Assessment of Technological Literacy in the United States[1]

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Abstract
Over the past decade, several prominent U.S. organizations have suggested Americans – particularly American students – should be more knowledgeable about technology to be successful, well-rounded citizens. However, these urgings have been made largely in the absence of data about technological literacy in the United States. The lack of such data reflects a near-absence of assessment of this critical competency. To help address this problem, The National Academies launched a study of the opportunities and obstacles to developing one or more scientifically valid and broadly useful assessment instruments for technological literacy. The paper provides background to the Academies and the study, proposes working definitions of technology and technological literacy, summarizes technology-related assessment instruments analyzed by the study committee, presents a conceptual framework suitable for constructing new assessments in this domain, and suggests future steps that might be needed to make assessment of technological literacy more prevalent.

Key words
assessment, technology, technological literacy, United States, knowledge, capability, critical thinking, decision making

Introduction

The work described in this article is based on a two-year study at The National Academies (www.nationalacademies.org) that concluded in summer 2006. The study, funded by the U.S. National Science Foundation, took place over a roughly two-year period and resulted in the publication of a report, Tech Tally: Approaches to Assessing Technological Literacy. The project was overseen by the 16-person Committee on Assessing Technological Literacy, which included four members from the technology education field, two of whom were from outside the United States: Rodney L. Custer, University of Illinois, Normal; William E. Dugger Jr., International Technology Education Association, Blacksburg, Virginia; Marc J. de Vries, Eindhoven University of Technology, Eindhoven, The Netherlands; and Richard Kimbell, Goldsmiths College University of London, United Kingdom. Others on the panel brought expertise related to curriculum development, state and national assessment, survey and communications research, informal education, engineering and science education, and the cognitive sciences.

The committee was tasked with determining the most viable approach or approaches for assessing technological literacy in three distinct populations in the United States: students in kindergarten through high school (K-12), their teachers, and out-of-school adults (the "general public"). This article will focus on assessment in students, touching only briefly on assessment in the other two populations.

The committee's charge included the following specifications:

- Assess the opportunities and obstacles to developing one or more scientifically valid and broadly useful assessment instruments for technological literacy in the three target populations.
- Recommend possible approaches to carrying out such assessments, including specification of subtest areas and actual sample test items representing a variety of formats.

The committee's study process included the commissioning of several background papers on learning related to engineering and technology, the collection and analysis of nearly 30 assessment instruments, including a few from outside the United States, and a workshop at which individuals from a variety of organizations with an interest in assessment participated. The committee met a total of seven times. Motivation for the report came largely from a previous Academies study (NAE and NRC, 2002) that argued all citizens ought to have some level of technological

[1] Portions of this article are adapted from *Tech Tally: Approaches to Assessing Technological Literacy. 2006.* National Academy of Engineering and National Research Council. E. Garmire and G. Pearson, eds. Washington, D.C.: National Academies Press.

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knowledge and capability but determined that there had been very few attempts to actually measure technological literacy in adults or in children. Without a way to ascertain an individual's or a population's technological literacy, the report noted, it is not possible to determine whether steps to enhance such literacy are working.

The National Academies

To provide context for the following discussion, readers may benefit from a brief description of The National Academies, their history, and their mode of operation. Founded in the 1860s as the National Academy of Sciences, the Academies have grown to include the National Research Council (NRC), the National Academy of Engineering (NAE), and the Institute of Medicine. In addition to serving as honorary membership organizations, these institutions conduct hundreds of studies every year, often at the request of the U.S. Congress or the executive branch, on a variety of topics. The studies, which may be funded by the federal government, corporate or non-profit foundations, individuals, or internal monies, are overseen by committees of experts who serve without compensation. In a typical year, there are some 10,000 volunteer experts and 1,200 staff working on nearly 700 studies. Annually, this work results in about 250 published reports.

The process of selecting individuals to serve on study committees includes steps to assure that the panel has all of the requisite expertise, there is balance among panelists' points of view on the issue at hand, and there are no conflicts of interest that might impugn the study results. The review of Tech Tally was conducted by a group of eleven individuals not directly involved in the project but with expertise very similar to those on the study committee. The identities of the reviewers were not revealed to the committee or project staff until after the report had been approved for publication. Reviewers' comments resulted in a number of editorial and organizational changes that improved the accuracy, completeness, and readability of the final document

Technology and Technological Literacy Defined

In order to make sense of any discussion of assessment of technological literacy, one must first have a clear conception of what "technology" means in this context. In the United States, technology is typically associated with information technology, particularly computers. In a 2004 Gallup poll, for example, 800 adult Americans were asked to name the first thing that came to mind when they heard the word technology. Sixty-eight percent answered computers. Only five percent gave the next most frequent answer, electronics (ITEA, 2004). The close association of technology with computers can be attributed at least in part to the dominance of the personal computer and computer-imbedded devices in modern life – at least in a technology-dependent society like the United States.

But of course technology is far more than computers and electronics. It is airplanes and automobiles, medicines and MRIs, paper and plastics. It is home building, road construction, and the manufacture of everything from turbines to toothbrushes. It is agriculture and electricity. It is books, clothing, furniture, telephones and television, fast food and home-cooked meals, kids' toys, the Space Shuttle, roller coasters, and swimming pools. In short, technology is everything that humans do or make to change the natural environment to suit their own purposes. In this article, it is this broad view of technology that is of interest.

Another way to conceptualize technology is to think of human beings as living in three interconnected worlds – the natural world, the social world, and the designed world. The natural world consists of plants and animals, rocks and minerals, rivers, streams, lakes, oceans, the soil beneath our feet, and the air we breathe – in short, everything that exists without human intervention or invention. The social world includes customs, cultures, political systems, legal systems, economies, religions, and the mores humans devise to govern their interactions and relationships. The designed world, or the world of technology, includes all of the modifications humans make to the natural world to satisfy their needs and wants.

With this idea of technology in mind, one can move to define technological literacy. In the most fundamental sense, technological literacy is a general understanding of technology. This understanding may not be comprehensive, but it must be developed enough so that a person can function effectively in a technology-dependent society where rapid technological change is the norm.

Rather than a fixed quantity, technological literacy can be thought of as occurring along a continuum, with types and levels of literacy varying according to the age and needs of the particular population. An analogy to traditional (reading) literacy is helpful. If a 10-year-old student reads at the level expected for a child of that age, she is considered literate. All other things being equal, a literate 15-year-old is expected to have a higher level of reading capability than a 10-year-old but a lower level than a 18-year-old, who, in turn, will be a less skilled reader and less well-read than a literate university graduate. But all of them are considered literate.

Technological literacy is similar to the more familiar concepts of scientific literacy, mathematical literacy (sometimes called numeracy), and historical literacy, as well as the more recently described information technology "fluency" (NRC, 1999). In all of these cases, people are not expected to be experts but are expected to be comfortable enough to, say, read and understand a newspaper article that includes information about that field or to apply that knowledge in some aspect of daily life – for example, knowing that a car requires regular maintenance. Like literacy in other fields, the goal of technological literacy is to provide people with the tools they need to participate intelligently and thoughtfully in the world around them.

In the United States, efforts to flesh out the concept of technological literacy date back at least 50 years. (See Dyrenfurth's 1991 review.) One of the most recent attempts is contained in *Tech Tally: Approaches for Assessing Technological Literacy*, a 2006 report from The National Academies in Washington, D.C. The report proposed a three-dimensional model (Figure 1).

In the real world, of course, the three dimensions of technological literacy are interdependent and inseparable. A person cannot have technological capabilities without some knowledge, and thoughtful decision making cannot occur without an

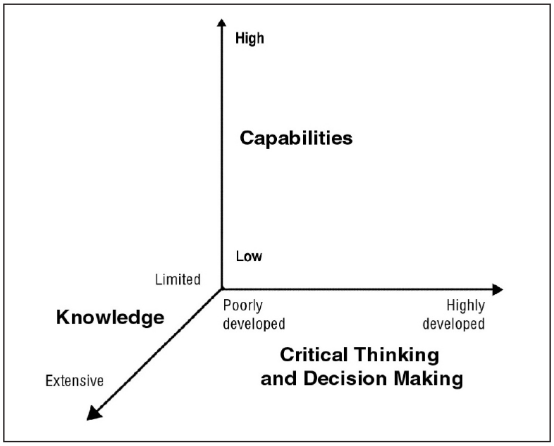

Figure 1.
The three dimensions of technological literacy.
SOURCE: NAE and NRC, 2006.

understanding of some basic features of technology. The capability dimension, too, must be informed at some level by knowledge. Conversely, the doing component of technological literacy invariably leads to a new understanding of certain aspects of the technological world. The characteristics of each dimension are spelled out in Table 1.

Table 1 – Characteristics of a Technologically Literate Person

Knowledge

- Recognizes the pervasiveness of technology in everyday life.
- Understands basic engineering concepts and terms, such as systems, constraints, and trade-offs.
- Is familiar with the nature and limitations of the engineering design process.
- Knows some of the ways technology has shaped human history and how people have shaped technology.
- Knows that all technologies entail risk, only some of which can be anticipated.
- Appreciates that the development and use of technology involve trade-offs and a balance of costs and benefits.
- Understands that technology reflects the values and culture of society.

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Critical Thinking and Decision Making

- Asks pertinent questions, of self and others, regarding the benefits and risks of technologies.
- Weighs available information about the benefits, risks, costs, and trade-offs of technology in a systematic way.
- Participates, when appropriate, in decisions about the development and uses of technology.

Capabilities

- Has a range of hands-on skills, such as operating a variety of home and office appliances and using a computer for word processing and surfing the Internet.
- Can identify and fix simple mechanical or technological problems at home or at work.
- Can apply basic mathematical concepts related to probability, scale, and estimation to make informed judgments about technological risks and benefits.
- Can use a design-thinking process to solve a problem encountered in daily life.
- Can obtain information about technological issues of concern from a variety of sources.

SOURCE: NAE and NRC, 2006.

Attitudes Toward Technology

The committee does not consider attitudes to be a cognitive dimension (the way knowledge, capability and critical thinking and decision making are). Still, attitudes toward technology can provide a context for interpreting the results of an assessment. In other words, what a person knows – or does not know – about a subject can sometimes be correlated with his or her attitude toward that subject. Individuals who do not understand the nature of technological design, for example, may not “trust” technology as much as individuals who understand the design process. However, it is just as likely that individuals who are more knowledgeable may be less trustful. That is because many factors in addition to knowledge, such as personal values, culture, and religion, can affect attitudes. Attitudes may also reveal motivations. For example, middle school girls may not believe that careers in the sciences or technology are possible, or even desirable, for them. Thus, attitudes can have cognitive, affective, and action-tendency components.

Technological Education and the U.S. Education System

Unlike some other nations (e.g. the United Kingdom), in the United States there is no national curriculum for the study of technology. In fact, there is no national curriculum in any subject. Curriculum, like most aspects of education, is determined at the state and local levels. Educational standards that suggest what children should know and be able to do in many subjects, including mathematics, science, and technology, have been developed through deliberative consensus processes. But it is the 50 states and their 13,000 school districts that ultimately set goals for student learning, often by adopting or adapting the consensus standards.

For technology, student learning goals appear in three documents. The two sets of U.S. science education standards (AAAS, 1993; NRC, 1995) include sections that emphasize the importance of technological knowledge and skills and the connections between science and technology. The International Technology Education Association’s *Standards for Technological Literacy: Content for the Study of Technology*, published in 2000, contains the most detailed exploration of potential learning outcomes. Although slightly more than three-quarters of states say they have adopted the ITEA standards, less than one-quarter require technology education for their students (Meade and Dugger, 2004).

A further limitation on the reach of technology education in the United States is that the cadre of technology teachers is a relatively small 35,000, about one-tenth the number of science teachers. So, despite the existence of standards and a group of teachers devoted to teaching about technology, the unfortunate truth is that, unlike science, mathematics, reading, and social studies (history), which are considered regular components of the school day, technology is not available to many students in the United States.

Assessment of technological literacy

Review of Instruments

Given the relative absence of courses and requirements for the study of technology, and the low profile of efforts to promote technological literacy generally, it should not be a surprise that there are very few assessments in this area. The committee was able to find 28 assessment instruments that it felt measured one or more dimensions of technological literacy, whether designed explicitly to do so or not. The instruments including formal criterion- or norm-referenced tests, performance-based activities intended to measure an aspect of design or problem-solving ability, attitude or opinion surveys, and informal quizzes. Item formats ran the gamut from multiple-choice and short-answer questions to essays and performance tasks. About half the instruments had been used more than once; a very few had been administered many times over the course of a decade or more. The others, such as assessments developed as research for Ph.D. dissertations, had been used once, if at all.

The population of interest for most of the instruments was K–12 students. Teachers were the target population for two. The rest were designed to test out-of-school adults. Although the focus of the project was on assessment in the United States, the committee also studied instruments developed in Canada, England, and Taiwan.

The purposes of the assessment tools varied as much as the instruments themselves. They included diagnosis and certification of students, input for curriculum development, certification of teachers, resource allocation, program evaluation, guidance for public policy, suitability for employment, and research. The developers of these assessments could be divided into four categories: state or federal agencies, private educational organizations, academic researchers, and test-development or survey companies. Table 2 (overleaf) provides basic information about the instruments.

The committee concluded that none of the instruments was completely adequate to the task of assessing technological literacy. None fully covered the three dimensions spelled out in *Technically Speaking,* and most concentrated on the knowledge dimension. A number of them also included items that explored technological capabilities, and a few focused solely on the capability dimension. Only a handful examined the critical thinking and decision making dimension.

Assessing technology-related capability, which includes the ability to use a design process, is more difficult than gauging knowledge. Only a few methods have been developed for assessing capability, partly because this tends to be very expensive, at least for large-scale application. Nevertheless, assessing the capability dimension is crucial. Existing assessments intended to determine the technological literacy of out-of-school adults tend to focus on awareness, attitudes, and opinions, rather than on knowledge or capabilities. One of the goals of all types of learning is to encourage higher-order thinking (i.e. thinking that considers uncertainty and requires nuanced judgment, rather than simply factual recall). Only a handful of the instruments collected by the committee encouraged higher-order thinking. For each instrument, *Tech Tally* includes a detailed summary, example test items, and committee commentary.

Although the technological literacy of students is not assessed in any substantive way in the United States, large-scale (i.e. state level) assessment of student learning in other subjects consumes a tremendous amount of human and capital resources. The pressure on teachers and schools to prepare students to take and score well on annual state-administered tests of achievement in core subjects like mathematics and reading increased substantially with Congressional passage of the No Child Left Behind Act of 2001. The law requires yearly testing in these subjects (and in science beginning in 2007), and schools must demonstrate continual improvements in student test scores or face sanctions. Separately, the National Assessment Governing Board (NAGB), a non-governmental group charged with monitoring trends in educational achievement across the nation, periodically conducts sample-based assessments in subjects ranging from mathematics and science to reading, history, and geography.

Development of a Conceptual Framework

A step common to the design of most large-scale assessments in the United States is the development of a framework that describes the cognitive and content components of the proposed assessment. The framework often suggests the relative emphasis on each area of content, depending on the age of the test population and other factors. The conceptual underpinnings of the framework can be represented visually as a two-dimensional matrix, which serves as a blueprint for the more detailed phases of assessment design, the development of test specifications and, ultimately, the development of actual test items.

Table 2: Technological-Literacy-Related Assessment Instruments

K–12 Students			
Name	**Developer**	**Primary Purpose**	**Frequency of Administration**
Assessment of Performance in Design and Technology	Schools Examinations and Assessment Council, London	Curriculum development and research.	Once in 1989.
Design Technology	International Baccalaureate Organization	Student achievement (part of qualification for diploma).	Regularly since 2003.
Design-Based Science	David Fortus, University of Michigan	Curriculum development and research.	Once in 2001–2002.
Design Team Assessments for Engineering Students	Washington State University	Assess students' knowledge, performance, and evaluation of the design process; evaluate student teamwork and communication skills.	Unknown.
Future City Competition – Judges Manual	National Engineers Week	To help rate and rank design projects and essays submitted to the Future City Competition.	Annually since 1992.
Illinois Standards Achievements Test—Science	Illinois State Board of Education	Measure student achievement in five areas and monitor school performance.	Annually since 2000.
Industrial Technology Literacy Test1	Michael Allen Hayden, Iowa State University	Assess the level of industrial-technology literacy among high school studen.	Once in 1989 or 1990.
Infinity Project Pretest and Final Test	Geoffrey Orsak, Southern Methodist University	Basic aptitude (pretest) and student performance.	Ongoing since 1999.
Information Technology in a Global Society	International Baccalaureate Organization	Student evaluation.	Semiannually at the standard level since 2002; higher-level exams will be available in 2006.
Massachusetts Comprehensive Assessment Systems—Science and Technology/Engineering	Massachusetts Department of Education	Monitor individual student achievement, gauge school and district performance, satisfy requirements of No Child Left Behind Act.	Annually since 1998.

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K–12 Students			
Name	**Developer**	**Primary Purpose**	**Frequency of Administration**
Multiple Choice Instrument for Monitoring Views on Science-Technology-Society Topics	G.S. Aikenhead and A.G. Ryan, University of Saskatchewan	Curriculum evaluation and research.	Once in September 1987–August 1989
New York State Intermediate Assessment in Technology*	State Education Department/State University of New York	Curriculum improvement and student evaluation.	Unknown.
Provincial Learning Assessment in Technological Literacy*	Saskatchewan Education	Analyze students' technological literacy to improve their understanding of the relationship between technology and society.	Once in 1999.
Pupils' Attitude Toward Technology*	E. Allen Bame and William E. Dugger Jr., Virginia Polytechnic Institute and State University; Marc J. de Vries, Eindhoven University	Assess student attitudes toward and knowledge of technology.	Dozens of times in many countries since 1988.
Student Individualized Performance Inventory	Rodney L. Custer, Brigitte G. Valesey, and Barry N. Burke, with funding from the Council on Technology Teacher Education, International Technology Education Association, and the Technical Foundation of America	Develop a model to assess the problem-solving capabilities of students engaged in design activities.	Unknown.
Survey of Technological Literacy of Elementary and Junior High School Students*	Ta Wei Le, et al., National Taiwan Normal University	Curriculum development and planning.	Once in March 1995.
Test of Technological Literacy*	Abdul Hameed, Ohio State University	Research.	Once in April 1988.
TL50: Technological Literacy Instrument*	Michael J. Dyrenfurth, Purdue University	Gauge technological literacy.	Unknown.
WorkKeys – Applied Technology	American College Testing Program	Measure job skills and workplace readiness.	Multiple times since 1992.

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K–12 Teachers			
Name	**Developer**	**Primary Purpose**	**Frequency of Administration**
Engineering K–12 Center Teacher Survey	American Society for Engineering Education	Inform outreach efforts to K–12 teachers.	Continuously available.
Praxis Specialty Area Test: Technology Education*	Educational Testing Service	Teacher licensing.	Regularly.

Out-of-School Adults			
Name	**Developer**	**Primary Purpose**	**Frequency of Administration**
Armed Services Vocational Aptitude Battery	U.S. Department of Defense	Assess potential of military recruits for job specialties in the armed forces and provide a standard for enlistment.	Ongoing in its present form since 1968.
Awareness Survey on Genetically Modified Foods	North Carolina Citizens' Technology Forum Project Team	Research on public involvement in decision making on science and technology issues.	Once in 2001.
Eurobarometer: Europeans, Science and Technology	European Union Directorate General for Press and Communication	Monitor changes in public views of science and technology to assist decision making by policy makers.	Surveys on various topics conducted regularly since 1973; this poll was conducted in May/June 2001.
European Commission Candidate Countries Eurobarometer: Science and Technology	Gallup Organization of Hungary	Monitor public opinion on science and technology issues of concern to policy makers.	Periodically since 1973; this survey was administered in 2002.
Gallup Poll on What Americans Think About Technology (2001)*	International Technology Education Association	Determine public knowledge and perceptions of technology to inform efforts to change and shape public views.	Once in 2001.
Gallup Poll on What Americans Think About Technology (2004)*	International Technology Education Association	Determine public knowledge and perceptions of technology to inform efforts to change and shape public views.	Once in 2004.
Science and Technology: Public Attitudes and Public Understanding	National Science Board	Monitor public attitudes, knowledge, and interest in science and technology issues.	Biennially from 1979 to 2001.

* Designed explicitly to measure some aspects of technological literacy.
SOURCE: NAE and NRC, 2006.

Table 3: Proposed Assessment Matrix for Technological Literacy

		Cognitive Dimensions		
		Knowledge	Capabilities	Critical Thinking and Decision Making
Content Areas	Technology and Society			
	Design			
	Products and Systems			
	Characteristics, Core Concepts, and Connections			

SOURCE: NAE and NRC, 2006.

The committee developed a sample assessment matrix (Table 3), which was heavily influenced by conceptual frameworks developed by NAGB for assessments in science and mathematics (NAGB, 2002, 2004). The matrix's column headings are the three dimensions of technological literacy previously described. The row headings are adapted from ITEA's *Standards for Technological Literacy.*
The purposes of the assessment tools varied as much as the instruments themselves. They included diagnosis and certification of students, input for curriculum development, certification of teachers, resource allocation, program evaluation, guidance for public policy, suitability for employment, and research. The developers of these assessments could be divided into four categories: state or federal agencies, private educational organizations, academic researchers, and test-development or survey companies. Table 3 provides basic information about the instruments.

The Special Case of Assessing Capability
The assessment of technological literacy will almost certainly benefit from, if not require, innovative approaches. This is especially true for assessment of the capability dimension, where test-takers must demonstrate iterative problem-solving techniques typical of a design process. Even thoughtfully developed paper-and-pencil approaches fall short in this regard. An alternative would be to give test-takers hands-on laboratory exercises, but the costs and complexities of developing, administering, and "grading" a truly hands-on design or problem-solving activity in a large sample of individuals are prohibitive. According to the committee, the increasing speed, power, and ubiquity of computers in various configurations (e.g., desktop, laptop, personal digital assistant, e-tablet, and cell phone), combined with increasing access to the Internet, suggest a variety of more innovative approaches to assessment. While computer-based testing likely will benefit many domains, the committee believes the approach is particularly appealing in the case of assessment of technological literacy. Computer-adaptive testing, for example, has the potential to be used to quickly, reliably, and inexpensively to assess student knowledge of technology. Simulation could be used as a safe and economical means to assess more procedural, analytical, and abstract capabilities and skills. The use of Internet-based, massive-multiplayer online games to conduct assessments could be sufficiently motivating and inexpensive to engage very large numbers of individuals for extended periods of time.

At the same time, it is clear that more research and development will be needed before computer-based assessment can be used with full confidence to assess technological literacy. For one thing, the formal, psychometric properties of simulation must be better understood. And the costs of developing simulations de novo may be prohibitive in many instances.

The Way Forward

There is no question that assessment of technological literacy in the United States faces many obstacles, some of them quite daunting. A major need is better information about how people learn about technology. The committee's report includes a summary of the literature in this domain, but the landscape is sparse. Thus, more cognitive science research is needed. As noted, there is a similar need to look more carefully and creatively at how computer-based technologies might be used to permit affordable, reliable, and valid measures of the capability dimension. The military and video game industry are two sectors where relevant technology development is already occurring. And more careful thought is needed to fully develop the conceptual frameworks that might underlie assessments of students as well as teachers and adults.

The committee suggests that existing national assessments (those developed by NAGB) and international comparative assessments (i.e. Trends in Mathematics and Science Study, Programme for International Student Assessment) in science and mathematics might be fairly easily modified to include technology-related items. In the long term, stand-alone assessments for technological literacy are desirable, if a truly comprehensive picture of peoples' technological savvy is to emerge.

In one hopeful development, NAGB decided in 2005 to sponsor a so-called probe study of technological literacy. Probe studies are small-scale research projects to determine the feasibility of developing new large-scale developments. Among other things, the probe study will look into the pros and cons of different assessment methods.

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