td>I.4.3: Communicate information and ideas effectively to an audience in order to accomplish a specified purpose.</td><td>I.8.3: Communicate information and ideas effectively using a variety of media, genres, and formats for multiple purposes and a variety of audiences.</td><td>I.12.3: Synthesize input from multiple sources to communicate ideas to a variety of audiences using various media, genres, and formats.</td></tr>
<tr><th colspan="3">NETS Category 2: Communication and Collaboration</th></tr>
<tr><td colspan="3">Students use digital media and environments to communicate and work collaboratively, including at a distance to support individual learning and contribute to the learning of others. Students:
a. interact, collaborate, and publish with peers, experts, or others employing a variety of digital environments and media.
b. communicate information and ideas effectively to multiple audiences using a variety of media and formats.
c. develop cultural understanding and global awareness by engaging with learners of other cultures.
d. contribute to project teams to produce original works or solve problems.</td></tr>
</table>

Framework for 21st Century Learning: Communication and Collaboration
Communicate Clearly • Articulate thoughts and ideas effectively using oral, written and nonverbal communication skills in a variety of forms and contexts. • Listen effectively to decipher meaning, including knowledge, values, attitudes and intentions. • Use communication for a range of purposes (e.g. to inform, instruct, motivate and persuade). • Utilize multiple media and technologies, and know how to judge their effectiveness a priori as well as assess their impact. • Communicate effectively in diverse environments (including multi-lingual). *Collaborate with Others* • Demonstrate ability to work effectively and respectfully with diverse teams. • Exercise flexibility and willingness to be helpful in making necessary compromises to accomplish a common goal. • Assume shared responsibility for collaborative work, and value the individual contributions made by each team member.

B. Information Research		
Fourth-grade students can use digital and network tools to find information and identify sources that may be biased in some way. Eighth-grade students are able to use digital resources to find information and also 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.4.4:** Digital and network tools and media resources are helpful for answering questions, but they can sometimes be biased or wrong.	**Students know that:** **I.8.4:** 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.12.4:** 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.4.5:** Use digital and network tools and media resources to collect, organize, and display data in order to answer questions and solve problems.	**Students are able to:** **I.8.5:** Select and use appropriate digital and network tools and media resources to collect, organize, analyze, and display supporting data to answer questions and test hypotheses.	**Students are able to:** **I.12.5:** Select digital and network tools and media resources to gather information and data on a practical task, and justify choices based on the tools' efficiency and effectiveness for a given purpose.
I.4.6: Search media and digital sources on a community issue and identify sources that may be biased.	**I.8.6:** Search media and digital resources on a community or world issue and identify specific examples of distortion, exaggeration, or misrepresentation of information.	**I.12.6:** 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.
NETS Category 3: Research and Information Fluency		
Students apply digital tools to gather, evaluate, and use information. Students: a. plan strategies to guide inquiry. b. locate, organize, analyze, evaluate, synthesize, and ethically use information from a variety of sources and media. c. evaluate and select information sources and digital tools based on the appropriateness to specific tasks. d. process data and report results.		

Framework for 21st Century Learning: Communication and Collaboration
Information Literacy *Access and Evaluate Information* • Access information efficiently (time) and effectively (sources). • Evaluate information critically and competently. *Use and Manage Information* • Use information accurately and creatively for the issue or problem at hand. • Manage the flow of information from a wide variety of sources. • Apply a fundamental understanding of the ethical/legal issues surrounding the access and use of information.

C. Investigation of Academic and Practical Problems		
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 complicated 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 hardware or software products.		
Grade 4	**Grade 8**	**Grade 12**
Students are able to: **I.4.7:** Use digital tools and resources to identify and investigate a local issue and generate possible solutions.	**Students are able to:** **I.8.7:** Use digital tools to identify a global issue and investigate possible solutions. Select and present the most promising sustainable solution.	**Students are able to:** **I.12.7:** Use digital tools and resources to identify a complicated global issue and develop a systematic plan of investigation. Present findings in terms of pros and cons of two or more innovative sustainable solutions.
I.4.8: Use digital tools to test simple hypotheses in various subject areas.	**I.8.8:** Use digital tools to gather and display data in order to test hypotheses of moderate complexity in various subject areas. Draw and report conclusions consistent with observations.	**I.12.8:** Use digital tools to collect, analyze, and display data in order to design and conduct complicated investigations in various subject areas. Explain rationale for the design and justify conclusions based on observed patterns in the data.
I.4.9: Use digital models to describe how parts of a whole interact with each other in a model of a system.	**I.8.9:** Use a digital model of a system to conduct a simulation. Explain how changes in the model result in different outcomes.	**I.12.9:** Having conducted a simulation of a system using a digital model, draw conclusions about the system, or propose possible solutions to a problem or ways to reach a goal based on outcomes of the simulation. Critique the conclusions based on the adequacy of the model.
NETS Category 4: Critical Thinking and Decision Making		
Students use critical thinking skills to plan and conduct research, manage projects, solve problems, and make informed decisions using appropriate digital tools and resources. Students: a. identify and define authentic problems and significant questions for investigation. b. plan and manage activities to develop a solution or complete a project. c. collect and analyze data to identify solutions and/or make informed decisions. d. use multiple processes and diverse perspectives to explore alternative solutions.		

Framework for 21st Century Learning: Communication and Collaboration

Critical Thinking and Problem Solving

Reason Effectively

- Use various types of reasoning (inductive, deductive, etc.) as appropriate to the situation.

Use Systems Thinking

- Analyze how parts of a whole interact with each other to produce overall outcomes in complex systems.

Make Judgments and Decisions

- Effectively analyze and evaluate evidence, arguments, claims and beliefs.
- Analyze and evaluate major alternative points of view.
- Synthesize and make connections between information and arguments.
- Interpret information and draw conclusions based on the best analysis.
- Reflect critically on learning experiences and processes.

Solve Problems

- Solve different kinds of non-familiar problems in both conventional and innovative ways.
- Identify and ask significant questions that clarify various points of view and lead to better solutions .

D. Acknowledgement of Ideas and Information		
Fourth-grade students exhibit digital citizenship by understanding that it is permissible to use others' ideas as long as appropriate credit is given but 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.		
Grade 4	**Grade 8**	**Grade 12**
Students know that: **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.	**Students know that:** **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.	**Students know that:** **I.12.10:** Legal requirements governing the use of copyrighted information and ethical guidelines for appropriate citations are intended to protect intellectual property.
Students are able to: **I.4.11:** Identify or provide examples demonstrating respect for copyrighted material, such as resisting the request from a friend to copy a song from a CD or placing copyrighted material online.	**Students are able to:** **I.8.11:** Identify or provide examples of fair use practices that apply appropriate citation of sources when using information from books or digital resources.	**Students are able to:** **I.12.11:** Identify or provide examples of responsible and ethical behavior that follow 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.

NETS Category 5: Digital Citizenship
Students understand human, cultural, and societal issues related to technology and practice legal and ethical behavior. Students: a. advocate and practice safe, legal, and responsible use information and technology. b. exhibit a positive attitude toward using technology that supports collaboration, learning, and productivity. c. demonstrate personal responsibility for lifelong learning. d. exhibit leadership for digital citizenship.

Framework for 21st Century Learning: Communication and Collaboration
Life and Career Skills: Leadership and Responsibility *Guide and Lead Others* • Use interpersonal and problem-solving skills to influence and guide others toward a goal. • Leverage strengths of others to accomplish a common goal. • Inspire others to reach their very best via example and selflessness. • Demonstrate integrity and ethical behavior in using influence and power. *Be Responsible to Others* • Act responsibly with the interests of the larger community in mind.

<table>
<tr><th colspan="3">E. Selection and Use of Digital Tools</th></tr>
<tr><td colspan="3">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.</td></tr>
<tr><th>Grade 4</th><th>Grade 8</th><th>Grade 12</th></tr>
<tr><td>Students know that:
I.4.12: Different digital tools have different purposes.</td><td>Students know that:
I.8.12: Certain 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.</td><td>Students know that:
I.12.12: 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.</td></tr>
<tr><td>Students are able to:
I.4.13: Use digital tools (appropriate for fourth-grade students) effectively for different purposes, such as searching, organizing, and presenting information.</td><td>Students are able to:
I.8.13: Use 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.</td><td>Students are able to:
I.12.13: Demonstrate the capability to use a variety of digital tools to accomplish a task or develop a solution for a practical problem. Justify the choice of tools, explain why other tools were not used based on specific features of the tools, and summarize the results.</td></tr>
<tr><th colspan="3">NETS Category 6: Technology Operations and Concepts</th></tr>
<tr><td colspan="3">Students demonstrate a sound understanding of technology concepts, systems, and operations. Students:
a. understand and use technology systems.
b. select and use applications effectively and productively.
c. troubleshoot systems and applications.
d. transfer current knowledge to learning of new technologies.</td></tr>
</table>

Framework for 21st Century Learning: Communication and Collaboration
Apply Technology Effectively • Use technology as a tool to research, organize, evaluate and communicate information. • Use digital technologies (computers, PDAs, media players, GPS, etc.), communication/networking tools and social networks appropriately to access, manage, integrate, evaluate and create information to successfully function in a knowledge economy. • Apply a fundamental understanding of the ethical/legal issues surrounding the access and use of information technologies.

Appendix G: Alignment Table – Comparing Design and Systems Sub-Areas to the ITEEA Standards for Technological Literacy

2014 NAEP	Standards for Technological Literacy
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.	**Standard 1:** Students will develop an understanding of the characteristics and scope of technology. **Standard 2:** Students will develop an understanding of the core concepts of technology. **Standard 3:** Students will develop an understanding of the relationships among technologies and the connections between technology and other fields of study.
B. Engineering Design Fourth-graders should start to answer the question "How are technologies created?" by learning to deal with simple yet systematic design challenges. Eighth-graders should be able to use a more elaborate engineering design process, including problem definition, the use of prototypes, testing and iteration, and trade-offs. Twelfth-graders should have a deep understanding and a broad array of design skills, including optimization.	**Standard 8:** Students will develop an understanding of the attributes of design. **Standard 9:** Students will develop an understanding of engineering design. **Standard 11:** Students will develop abilities to apply the design process.

C. Systems Thinking Fourth-graders should be able to identify systems, subsystems, components, and boundaries in their everyday world and to construct simple systems designed to accomplish particular goals. Eighth-graders should be able to describe goals, inputs, outputs, and processes of systems, to use reverse engineering and life cycles to analyze systems in terms of feedback and the flow of energy, and to modify and construct moderately complicated systems. Twelfth-graders should understand that systems are embedded in larger systems, to recognize factors that stabilize systems, to use systems for forecasting, and to redesign complicated systems to improve reliability.	**Standard 1:** Students will develop an understanding of the characteristics and scope of technology. **Standard 2:** Students will develop an understanding of the core concepts of technology. **Standard 13:** Students will develop abilities to assess the impact of products and systems.
D. 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.	**Standard 10:** Students will develop an understanding of the role of troubleshooting, research and development, invention and innovation, and experimentation in problem solving. **Standard 12:** Students will develop abilities to use and maintain technological products and systems.

Appendix H: NAEP Technology and Engineering Literacy Preliminary Achievement Level Definitions

Congress authorized the National Assessment Governing Board to develop appropriate student achievement levels on the National Assessment of Educational Progress (NAEP). The achievement level definitions are statements of what students should know and be able to do on NAEP at grades 4, 8, and 12. To fulfill its statutory responsibility, the Governing Board developed a policy to guide the development of achievement levels for all NAEP subjects. Three levels of achievement were identified to provide the public, educators, and policymakers with information on student performance on NAEP. These levels—Basic, Proficient, and Advanced—are used as a primary means of reporting NAEP results to describe “how good is good enough” at grades 4, 8, and 12.

Table H-1 displays the Board’s generic policy definitions for Basic, Proficient, and Advanced achievement that pertain to all NAEP subjects and grades.

Table H-1. Generic Achievement Level Policy Definitions for the National Assessment of Educational Progress

Achievement Level	Policy Definition
Advanced	This level signifies superior performance.
Proficient	This level 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.
Basic	This level denotes partial mastery of prerequisite knowledge and skills that are fundamental for proficient work at each grade.

During the framework development process the project committees are asked to develop preliminary achievement level definitions, based on the generic policy definitions, to guide item development. Essentially the purpose of these statements is to provide examples of what students performing at the basic, proficient, and advanced achievement levels should know and be able to do in terms of the technology and engineering literacy content areas and practices identified in the framework. The intended audiences for these preliminary definitions are the NAEP assessment development contractor and item writers. The definitions are to be used to ensure that a broad range of items is developed at each grade level. Tables H-2, H-3, and H-4 present the preliminary achievement level definitions for grades 4, 8, and 12 as bullet points to clearly illustrate the technology and engineering literacy content and practices expected at each grade level.

The preliminary definitions include *illustrative* statements selected from the framework's technology and engineering literacy content and practices. The statements are not intended to represent the entire set of objectives from the assessment targets, practices, or contexts, nor do the preliminary achievement level definitions denote a sense of priority or importance based on the statements selected.

After the assessment is administered, broadly representative panels engage in a standard setting process to determine the achievement level cut scores on the NAEP scale. The cut scores represent the minimum score required for performance at each NAEP achievement level. Part of this standard setting process is the development of a set of paragraphs, derived from the preliminary achievement level definitions, to be used in reporting the NAEP Technology and Engineering Literacy Assessment results to the general public and other audiences. At each grade level there will be paragraphs describing what students should know and be able to do at the Basic, Proficient, and Advanced level in terms of the technology and engineering literacy content and practices identified in the framework.

Further information on NAEP achievement levels can be found at www.nagb.org.

Table H-2. Grade 4 Preliminary Achievement Level Definitions

	BASIC	PROFICIENT	ADVANCED
	Students know that:	**Students know that:**	**Students know that:**
Technology and Society	A new tool, product, or machine may have benefits and costs.	The introduction of a new tool, product, or machine may change how people live and work.	The introduction of a new tool, product, or machine usually brings both benefits and costs, and it may change how people live and work.
Design and Systems	Tools help people do their work, and certain common tools have particular uses.	Different tools are better for different purposes.	Different tools are better for different purposes because they have different features and function in different ways.
Information and Communication Technology	Digital and network tools can be used to answer questions.	Digital and network tools and media resources are helpful for answering questions, but they can sometimes be biased or wrong.	Digital and network tools and media resources are helpful for answering questions, and information gathering can help to determine if they are biased or wrong.
	Students are able to:	**Students are able to:**	**Students are able to:**
Technology and Society	Name two different technologies in their own lives.	Compare the impact of two different technologies on their own lives.	Compare the ways that their lives would change if one or the other technology were to disappear.
Design and Systems	Build a model from a kit with instructions.	Build and test a model to see if it works as intended.	Build and test a model to see if it works as intended, and use test data to determine how to improve the model.
Information and Communication Technology	Use digital and network tools and media resources to collect, organize, and display data.	Use digital and network tools and media resources to collect, organize, and display data in order to answer questions and solve problems.	Select and use digital and network tools and media resources to collect, organize, and display data in order to answer questions and solve problems.

Table H-3. Grade 8 Preliminary Achievement Level Definitions

	BASIC	PROFICIENT	ADVANCED
	Students know that:	**Students know that:**	**Students know that:**
Technology and Society	Technology interacts with society, sometimes bringing about changes in a society's economy.	Technology interacts with society, sometimes bringing about changes in a society's economy, and culture, and may lead to new needs and wants.	Technology interacts with society, sometimes bringing about changes in a society's economy, politics, and culture, and often leading to the creation of new needs and wants.
Design and Systems	One tool is better than another for a given task as a result of prior improvements.	Tools have been improved over time to further the reach of hands, voices, memory, and the five human senses.	Tools have been improved over time to further the reach of hands, voices, memory, and the five human senses, and to do so more efficiently, accurately, or safely.
Information and Communication Technology	Some information available through electronic means is exaggerated or wrong.	Increases in the ease by which knowledge can be published have heightened the need to check sources for possible distortion, exaggeration, or misrepresentation.	There are various effective ways to check information available through electronic means to identify possible distortion, exaggeration, or misrepresentation.
	Students are able to:	**Students are able to:**	**Students are able to:**
Technology and Society	Identify the impacts of a given technology in a society.	Identify the impacts of a given technology in a society, and predict how it might impact a different society.	Compare the impacts of a given technology on two different societies, noting factors that may make a technology appropriate and sustainable in one society but not in another.
Design and Systems	Design and build a simple model that meets a requirement	Design and build a simple model that meets a requirement, fix it until it works (iteration), test it and gather and display data that describes its properties using graphs and tables.	Design and build a simple model that meets a requirement, fix it until it works (iteration), test it and gather and display data that describes its properties using graphs and tables. Interpret the results to suggest improvements and new designs.
Information and Communication Technology	Select and use appropriate digital and network tools and media resources to collect, organize, and display data.	Select and use appropriate digital and network tools and media resources to collect, organize, analyze, and display supporting data to answer simple questions and test basic hypotheses.	Select and use appropriate digital and network tools and media resources to collect, organize, analyze, and display supporting data to answer complicated questions and test hypotheses, and explain how to go about this to others working on the same project.

Table H-4. Grade 12 Preliminary Achievement Level Definitions

	BASIC	PROFICIENT	ADVANCED
	Students know that:	**Students know that:**	**Students know that:**
Technology and Society	Changes caused by the introduction and use of a new technology can be gradual or rapid as well as big or small.	Changes caused by the introduction and use of a new technology can range from gradual to rapid and from subtle to obvious, and can change over time.	Changes caused by the introduction and use of a new technology can range from gradual to rapid and from subtle to obvious and can change over time. These changes may vary from society to society as a result of differences in a society's economy, politics, or culture.
Design and Systems	The development of tools has influenced and advanced society.	The evolution of tools and materials has played an essential role in the development and advancement of cities and industrial societies.	The evolution of tools and materials has played an essential role in the advancement of civilization, from the establishment of cities and industrial societies to today's global trade and commerce networks.
Information and Communication Technology	Advanced search techniques can be used with digital and network tools and media resources to locate information.	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.	Advanced search techniques can be used with digital and network tools and media resources to locate different kinds of information and to check credibility and expertise of different types of sources.
	Students are able to:	**Students are able to:**	**Students are able to:**
Technology and Society	Analyze the cultural, social, economic, and/or political changes that may be triggered by the introduction of a specific technology into a society.	Analyze cultural, social, economic, and/or political changes that may be triggered by the transfer of a specific technology from one society to another.	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 anticipated and unanticipated effects.
Design and Systems	Construct and test a model to see if it meets the requirements of a problem, then suggest improvements.	Construct and test several models to determine which is best in meeting the requirements of a problem.	Construct and test several models to see if they meet the requirements of a problem. Combine features to achieve the best solution.
Information and Communication Technology	Select digital and network tools and media resources to gather information and data on a practical task.	Select digital and network tools and media resources to gather information and data on a practical task, and justify choices based on the tool's efficiency and effectiveness for a given purpose.	Select digital and network tools and media resources to gather information and data on a practical task, justify choices based on the tool's efficiency and effectiveness for a given purpose, and advise others on which tools and resources would best meet their needs.

Appendix I: Development of Sample Items for the NAEP Technology and Engineering Literacy Assessment

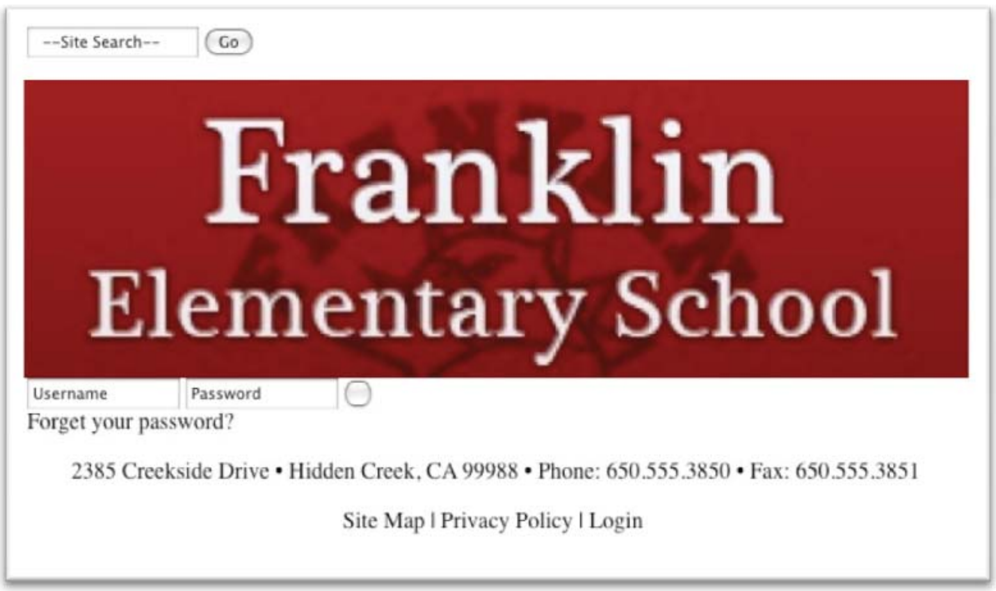
Discrete Items

Selected Response Items

1. Given a specific issue that is relevant to a fourth grade student, choose the search terms that will provide the most useful results.

Grade 4
I.4.B Information Research (practice: Developing Solutions and Achieving Goals)
I.4.5 Use digital and network tools and media resources to collect, organize, and display data in order to answer questions and solve problems.

Martin is in 4th grade at Jefferson Elementary. Next year he will be going to a different school, Franklin Elementary. He is looking at the school's website to find out what school will be like next year, shown below.



(Source: http://franklin.bsd.k12.ca.us)

Which words would be **best** for searching his school's website?

A. new students*
B. important dates
C. elementary schools
D. Franklin elementary

In this item, the context establishes a need to gather information, focusing on an early step in the practice of developing solutions and achieving goals. The issue, a student planning to attend a new school, is relevant to 4th grade students, as most have either attended more than one school, or have a classmate who was at one time new to the students' school. Only the correct answer directly addresses the central idea of this issue, being a new student, and is therefore best for searching the school's website. Students who understand that searching for "new students" means searching for pages with information for new students are more likely to answer correctly. The other options are either tangentially related to the issue or include unnecessary terms, given that the student has already accessed the school's website and is searching within it.

2. Given a specific issue that is relevant to a fourth grade student, choose the source that will provide the most accurate and useful results.

Grade 4
I.4.B Information Research (practice: Developing Solutions and Achieving Goals)
I.4.6 Search media and digital sources on a community issue and identify sources that may be biased.

Anna has a new pet and wants to find a store where she can buy pet food. She lives in Hidden Creek, and her zip code is 99988. Anna searches for a website using “pet food in zip code 99988.” Which of the following would be the best website to find the information she needs?*

A. **Pet** Supply, Inc. k
List of stores where **Pet** Supply brand **pet food** is sold. 123 Main St, Hidden k
Creek, CA k**ip Code** **988** … 1901 Oak St, Fairview, CA k**ip Code** 99981 k
www.petsupplyinc.com/stores.htm k

B. k idden Creek **Pet** Rescue k
We need donations to buy **pet food**. Help care for lost **pets** in the Hidden Creek k
area. PO Box 110, Hidden Creek, CA **Zip Code 9** **88** k
www.hcpets.org k

C. **Pet** Stores in Hidden Creek CA k
Pet Food & Supply. 1201 5th St, Hidden Creek, CA **988** … Hidden Creek **Pet** k
5120 Hwy 11, Hidden Creek, CA **988** … k
www.ci.hidden-creek.ca.us/Pet_Stores.html k

D. k Mary’s **Pet** Service k
30 years of experience in **pet** care, training, feeding, and cleaning. 333 Creekside k
Lane, Hidden Creek, CA **988** k
www.MBpets.com k

*The specifications’ developers created this item for illustrative purposes; it requires further development in that it is not field tested or published. k

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This item focuses on a critical skill necessary to conduct information research: evaluating sources. The display of search results is a common context in which this evaluation may take place. In this example, the sources include two businesses, one organization, and one local government agency. Although all four sources contain text that matches the search terms, only two provide the type of information that the student is searching for. Between these two sites, one is clearly best as it contains more relevant information (local pet store locations) and does not reflect the commercial interests of a particular company (stores where a particular brand of pet food is sold). Students who are more skilled at reviewing search results will be more likely to compare these two sites. Students who are less skilled will be more likely to simply pick the first site listed.

3. Given a specific consumer electronics product such as a cellular telephone, compare recycling to disposal, repair, and replacement. Identify costs and benefits, and whether there are trade-offs to a given solution.

Grade 8
T.8.B Effects of Technology on the Natural World (practice: Developing Solutions and Achieving Goals)
T.8.5 Some technological decisions involve trade-offs between environmental and economic needs, while others have positive effects for both the economy and environment.

Zander's school is starting a program to recycle electronics, such as old cellular telephones and broken computers. The school will receive money for the electronics they recycle.

Which effects will the recycling program **most likely** have?

A. It will reduce waste and the use of raw materials.*
B. It will reduce manufacturing and the cost of hauling garbage.
C. It will reduce manufacturing and increase the use of raw materials.
D. It will reduce the cost of repairs and increase the cost of new electronics.

(Source: http://www.ecophones.com/Schools.aspx)

This item focuses on whether there are trade-offs to a given solution, within the context of an issue related to the effects of technology on the natural world. In this example, the solution has both positive environmental and economic effects. The environmental benefit of recycling, reducing waste, is likely a familiar one. However, recognizing the environmental and economic benefit of some recycling programs, reducing the use of raw materials, may require additional analysis of the context. This is not always true, and requires that the student consider whether the recycling program represents a trade-off or has positive effects for both the economy and environment. Given that the school is receiving compensation for collecting electronics, the student may reason that the materials they contain have some value, a result of the likely lower cost of reusing these materials than exploiting virgin sources.

4. Given a specific advancement in technology, describe the impact on science.

Grade 12
D.12.A Nature of Technology (practice: Understanding Technological Principles)
D.12.2 Engineers use science, mathematics, and other disciplines to improve technology, while scientists use tools devised by engineers to advance knowledge in their disciplines. This interaction has deepened over the past century.

In 2009, the Cray XT5 “Jaguar” supercomputer was completed. At that time, it was the fastest computer in the world, capable of up to 2,300 trillion calculations per second. It has been used to test aircraft designs, predict energy use, and show how Earth’s climate might change.

Which statement **best** explains why building new supercomputers is important?

A. Engineers can use advances in supercomputer design to become scientists.
B. Scientists can compare the designs of supercomputers to other complex systems.
C. Designing supercomputers allows scientists to apply their knowledge to engineering.
D. Advances in supercomputer design allow scientists to build more complex simulations.

(Sources:
http://www.nccs.gov/jaguar
http://www.nccs.gov/2010/02/09/worlds-no-1-computer-has-long-list-of-tasks
http://www.cray.com/Products/XT/ORNLJaguar.aspx)

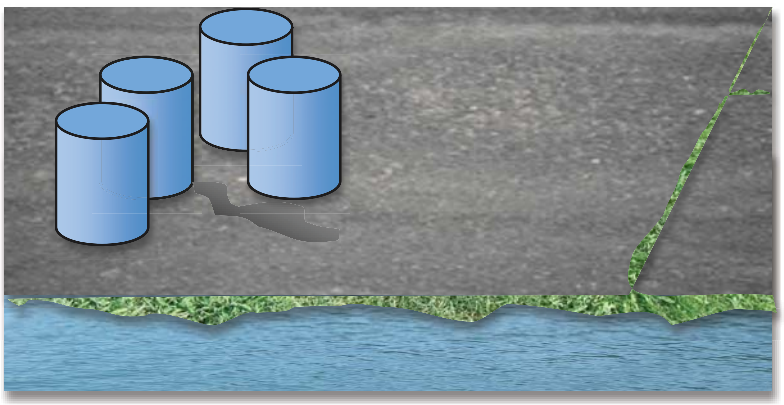
This item focuses on the relationship between advances in technology and engineering, requiring students to identify the principle that advances in technology may be necessary for scientific progress. The item stem provides a high-interest context, the fastest computer in the world, and describes several applications of this technology, including applications to engineering design and scientific research.

Constructed Response Items

5. Predict the impacts of an oil spill. Write questions that need to be answered in order to clean up or prevent another spill.

Grade 4
T.4.B. Effects of Technology on the Natural World (practices: Understanding Technological Principles; Developing Solutions and Achieving Goals)
T.4.7: Identify the impact of a specific technology on the environment and determine what can be done to reduce negative effects and increase positive effects.

The picture shows a place where oil is stored. Some of the oil is leaking. When it rains, oil is washed into a river.



People living near the river want to help clean up the oil. They also want to make sure oil does not spill into the river next time it rains.

Write two questions that the people should ask that will help them solve either of these problems.*

*The specifications' developers created this item for illustrative purposes; it requires further development in that it is not field tested or published. k

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This item requires students to demonstrate an ability to ask questions relevant to developing a particular solution. The example of technology causing environmental harm fits the expectations for fourth-grade students, providing a high-interest and accessible context. Possible questions that a fourth-grade student might ask include, "Why did the oil get put there?" and "Can you move the place where it is stored?" Both of these questions would help find a new location to store the oil, which could reduce runoff into the river.

6. Communicate with a virtual collaborator to evaluate changes to the design of a school kitchen.

Grade 8
D.8.B Engineering Design (Practice: Communicating and collaborating)
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.

The picture below shows a school kitchen. You can click on any of the people to see how they work in the kitchen.

(Source: www.safework.sa.gov.au/contentPages/EducationAndTraining/ActivitiesAndTests/VirtualKitchen/vkitchenframe.htm)

[Note: This interactive virtual kitchen features animations that show the following:

- Using the on/off switch to start and stop a large mixer.
- Using a control knob on the back of a gas stove to increase the flame below a pot of water.
- Using an oven by setting analog controls for time and temperature]

You are going to work with another student, Kenji, to find ways to make the kitchen more efficient. Click on the picture of Kenji to hear his ideas about how to make the kitchen more efficient.

[Note: When students mouse over each tool, an image of Kenji appears in a pop-up window. Clicking on Kenji plays an audio clip and displays the text that is being read. Kenji's ideas are: Put a timer on the mixer. Move the control knobs from the back of the stove to the front. Replace the dials on the oven with buttons and a digital display.]

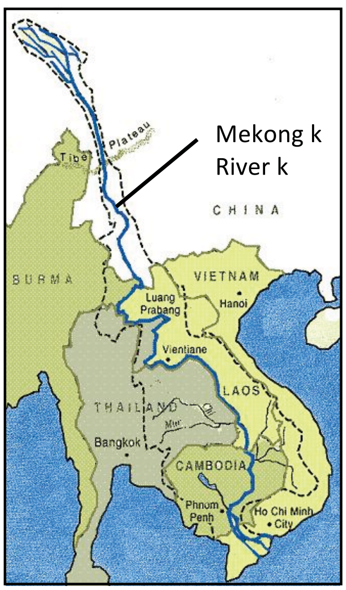
Pick one of Kenji's ideas. Tell him one advantage and one disadvantage of that idea.

This item focuses on identifying the benefits and possible unintended consequence of a design change in the context of communicating with a collaborator. The stimulus described would provide access to a rich source of information within the timeframe expected for a discrete item. The use of simple animations within a static image minimizes the development cost while providing many of the same affordances of more complex stimuli that might be needed in other contexts.

7. Synthesize information from two sources with opposing points of view on a high-interest, real-world issue that may be novel to the 12th-grade student, but is sufficiently similar to material likely included in typical high school curricula. Draw a conclusion from these sources without supporting one point of view over another.

Grade 12
I.12.A Construction and Exchange of Ideas and Solutions (Practice: Communicating and Collaborating)
I.12.3: Synthesize input from multiple sources to communicate ideas to a variety of audiences using various media, genres, and formats.

You are writing a report with a team of students. Your team members collected information about causes of the low water level of the Mekong River. The Mekong River is in Southeast Asia, as shown in the map below.



Your team members recorded information from two sources on the electronic research index cards below. Your job is to write a conclusion without supporting one point of view over another.

Card #1 k	Title of k Document: k	Author of k Document:k	Key Concepts: k
Source: k www.mrcmekong.org/ MRC_news/press10/ Op-Ed-13-3-10.htm	Low river levels caused by extreme low rainfall	Jeremy Bird, CEO of the Mekong River Commission	River is low because of low rainfall, dams may be helpful
Analysis of the Mekong River Commission's data shows that low water levels are the result of extreme natural conditions. The rainy season ended early and rainfall was very low during the dry season. Dams had the effect of delaying the extremely low levels on the river.			

Card #2 k	Title of k Document:k	Author of k Document: k	Key Concepts: k
Source:k www.livingriversiam.org/mk/mek_down_a_e1.htm	Lancang Development in China: Downstream Perspectives from Thailand	Pianporn Deetes, Southeast Asia Rivers Network	Dams cause ecological damage and impact water supply
The Mekong river has drastically changed, causing great ecological damage. The impacts include decreased fishing, riverbank cultivation, water supply, and shelter. The culprit of these drastic changes is the installation of dams on the Mekong River.			

Write one conclusion that would be supported by both sources.

(Sources:
commons.wikimedia.org/wiki/File:Mekong_river_location.jpg
www.mrcmekong.org/MRC_news/press10/Op-Ed-13-3-10.htm
www.livingriversiam.org/mk/mek_down_a_e1.htm)

This item places the student mid-way into the process of constructing and exchanging information, focusing on communicating with collaborators. The research cards represent one part of the communication. Without access to the source material, the student must rely on this communication to write an objective conclusion. The conclusion represents another part of the communication, either back to the collaborators or to the reader of the report described in the stem. One possible conclusion would be that dams have an effect on the river. Another would be that the river is not a constant source of water.

In another version of the item, the student could be asked to compare the difference between the points of view in each card or to compare these two sources to a third source that takes a neutral point of view.

The electronic research index card provides a useful format for a variety of stimuli. The card serves as a way to present several pieces of related information that the student might need to consider in a way that supports understanding, particularly when comparing information from multiple sources. The document title and key concepts encapsulate the main point of a source document, thus organizing information that would otherwise require more reading than might be feasible during the assessment. These sections also provide the student with the opportunity to prepare himself prior to reading the research notes.

Scenarios and Scenario-Based Items

Scenario Shells

Scenario shells outline the major features of a set of tasks and items related to a common context and problem. A sample shell is shown below. A shell precedes the sets of sample items in each of the following scenarios.

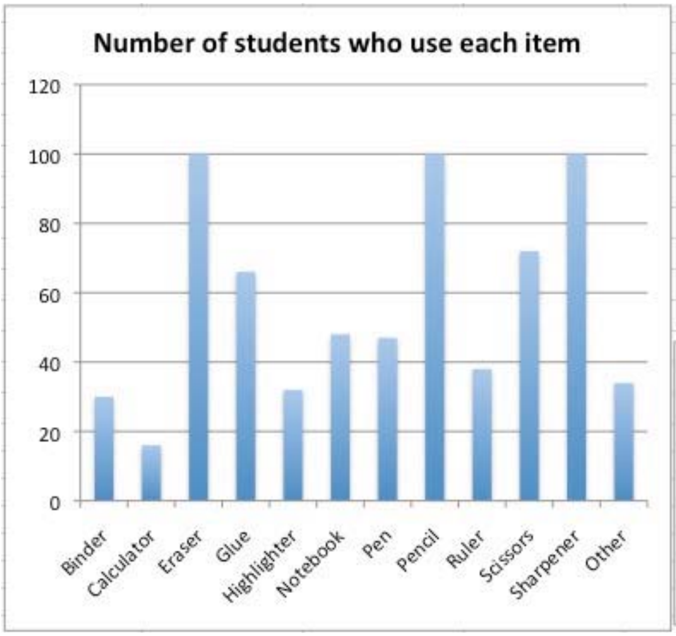
Grade	4, 8, or 12
Major Assessment Areas	Technology and Society Design and Systems Information and Communication
Practices	*Which of the NAEP practices can be addressed?*
Targets	*Which of the NAEP targets can be addressed?*
Context	*What is the context of the scenario?*
Problem	*What are the big ideas and tasks for the student?*
Available Resources and Information	*What is given to the student to solve the problem?*
Tools Used	*What generic productivity tools will students use?* *What domain-specific tools will the student use?*
Sources	*What are potential sources of ideas for stimuli and information used in the scenario?*

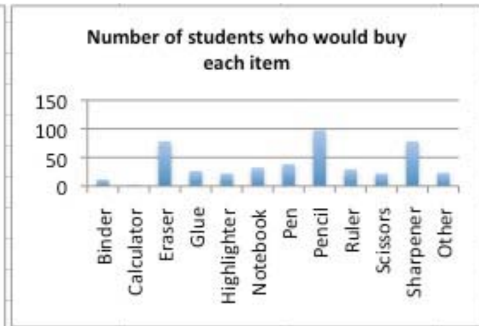
Sample Short Scenarios

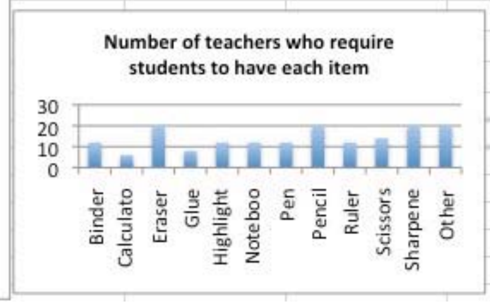
Shell

Grade	4
Major Assessment Areas	Information and Communication
Practices	Developing Solutions and Achieving Goals
Targets	I.4.5: Use digital and network tools and media resources to collect, organize, and display data in order to answer questions and solve problems. I.4.8: Use digital tools to test simple hypotheses in various subject areas.
Context	Setting up a school store
Problem	What items should the students order for the store? At what times of year will they need more of certain items? What purchasing cycle do they need? How will they advertise potential bargains at the store?
Available Resources and Information	Survey results from students (what they want) and teachers (what they require students to have), purchasing trends, and pricing information for the store
Tools Used	Graphs, spreadsheet
Sources	www.fbla-pbl.org/data/files/fbla/school_store_manual.pdf www.officedepot.com

Your class is planning to open a school store. The class started with a survey, asking students and teachers about items that might be sold at the store. 100 students and 20 teachers were asked about items they use in school. The graphs show data from the school store survey. Click on a graph to make it larger. Click on two graphs to combine them.*



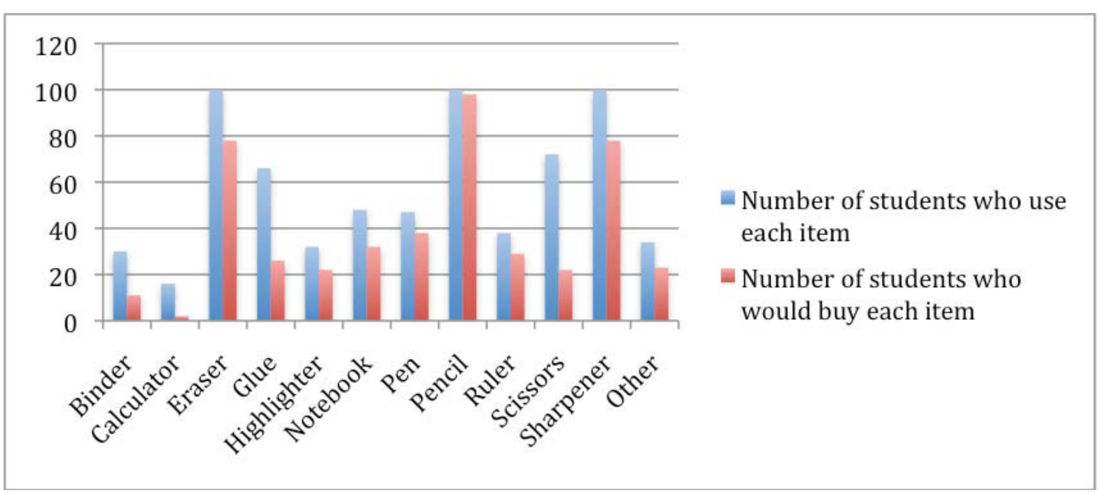




*The specifications' developers created this item for illustrative purposes; it requires further development in that it is not field tested or published. k

This screen introduces students to the context. Data are provided on graphs. Students can click on a graph to view it larger. When students hover the mouse over a column, the value is shown.

Students can click on two graphs to combine them and compare data, as shown below.



<u>Sample Items</u>

> Which three items are most popular among students?
>
> Which two items would be most difficult to sell at the store? Explain your answer using information from the table.

These items ask students to compare data, part of the practice of Understanding Technological Principles. Students could select the correct items from the table. This part of the response could be scored automatically.

(Item 008 and 009, Target I.4.5)

> Marlee wants to increase sales with a coupon. The coupon gives students a discount for buying several items together. Marlee wants to have a coupon for buying a pencil, pen, and a highlighter. Do you think Marlee’s coupon will help sell items at the store? Use examples from the table to support your answer.

This item asks students to compare data, part of the practice of Understanding Technological Principles. Students could answer the question with either a yes or no, so long as they support the answer with data from the table. For example, a student might note that pencils are the most popular item; students who buy a pencil might buy the pen and highlighter too if they have a coupon. Alternatively, a student might argue that only 32 students use a highlighter, so most students wouldn’t want to use the coupon just to get a deal on something they don’t use.

(Item 010, I.4.8)

The table below shows the items that your class decided to sell at the school store. Column B shows how much your class pays to buy items to put in the store. Column C shows how much students will pay to buy items at the store.

You need to make your own coupon. Pick three items from the list. Then choose a price that will help the school store make money and sell more items. Enter the sale price on the coupon.*

A	B	C
Item	Your class pays	Students pay
Eraser ☑	30¢k	50¢k
Glue ☐	50¢	75¢k
Notebook ☐	65¢k	95¢k
Pen ☐	15¢	25¢k
Pencil ☑	5¢ k	10¢k
Scissors ☐	40¢	75¢k
Sharpener ☑	30¢k	50¢k
TOTAL	65¢k	$1.10
SORT ☐	SORT ☐	SORT ☐

School Store 9

Coupon9

When you buy: k	You pay
Pencil k	**9¢ 9**
Eraser k	
Sharpenerk	

Regular Price $1.10 k

*The specifications' developers created this item for illustrative purposes; it requires further development in that it is not field tested or published. k

This item asks students to apply skills to address a problem, part of the practice of Developing Solutions and Achieving Goals. Identifying the sale price is scored as a constructed response item. Students need to choose a sale price between the two price totals displayed on the spreadsheet. The other calculations are automated by the spreadsheet.

To make the activity less abstract, an image of the coupon is generated in real time. The display of the coupon varies depending on what is selected.

(Item 011, I.4.5)

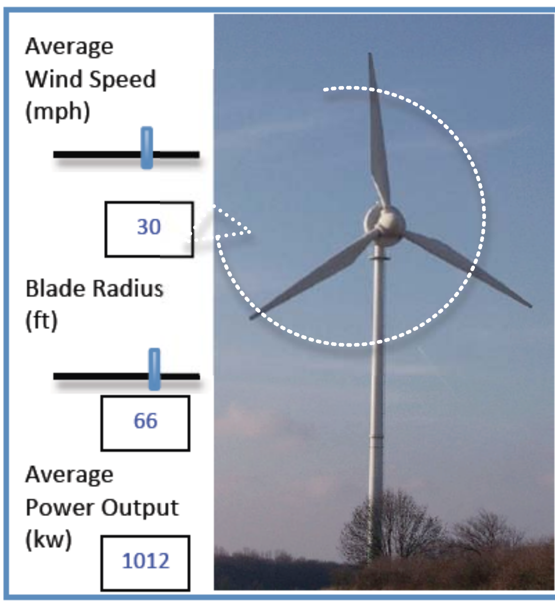
<u>Shell</u>

Grade	8
Major Assessment Areas	Technology and Society Engineering Design
Practices	Understanding Technological Principles, Developing Solutions and Achieving Goals, Communicating and Collaborating
Targets	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. T.8.5 Some technological decisions involve trade-offs between environmental and economic needs, while others have positive effects for both the economy and environment. D.8.9: Construct and test a model and gather data to see if it meets the requirements of a problem.
Context	Energy; Wind Turbines
Problem	Create a presentation that presents the positive and negative impacts of residential wind turbines to a group of homeowners
Available Resources and Information	Variety of sources available via simulated Internet; energy use data, wind turbine simulation
Tools Used	Simulation, Spreadsheet, presentation software
Sources	http://commons.wikimedia.org/wiki/File:Enercon_E-40_in_der_D%C3%A4mmerung.jpg http://environment.nationalgeographic.com/environment/global-warming/wind-power-interactive

<u>Sample Items</u>

In this set of sample items, students explore the conditions needed for wind power. They have to balance technological decisions with environmental and economic trade-offs. The sequence of tasks takes the student through a logical progression across the three cross-cutting practices. (Note: The specifications' developers created these items for illustrative purposes; they require further development in that they are not field tested or published.) k

The first item focuses on the practice of understanding technological principles. A village wants to install a wind turbine to use renewable energy. The student is given the task of testing a model of a wind turbine to determine whether it can generate enough power for 120 homes in the village. Students must test the effects of wind speed and blade radius on power output. The item includes a simulation that allows the student to explore the relationships among wind speed, blade radius, and power output. Students set the values for wind speed and blade radius on the left. The blades turn relative to the wind speed. The power output is displayed for the student at the bottom. Students can click "SAVE DATA" to save the values from the simulation onto a row in one of the spreadsheets.



	A	B	C
1	average wind speed (mph)	blade radius (ft)	average power output (kW)
2	10	66	137
3	20	66	720
4	30	66	1012

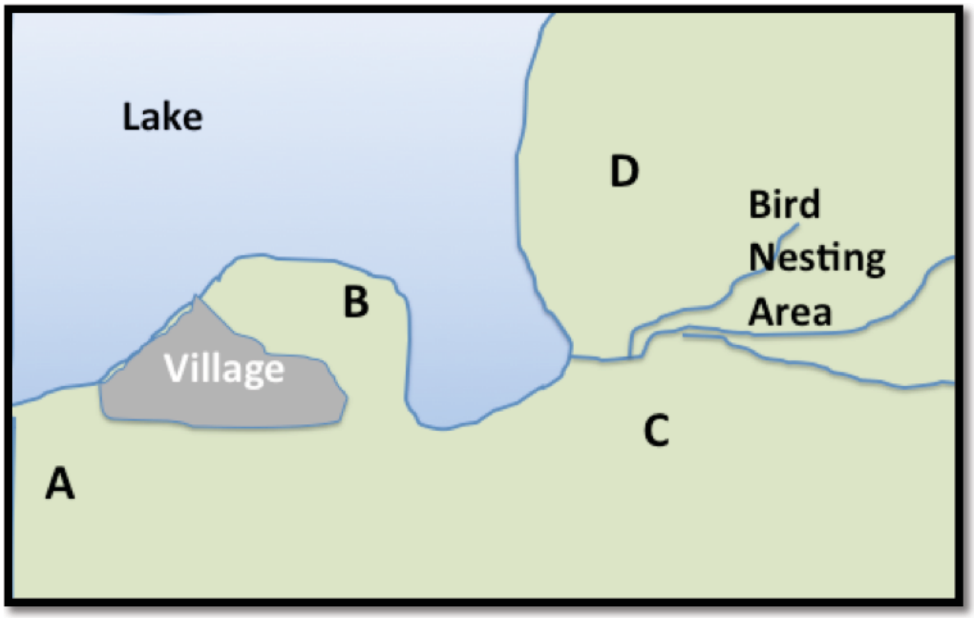
	A	B	C
1	average wind speed (mph)	blade radius (ft)	average power output (kW)
2	30	33	506
3	30	49	751
4	30	66	1012

SAVE DATA

After saving the data, students answer a multiple choice or short constructed response item about residential power use data. Students respond by describing whether the wind turbine can be designed to meet the requirements.

(Item 012, Target: D.8.9)

The second item focuses on the practice of developing solutions and achieving goals. Four sites have been identified, but no site is perfect. The student gathers data and chooses one site that would be best to locate the wind turbine.



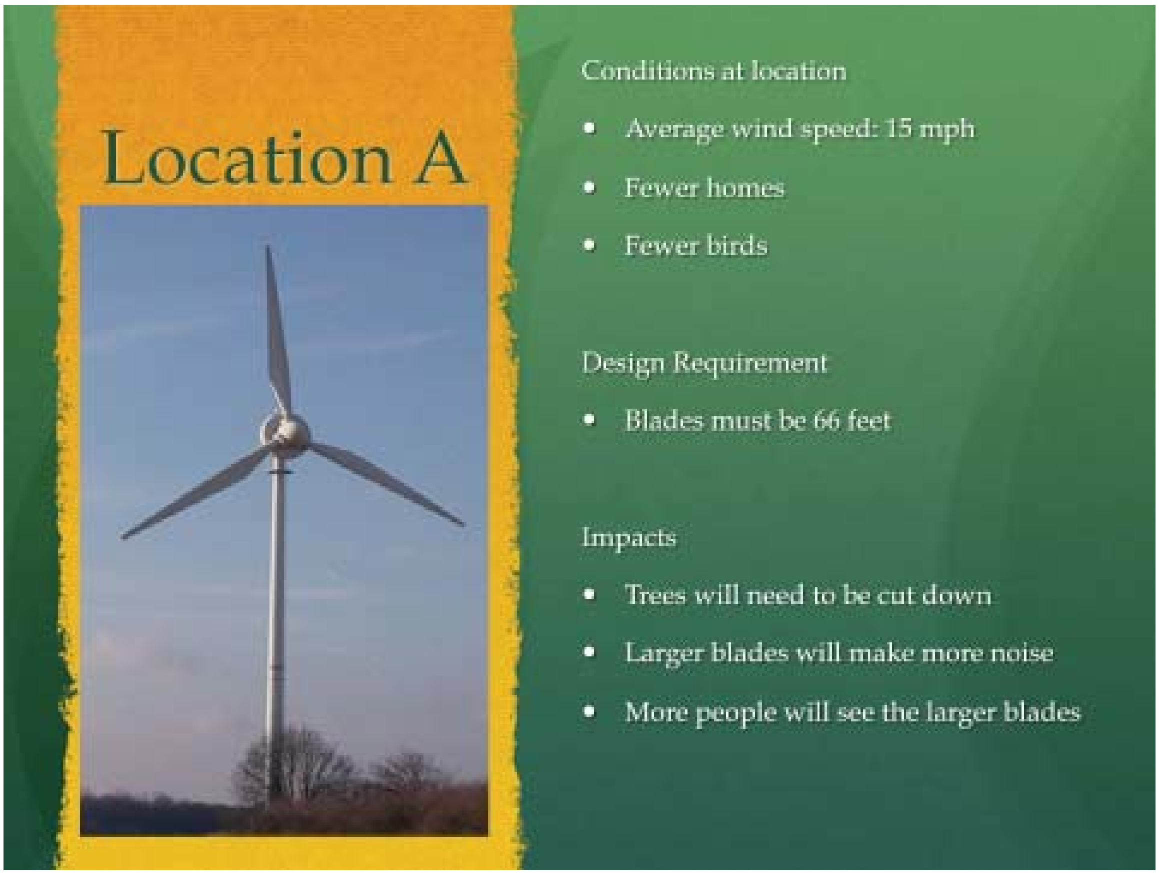
A student would mouse over or click on each location (A-D) to display information about average wind speed, impact on wildlife, and impact on humans. Students are able to return to the simulation to collect additional data, if needed, on generating power at different speeds. Students then select a site.

Location A	Average wind speed	Medium: 15 mph
	Impact on wildlife	Low: Some trees would be cut down
	Impact on humans	Medium: People on west side of village would see it
Location B	Average wind speed	High: 25 mph
	Impact on wildlife	Medium: Some birds nest here in spring
	Impact on humans	High: Everyone in the village would see it and hear it
Location C	Average wind speed	Medium: 15 mph
	Impact on wildlife	High: Many birds from the nesting area would be hit by the blades
	Impact on humans	Medium: People on south side of village would see it
Location D	Average wind speed	Medium: 15 mph
	Impact on wildlife	High: Many birds from the nesting area would be hit by the blades
	Impact on humans	Medium: Everyone in the village would see it but it would be far away

(Item 013, Target: T.8.5)

In the third item, students create a presentation slide describing one site. Students are able to return to the simulation and map to copy and paste information to include on the slide.

The presentation slide needs to be designed for a meeting with people from the village. Students are instructed to emphasize how the wind speed affects the design requirement of blade radius, and how the blade radius modifies the impacts on wildlife and on humans. For example, if the blades could be smaller in a given location, fewer people will see it and hear it, and fewer birds would be hit.

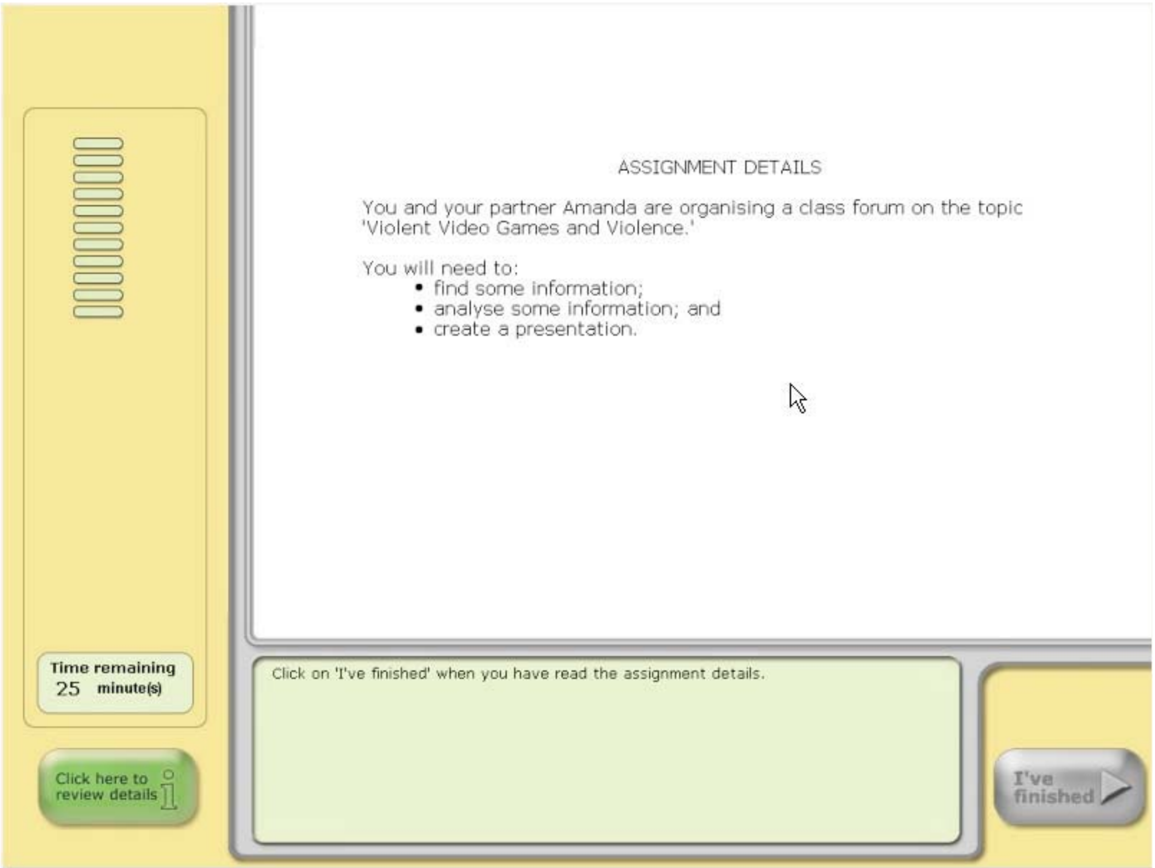


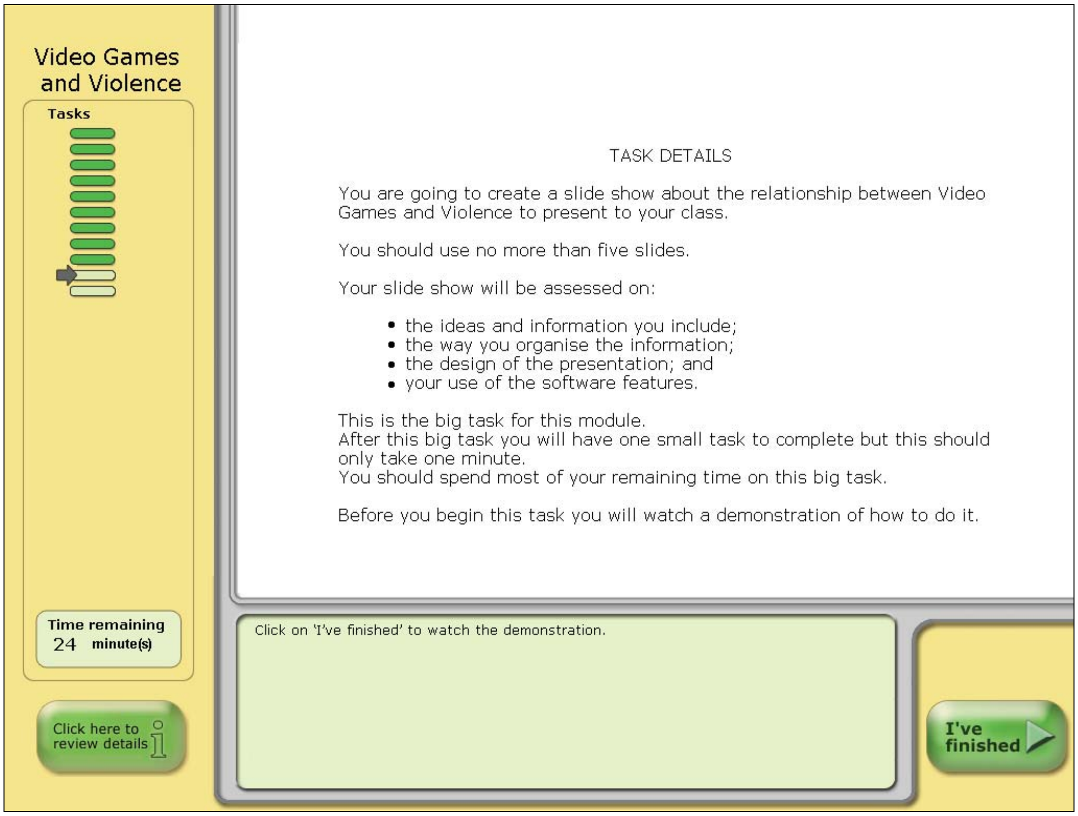
(Item 014, Target: T.8.3)

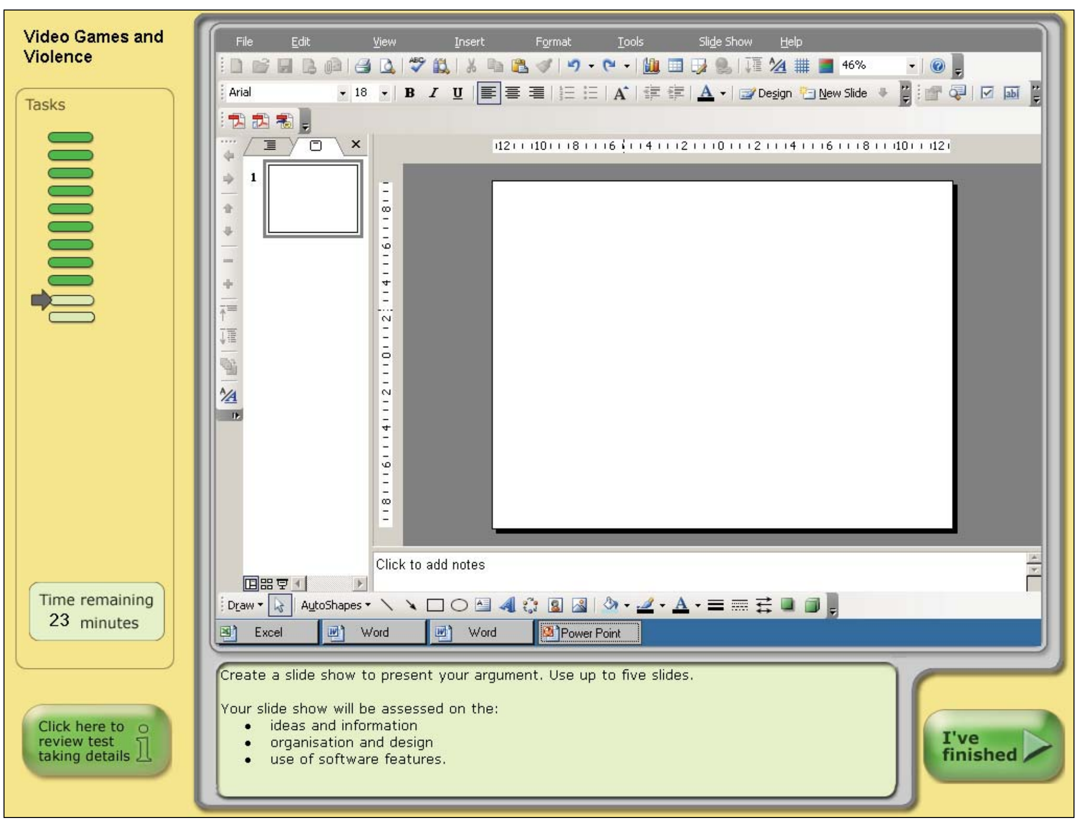
Shell

Grade	12
Major Assessment Areas	Technology and Society Information and Communication
Practices	Communicating and Collaborating
Targets	I.12.2 Work through a simulation of a collaborative process. 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. I.12.3 Synthesize input form multiple sources to communicate ideas to a variety of audiences using various media, genres, and formats. I.12.6 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. 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.
Context	Human Society; Video Games and Violence
Problem	Gather information, organize date, prepare a presentation to describe several effects of video games on society
Available Resources and Information	Variety of sources available via simulated Internet; simulated collaborator
Tools Used	Web search, word processing, spreadsheet, presentation software
Sources	Ministerial Council for Education, Early Childhood Development and Youth Affairs [MCEECDYA], 2008

The example below calls upon the student to employ the practice of Developing Solutions and Achieving Goals. In this task, the student must use ICT tools to analyze the impacts of technology on human society. This example employs a computer-based interactive format in which students search for information concerning video games and violence and then use word processing, spreadsheet, and Web-based tools to develop a PowerPoint presentation. The PowerPoint presentation calls upon the cross-cutting practice of Communicating and Collaborating. An active example is available on the DVD included with this document.







(Source: Australian MCEECDYA, 2008)
(Item 015, Target I.12.3)

Sample Long Scenarios

Shell

Grade	8
Major Assessment Areas	Information and Communication
Practices	Developing Solutions and Achieving Goals
Targets	I.8.4: 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. I.8.5: Select and use appropriate digital and network tools and media resources to collect, organize, analyze, and display supporting data to answer questions and test hypotheses. I.8.8: Use digital tools to gather and display data in order to test hypotheses of moderate complexity in various subject areas. Draw and report conclusions consistent with observations. I.8.9: Use a digital model of a system to conduct a simulation. Explain how changes in the model result in different outcomes. I.8.13: Use 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.
Context	The Gold Rush of 1849 and Technology Literacy
Problem	Research the Gold Rush of 1849: Gather information to determine which would be the best route to travel to the California gold fields in 1849 and give a presentation on findings
Available Resources and Information	Variety of sources available via simulated Internet, including, historical documents, and political cartoons, maps, and PowerPoint
Tools Used	Web search; presentation software
Sources	www.google.com http://ceres.ca.gov/ceres/calweb/geology/goldrush.html www.loc.gov Microsoft Encarta Reference Library

<u>Sample Items</u>

In this set of sample items, students use online documents to evaluate which would be the best route to the California gold fields in 1849. They then use presentation software to create a short presentation about which route they believe would be most appropriate to take. The item sequence provides scaffolding for the interface by changing the tasks that students must perform. (Note: The specifications' developers created these items for illustrative purposes; they require further development in that they are not field tested or published.)

In the first item, students demonstrate their ability to search and evaluate websites containing historical documents. They use a secure intranet website showing the search results for the California Gold Rush with several websites. Students should be able to interact with the websites. The websites should provide information, indicating the cost of travel for each route, the amount of time it takes to travel by each route, the environmental challenges travelers would face with each route (e.g., weather, drought, disease), and the supplies they will need for each route.

To complete the item students need to select a source of information that helps them determine which route to the California gold fields would be most appropriate.

A.Hk**California's** Natural Resources: A Brief History of the **Gold Rush**. k
The **California Gold Rush**, from the State of California's CERES. k
ceres.ca.gov/ceres/calweb/geology/**goldrush**.html k

B.HkThe **California Gold Rush** (1848 to 1859) k
The **Gold Rush** was one of the most significant events in **California9**history. It k
brought people from all over the United States and the world in search for … k
www.kidport.com/REfLib/…/Cal**GoldRush**/Cal**GoldRush**.htm k

C.Hk**Gold Rush! California's** Untold Stories, Oakland Museum of **California 9**
This site preserves and supplements four major exhibitions celebrating the **gold 9**
rush sesquicentennial, at the Oakland Museum of **California9**k
museumca.org/**goldrush**/ k

D.Hk**California9**First Person Narratives: General Collections k
The **California9**As I Saw It: First-Person Narratives of **California's** Early … The k
collection covers the dramatic decades between the **Gold Rush** and the turn … k
memory.loc.gov/ammem/cbhtml/cbhome.html k

(Item 016, Targets: I.8.4)

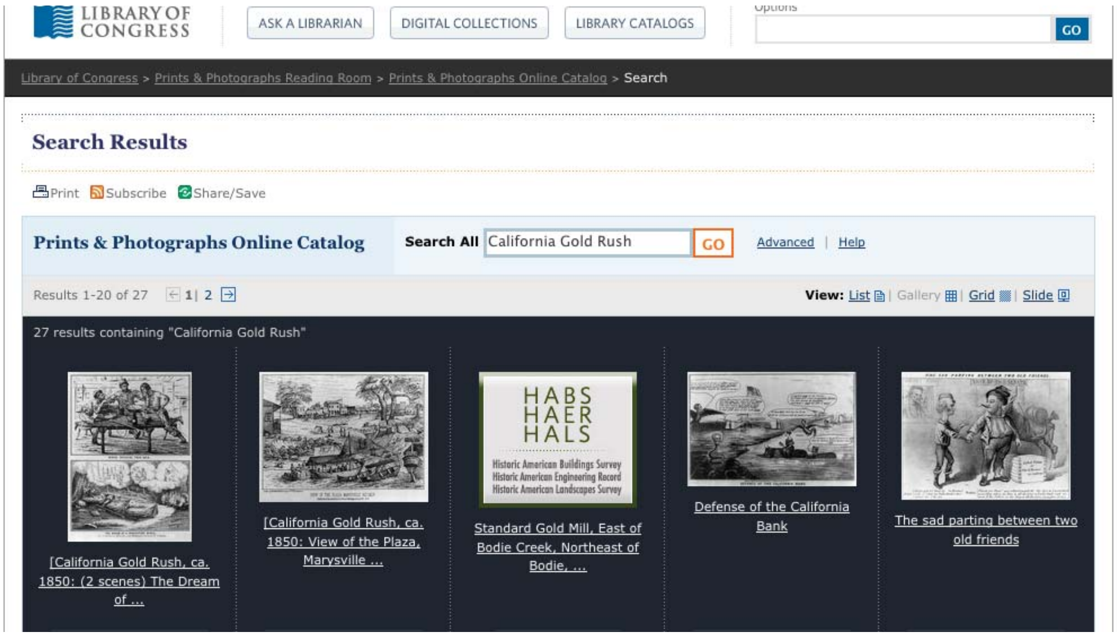
In the second item, students demonstrate their ability to gather information. They use a secure intranet website containing several historical websites that address the California Gold Rush. Students should copy and paste sections they believe to be relevant into electronic research index cards that include source information.

Sample Electronic Research Index Card

<table>
<tr><td>Card #1</td><td rowspan="2">Title of Document: The California Gold Rush</td><td rowspan="2">Author of Document: California Natural Resource Agency</td><td rowspan="2">Key Concepts: Important Dates and Discoveries</td></tr>
<tr><td>Source:
http://ceres.ca.gov/ceres/calweb/geology/goldrush.html</td></tr>
<tr><td colspan="4">1848, American River near Sacramento
1849, Mariposa mine in Mariposa County
1851, Greenhorn Creek, Kern County
1853, Columbia, Tuolomne County
1854, Carson Hill in Calaveras County
1859, Magalia in Butte County
By 1864, California’s gold rush had ended.</td></tr>
</table>

(Item 017, Target: I.8.5)

In the third item, students demonstrate their ability to navigate a website to locate political cartoons or pictures to help them develop a presentation about which route they believe would be most appropriate to take to get to the gold fields. They use a secure intranet website that shows a sample of political cartoons or pictures. Students click on an image to select their answer. They also copy the image and paste it into the presentation program.

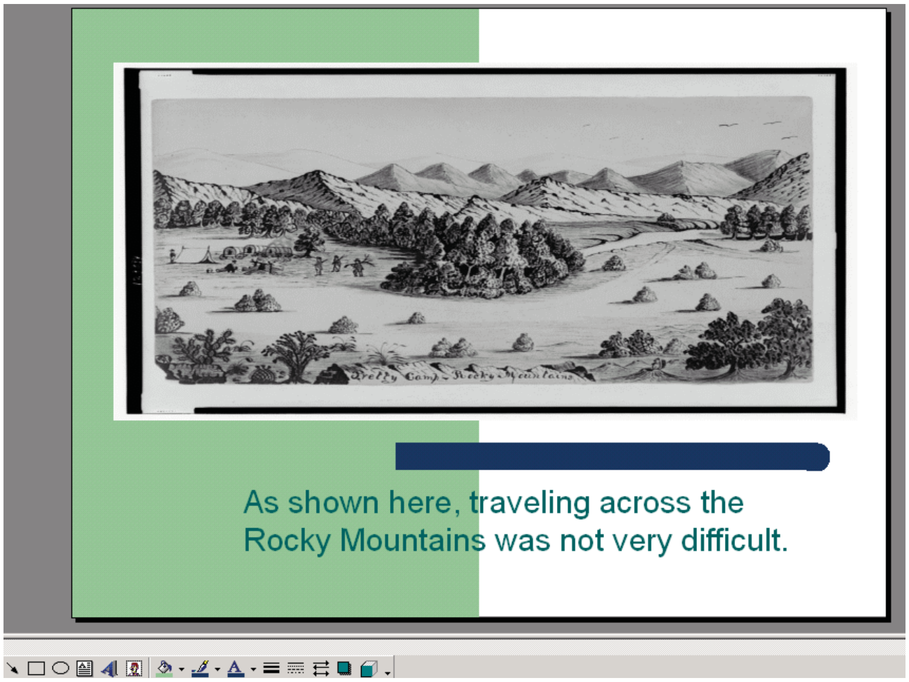


(Item 018, Target: I.8.8)

In the fourth item, students should trace the route they would take from either St. Louis or New York City, using an interactive map. The map should have a tool that allows them to trace and save their route. The map should also have features that show mountains, rivers, and towns. After completing the map, they should be able paste the map into the presentation program.

(Item 019, Target: I.8.9)

In the fifth item, the students will create a presentation using the presentation software. The presentation should be four slides in length. The presentation should explain why they have chosen the route they believe would be most appropriate to take. It should integrate the information the students have found on the intranet websites as well as the map they created.



(Item 020, Target: I.8.13)

Shell

Grade	8
Major Assessment Areas	Design and Systems Information and Communication
Practices	Developing Solutions and Achieving Goals
Targets	D.8.8: Carry out a design process to solve a moderately difficult problem by identifying criteria and constraints, determining how they will affect the solution, researching and generating ideas, and using trade-offs to choose between alternative solutions. I.8.8: Use digital tools to gather and display data in order to test hypotheses of moderate complexity in various subject areas using digital tools to gather and display data. Draw and report conclusions consistent with observations. I.8.9: Use a digital model of a system to conduct a simulation. Explain how changes in the model result in different outcomes.
Context	School bus routes
Problem	Gather information, describe ways to make bus routes more efficient, create a report and presentation to the school board
Available Resources and Information	Map with bus stops, traffic data, distance, and time
Tools Used	Spreadsheet, Presentation Software, Maps, Geographic Information System (GIS)
Sources	http://aps-schoolmap.apsk12.org

<u>Sample Items</u>

In this set of sample items, students use an interactive map to plan bus routes. The item sequence provides scaffolding for the interface by gradually increasing the number of options. The items increase in cognitive complexity, from more concrete (bus stops marked on the map) to more abstract (the affect of traffic on travel time) and from a focus only on the components in a system (one route with several stops) to interactions between components (the bus and other traffic) to the design of a system (with multiple components and interactions). This set of items would be part of a scenario that might also include organizing data using a spreadsheet and presenting data and maps using a slide show. (Note: The specifications' developers created these items for illustrative purposes; they require further development in that they are not field tested or published.)

In the first item, students use the map to create a bus route. They adjust the route to include several bus stops. The students can also adjust the route to make the total distance for the route as short as possible. The distance is automatically calculated. Evidence of mastery of the relevant targets may include connecting all seven stops, using fewer moves to create the bus route, and changing the route to make it shorter.

1. You need to draw a new bus route.
   - The route must go to each of the seven bus stops
   - The route must end at the school

   Try making your route as short as possible.
   When you are done, click "SAVE ROUTE."

(Map courtesy of Atlanta Public Schools)

In this example, the student has set the start and end points for the bus route. The interface generates a possible route. Only three stops are included in the route. The student must drag the route to other streets until it includes all seven stops.

(Item 021, Target: D.8.8)

In the second item, students are given a different route and asked to adjust the route to make the total time as short as possible, using traffic information. There is a trade-off between the distance and time for the route.

2. Bus route 92 is taking too long. The bus gets stuck in traffic.

Change the bus route so that it will take as little time as possible.
When you are done, click "SAVE ROUTE"

(Map courtesy of Atlanta Public Schools)

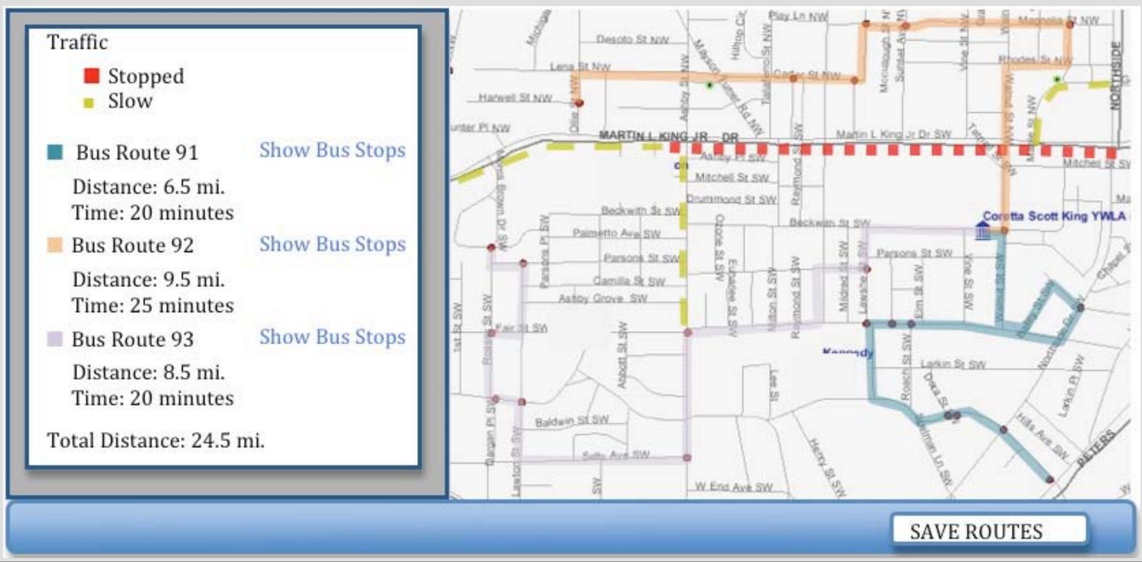
In this example, the student is given a route that includes two busy streets. The route takes 25 minutes. The student must drag the route to make it take less time. An additional item could be inserted here that asks students to explain the changes they made, testing their understanding of the trade-off between distance and time.

(Items 022 and 023, Targets: I.8.9, D.8.8)

In the third item, students are given three routes and asked to make the system as efficient as possible, considering travel times for each route and total distance for all the routes. Students are allowed to change the starting point for each route and to select which routes make which stop. Students can show and hide the bus stops for each route.

3. You need to draw three bus routes.
- The routes must go to all of the bus stops
- The routes must end at the school

Try making each route take as little time as possible.
Try making the total distance as short as possible.
When you are done, click "SAVE ROUTES."



(Map courtesy of Atlanta Public Schools)

In this example, the student has designed a system that meets all the requirements. Many different versions of the system could be designed that would also meet all the requirements, however, some would be more efficient than others.

(Item 024, Target: I.8.9)

The student could use these data and the map in a subsequent item. Students would need to organize the data and then present the map and data to a specific audience, such as a school board, in order to show how to increase the efficiency of the bus system.

(Item 025, Target: I.8.8)

Appendix J: NAEP Item Development and Review Policy Statement

National Assessment Governing Board

Adopted: May 18, 2002

It is the policy of the National Assessment Governing Board to require the highest standards of fairness, accuracy, and technical quality in the design, construction, and final approval of all test questions and assessments developed and administered under the National Assessment of Educational Progress (NAEP). All NAEP test questions or items must be designed and constructed to reflect carefully the assessment objectives approved by the National Assessment Governing Board. The final assessments shall adhere to the requirements outlined in the following Guiding Principles, Policies and Procedures for NAEP Item Development and Review.

The Governing Board's Assessment Development Committee, with assistance from other Board members as needed, shall be responsible for reviewing and approving NAEP test questions at several stages during the development cycle. In so doing, the Guiding Principles, Policies and Procedures must be adhered to rigorously.

Introduction

The No Child Left Behind Act of 2001 (P.L. 107-110) contains a number of important provisions regarding item development and review for the National Assessment of Educational Progress (NAEP). The legislation requires that:

- "the purpose [of NAEP] is to provide…a fair and accurate measurement of student academic achievement"
- "[NAEP shall]…use widely accepted professional testing standards, objectively measure academic achievement, knowledge, and skills, and ensure that any academic assessment authorized….be tests that do not evaluate or assess personal or family beliefs and attitudes or publicly disclose personally identifiable information;"
- "[NAEP shall]…only collect information that is directly related to the appraisal of academic achievement, and to the fair and accurate presentation of such information;"
- "the Board shall develop assessment objectives consistent with the requirements of this section and test specifications that produce an assessment that is valid and reliable, and are based on relevant widely accepted professional standards;"
- "the Board shall have final authority on the appropriateness of all assessment items;"
- "the Board shall take steps to ensure that all items selected for use in the National Assessment are free from racial, cultural, gender, or regional bias and are secular, neutral, and non-ideological;" and
- "the Board shall develop a process for review of the assessment which includes the active participation of teachers, curriculum specialists, local school administrators, parents, and concerned members of the public."

Given the importance of these mandates, it is incumbent upon the Board to ensure that the highest standards of test fairness and technical quality are employed in the design, construction, and final approval of all test questions for the National Assessment. The validity of educational inferences made using NAEP data could be seriously impaired without high standards and rigorous procedures for test item development, review, and selection.

Test questions used in the National Assessment must yield assessment data that are both valid and reliable in order to be appropriate. Consequently, technical acceptability is a necessary, but not a sufficient condition, for judging the appropriateness of items. In addition, the process for item development must be thorough and accurate, with sufficient reviews and checkpoints to ensure that accuracy. The Guiding Principles, Policies, and Procedures governing item development, if fully implemented throughout the development cycle, will result in items that are fair and of the highest technical quality, and which will yield valid and reliable assessment data.

Each of the following Guiding Principles is accompanied by Policies and Procedures. Full implementation of this policy will require supporting documentation from the National Center for Education Statistics (NCES) regarding all aspects of the Policies and Procedures for which they are responsible.

This policy complies with the documents listed below which express acceptable technical and professional standards for item development and use. These standards reflect the current agreement of recognized experts in the field, as well as the policy positions of major professional and technical associations concerned with educational testing.

Standards for educational and psychological testing. (1999). Washington, DC: American Educational Research Association (AERA), American Psychological Association (APA), and National Council on Measurement in Education (NCME).

Code of fair testing practices in education. (1988). Washington, DC: Joint Committee on Testing Practices.

National Center for Education Statistics (NCES) Statistical Standards, DRAFT, February 2002.

Guiding Principles – Item Development and Review Policy

Principle 1
NAEP test questions selected for a given content area shall be representative of the content domain to which inferences will be made and shall match the NAEP assessment framework and specifications for a particular assessment.

Principle 2
The achievement level descriptions for basic, proficient, and advanced performance shall be an important consideration in all phases of NAEP development and review.

Principle 3
The Governing Board shall have final authority over all NAEP test questions. This authority includes, but is not limited to, the development of items, establishing the criteria for reviewing items, and the process for review.

Principle 4
The Governing Board shall review all NAEP test questions that are to be administered in conjunction with a pilot test, field test, operational assessment, or special study administered as part of NAEP.

Principle 5
NAEP test questions will be accurate in their presentation and free from error. Scoring criteria will be accurate, clear, and explicit.

Principle 6
All NAEP test questions will be free from racial, cultural, gender, or regional bias, and must be secular, neutral, and non-ideological. NAEP will not evaluate or assess personal or family beliefs, feelings, and attitudes, or publicly disclose personally identifiable information.

Policies and Procedures for Guiding Principles

Principle 1

NAEP test questions selected for a given content area shall be representative of the content domain to which inferences will be made and shall match the NAEP assessment framework and specifications for a particular assessment.

Policies and Procedures

1. Under the direction of the Board, the framework for each assessment will be developed in a manner that defines the content to be assessed, consistent with NAEP's purpose and the context of a large-scale assessment. The framework development process shall result in a rationale for each NAEP assessment, which delineates the scope of the assessment relative to the content domain. The framework will consist of a statement of purpose, assessment objectives, format requirements, and other guidelines for developing the assessment and items.
2. In addition to the framework, the Board shall develop assessment and item specifications to define the: a) content and process dimensions for the assessment; b) distribution of items across content and process dimensions at each grade level; c) stimulus and response attributes (or what the test question provides to students and the format for answering the item); d) types of scoring procedures; e) test administration conditions; and f) other specifications pertaining to the particular subject area assessment.
3. The Board will forward the framework and specifications to NCES, in accordance with an appropriate timeline, so that NCES may carry out its responsibilities for assessment development and administration.
4. In order to ensure that valid inferences can be made from the assessment, it is critical that the pool of test questions measures the construct as defined in the framework. Demonstrating that the items selected for the assessment are representative of the subject matter to which inferences will be made is a major type of validity evidence needed to establish the appropriateness of items.
5. A second type of validity evidence is needed to ensure that NAEP test items match the specific objectives of a given assessment. The items must reflect the objectives, and the item pool must match the percentage distribution for the content and cognitive dimensions at each grade level, as stated in the framework. Minor deviations, if any, from the content domain as defined by the framework will be explained in supporting materials.
6. Supporting material submitted with the NAEP items will provide a description of procedures followed by item writers during development of NAEP test questions. This description will include the expertise, training, and demographic characteristics of the groups. This supporting material must show that all item writing and review groups have the required expertise and training in the subject matter, bias, fairness, and assessment development.
7. In submitting items for review by the Board, NCES will provide information on the relationship of the specifications and the content/process elements of the pool of NAEP items. This will include procedures used in classifying each item.

8. The item types used in an assessment must match the content requirements as stated in the framework and specifications, to the extent possible. The match between an objective and the item format must be informed by specifications pertaining to the content, knowledge or skill to be measured, cognitive complexity, overall appropriateness, and efficiency of the item type. NAEP assessments shall use a variety of item types as best fit the requirements stated in the framework and specifications.
9. In order to ensure consistency between the framework and specifications documents and the item pools, NCES will ensure that the development contractor engages a minimum of 20% of the membership of the framework project committees in each subject area to serve on the item writing and review groups as the NAEP test questions are being developed. This overlap between the framework development committees and the item developers will provide stability throughout the NAEP development process, and ensure that the framework and specifications approved by the Board have been faithfully executed in developing NAEP test questions.

Principle 2

The achievement level descriptions for basic, proficient, and advanced performance shall be an important consideration in all phases of NAEP development and review.

Policies and Procedures

1. During the framework development process, the project committees shall draft preliminary descriptions of the achievement levels for each grade to be assessed. These preliminary descriptions will define what students should know and be able to do at each grade, in terms of the content and process dimensions of the framework at the basic, proficient, and advanced levels. Subsequent to Board adoption, the final achievement level descriptions shall be an important consideration in all future test item development for a given subject area framework.
2. The achievement level descriptions will be used to ensure a match between the descriptions and the resulting NAEP items. The achievement level descriptions will be examined, and appropriate instruction provided to item writers to ensure that the items represent the stated descriptions, while adhering to the content and process requirements of the framework and specifications. The descriptions will be used to evaluate the test questions to make certain that the pool of questions encompasses the range of content and process demands specified in the achievement level descriptions, including items within each achievement level interval, and items that scale below basic.
3. As the NAEP item pool is being constructed, additional questions may need to be written for certain content/skill areas if there appear to be any gaps in the pool, relative to the achievement level descriptions.
4. Supporting materials will show the relationship between the achievement levels descriptions and the pool of NAEP test questions.

Principle 3

The Governing Board shall have final authority over all NAEP test questions. This authority includes, but is not limited to, the development of items, establishing the criteria for reviewing items, and the process for review.

Policies and Procedures

1. Under the No Child Left Behind Act, a primary duty of the Governing Board pertains to "All Cognitive and Noncognitive Assessment Items." Specifically, the statute states that, "The Board shall have final authority on the appropriateness of all assessment items." Under the law, the Board is therefore responsible for all NAEP test questions as well as all NAEP background questions administered as part of the assessment.
2. To meet this statutory requirement, the Board's Policy on NAEP Item Development and Review shall be adhered to during all phases of NAEP item writing, reviewing, editing, and assessment construction. The National Center for Education Statistic (NCES), which oversees the operational aspects of NAEP, shall ensure that all internal and external groups involved in NAEP item development activities follow the Guiding Principles, Policies and Procedures as set forth in this Board policy.
3. Final review of all NAEP test questions for bias and appropriateness shall be performed by the Board, after all other review procedures have been completed, and prior to administration of the items to students.

Principle 4

The Governing Board shall review all NAEP test questions that are to be administered in conjunction with a pilot test, field test, operational assessment, or special study administered as part of NAEP.

Policies and Procedures

1. To fulfill its statutory responsibility for NAEP item review, the Board shall receive, in a timely manner and with appropriate documentation, all test questions that will be administered to students under the auspices of a NAEP assessment. These items include those slated for pilot testing, field testing, and operational administration.
2. The Board shall review all test items developed for special studies, where the purpose of the special study is to investigate alternate item formats or new technologies for possible future inclusion as part of main NAEP, or as part of a special study to augment main NAEP data collection.
3. The Board shall not review items being administered as part of test development activities, such as small-scale, informal try-outs with limited groups of students designed to refine items prior to large-scale pilot, field, or operational assessment.
4. NCES shall submit NAEP items to the Board for review in accordance with a mutually agreeable timeline. Items will be accompanied by appropriate documentation as required in this policy. Such information shall consist of procedures and personnel involved in

item development and review, the match between the item pool and the framework content and process dimensions, and other related information.

5. For its first review, the Board will examine all items prior to the pilot test or field test stage. In the case of the NAEP reading assessment, all reading passages will be reviewed by the Board prior to item development. For each reading passage, NCES will provide the source, author, publication date, passage length, rationale for minor editing to the passage (if any), and notation of such editing applied to the original passage. NCES will provide information and explanatory material on passages deleted in its fairness review procedures.
6. For its second review, the Board will examine items following pilot or field testing. The items will be accompanied by statistics obtained during the pilot test or field test stage. These statistics shall be provided in a clear format, with definitions for each item analysis statistic collected. Such statistics shall include, but shall not be limited to: p-values for multiple-choice items, number and percentage of students selecting each option for a multiple-choice item, number and percentage not reaching or omitting the item (for multiple-choice and open-ended), number and percentage of students receiving various score points for open-ended questions, mean score point value for open-ended items, appropriate biserial statistics, and other relevant data.
7. At a third stage, for some assessments, the Board will receive a report from the calibration field test stage, which occurs prior to the operational administration. This "exceptions report" will contain information pertaining to any items that were dropped due to differential item functioning (DIF) analysis for bias, other items to be deleted from the operational assessment and the rationale for this decision, and the final match between the framework distribution and the item pool. If the technology becomes available to perform statistically sound item-level substitutions at this point in the cycle (from the initial field test pool), the Board shall be informed of this process as well.
8. All NAEP test items will be reviewed by the Board in a secure manner via in-person meetings, teleconference or videoconference settings, or on-line via a password-protected Internet site. The Board's Assessment Development Committee shall have primary responsibility for item review and approval. However, the Assessment Development Committee, in consultation with the Board Chair, may involve other NAGB members in the item review process on an *ad hoc* basis. The Board may also submit items to external experts, identified by the Board for their subject area expertise, to assist in various duties related to item review. Such experts will follow strict procedures to maintain item security, including signing a Nondisclosure Agreement.
9. Items that are edited between assessments by NCES and/or its item review committees, for potential use in a subsequent assessment, shall be re-examined by the Board prior to a second round of pilot or field testing.
10. Documentation of the Board's final written decision on editing and deleting NAEP items shall be provided to NCES within 10 business days following completion of Board review at each stage in the process.

Principle 5

NAEP test questions will be accurate in their presentation, and free from error. Scoring criteria will be accurate, clear, and explicit.

Policies and Procedures

1. NCES, through its subject area content experts, trained item writers, and item review panels, will examine each item carefully to ensure its accuracy. All materials taken from published sources must be carefully documented by the item writer. Graphics that accompany test items must be clear, correctly labeled, and include the data source where appropriate. Items will be clear, grammatically correct, succinct, and unambiguous, using language appropriate to the grade level being assessed. Item writers will adhere to the specifications document regarding appropriate and inappropriate stimulus materials, terminology, answer choices or distractors, and other requirements for a given subject area. Items will not contain extraneous or irrelevant information that may differentially distract or disadvantage various subgroups of students from the main task of the item.
2. Scoring criteria will accompany each constructed-response item. Such criteria will be clear, accurate, and explicit. Carefully constructed scoring criteria will ensure valid and reliable use of those criteria to evaluate student responses to maximize the accuracy and efficiency of scoring.
3. Constructed-response scoring criteria will be developed initially by the item writers, refined during item review, and finalized during pilot or field test scoring. During pilot or field test scoring, the scoring guides will be expanded to include examples of actual student responses to illustrate each score point. Actual student responses will be used as well, to inform scorers of unacceptable answers.
4. Procedures used to train scorers and to conduct scoring of constructed-response items must be provided to the Board, along with information regarding the reliability and validity of such scoring. If the technology becomes available to score student responses electronically, the Board must be informed of the reliability and validity of such scoring protocol, as compared to human scoring.

Principle 6

All NAEP test questions will be free from racial, cultural, gender, or regional bias, and must be secular, neutral, and non-ideological. NAEP will not evaluate or assess personal or family beliefs, feelings, and attitudes, or publicly disclose personally identifiable information.

Policies and Procedures

1. An item is considered biased if it unfairly disadvantages a particular subgroup of students by requiring knowledge of obscure information unrelated to the construct being assessed. A test question or passage is biased if it contains material derisive or derogatory toward a particular group. For example, a geometry item requiring prior knowledge of the specific dimensions of a basketball court would result in lower scores for students unfamiliar with that sport, even if those students know the geometric concept being measured. Use of a regional term for a soft drink in an item context may provide an unfair advantage to students from that area of the country. Also, an item that refers to a low-achieving student as “slow” would be unacceptable.
2. In conducting bias reviews, steps should be taken to rid the item pool of questions that, because of their content or format, either appear biased on their face, or yield biased estimates of performance for certain subpopulations based on gender, race, ethnicity, or regional culture. A statistical finding of differential item functioning (DIF) will result in a review aimed at identifying possible explanations for the finding. However, such an item will not automatically be deleted if it is deemed valid for measuring what was intended, based on the NAEP assessment framework. Items in which clear bias is found will be eliminated. This policy acknowledges that there may be real and substantial differences in performance among subgroups of students. Learning about such differences, so that performance may be improved, is part of the value of the National Assessment.
3. Items shall be secular, neutral, and non-ideological. Neither NAEP nor its questions shall advocate a particular religious belief or political stance. Where appropriate, NAEP questions may deal with religious and political issues in a fair and objective way. The following definitions shall apply to the review of all NAEP test questions, reading passages, and supplementary materials used in the assessment of various subject areas:

    Secular – NAEP questions will not contain language that advocates or opposes any particular religious views or beliefs, nor will items compare one religion unfavorably to another. However, items may contain references to religions, religious symbolism, or members of religious groups where appropriate. Examples: The following phrases would be acceptable: “shaped like a Christmas tree”, “religious tolerance is one of the key aspects of a free society,” “Dr. Martin Luther King, Jr. was a Baptist minister,” or “Hinduism is the predominant religion in India.”

Neutral and Non-ideological - Items will not advocate for a particular political party or partisan issue, for any specific legislative or electoral result, or for a single perspective on a controversial issue. An item may ask students to explain both sides of a debate, or it may ask them to analyze an issue, or to explain the arguments of proponents or opponents, without requiring students to endorse personally the position they are describing. Item writers should have the flexibility to develop questions that measure important knowledge and skills without requiring both pro and con responses to every item. Examples: Students may be asked to compare and contrast positions on states rights, based on excerpts from speeches by X and Y; to analyze the themes of Franklin D. Roosevelt's first and second inaugural addresses; to identify the purpose of the Monroe Doctrine; or to select a position on the issue of suburban growth and cite evidence to support this position. Or, students may be asked to provide arguments either for or against Woodrow Wilson's decision to enter World War I. A NAEP question could ask students to summarize the dissenting opinion in a landmark Supreme Court case. The criteria of neutral and non-ideological also pertain to decisions about the pool of test questions in a subject area, taken as a whole. The Board shall review the entire item pool for a subject area to ensure that it is balanced in terms of the perspectives and issues presented.

4. The Board shall review both stimulus materials and test items to ensure adherence to the NAEP statute and the polices in this statement. Stimulus materials include reading passages, articles, documents, graphs, maps, photographs, quotations, and all other information provided to students in a NAEP test question.
5. NAEP questions will not ask a student to reveal personal or family beliefs, feelings, or attitudes, or publicly disclose personally identifiable information.

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