2006-695: WHAT IS TECHNOLOGICAL LITERACY AND WHY DOES IT MATTER?

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Introduction

In February 2005, I was asked to speak before a group of several hundred high-achieving high school students from around the world who were visiting Washington, D.C., as part of a program called Presidential Classroom. I choose to talk about technological literacy, since the students' week in D.C. was focused on science and technology policy. I began with a simple interactive challenge. I flashed the following question on the screen at the front of the auditorium: "When you hear the word "technology," the first thing that comes to mind is "___________." After 5 seconds, I asked those who had thought first of "computer" or "computers" to raise their hands. Well over half the group did so.

I wasn't surprised, but I was a bit disappointed. Two recent Gallup polls had asked the same question [1, 2], and nearly 70 percent of respondents, all adults, also said computers. (The next most common response, at 4%, was "electronics.") But this auditorium was filled with teenagers with a keen interest in science and technology. Was their view of technology really so narrow? And if it was, what did that suggest? Did it simply reflect the omnipresence of computers and computer-driven devices in these youngsters' lives? Might we wish something different of these "digital natives," Prensky's [3] term for people who since birth have known nothing but a world dominated by the silicon chip? If so, what? And what about the "digital immigrants" like me and most readers of this paper, who are part of the large but dwindling population of people older than the introduction of the personal computer. What ought we to make of their view of technology?

This paper will address these and related questions. It will begin by proposing a broad definition of technology and then using that foundation to build an equally encompassing concept of technological literacy. Technological literacy has strong links to science literacy, and to engineering, and the paper will discuss these connections. It will elucidate some of the potential benefits of technological literacy, which accrue to the individual as well as to society at large. And it will describe some of the initiatives around the country that aim to promote greater technological understanding. The paper draws heavily on *Technically Speaking: Why All Americans Need to Know More About Technology* [4], a report from the National Academy of Engineering (NAE) and National Research Council (NRC). A web-based version of the report is at www.nae.edu/techlit.

Technology Defined

It is not wrong to associate the word technology with computers, as many people do. Computers are technology, of course, and arguable one of the most transformational of our time, or any other. But they are far from the only technology that plays such a pivotal role. A carefully vetted list of 20 of the most important engineering achievements of the 20th century includes computers, but seven other technologies (electrification, the automobile, the airplane, water purification and distribution, electronics, radio and television, and agricultural mechanization) are ranked higher in importance. [5, 18] As the achievements list makes clear, technology encompass not just the individual, tangible artifacts but the larger systems of which the artifacts are a part. A truly inclusive view of technology also includes the people and infrastructure needed to design, manufacture, operate, and repair the artifacts.

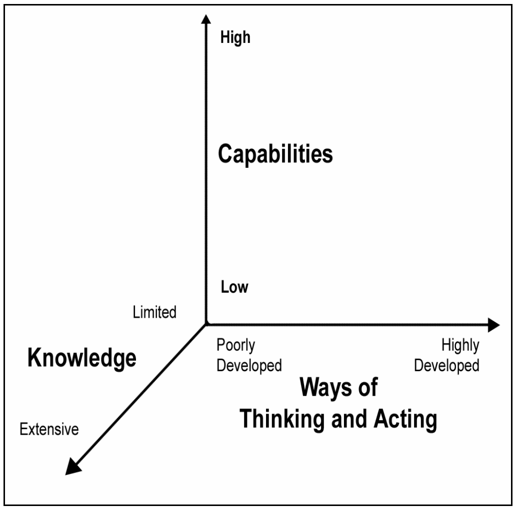
This expansive view was captured in *Technically Speaking*, which defined technology as "the process by which humans modify nature to meet their needs and wants" [4] (p. 13). Two years earlier, the *Standards for Technological Literacy: Content for the Study of Technology*, declared technology to be "the innovation, change, or modification of the natural environment in order to satisfy perceived human wants and needs" [6] (p. 242). Similarly sweeping definitions are contained in the two sets of national K-12 science education standards, one developed by the American Association for the Advancement of Science [7] and the other by the NRC [8]. It is this broader conception of technology that seems largely absent for most Americans, if the polling data, my Presidential Classroom experience, and other indicators are to be believed.

Technological Literacy

It seems a fair statement that if technology is more that computers, than technological literacy is more than computer literacy.[1] This is indeed the case, although it is not uncommon to hear the term "technological literacy" used to refer to facility with computers, usually in an educational setting. According to the committee that drafted *Technically Speaking*, technological literacy can be thought of as having three interdependent dimensions: knowledge, capabilities, and ways of thinking and acting (Figure 1). A later Academies study [10] that examined approaches to assessing technological literacy renamed the last dimension "critical thinking and decision making," and that is the convention I will follow.

Along the knowledge dimension, we might expect a technologically literate person to understand basic engineering concepts and terms, such as systems, constraints, and trade-offs; know something about the nature of the engineering design process; and appreciate that technology shapes human history just as people shape technology. In terms of critical thinking and decision making (ways of thinking and acting in Figure 1), a technologically literate individual would be expected to ask questions of him- or herself and others regarding the benefits and risks of technologies; weigh available information about the benefits and risks, costs, and trade-offs of technology in a systematic way; and

FIGURE 1 The Dimensions of Technological Literacy



SOURCE: (4)

participate, when appropriate, in decisions about the development and use of technology. As for capabilities, a technologically literate person ought to have a range of hands-on skills, such as using a computer for word processing, surfing the Internet, and operating a variety of home and office appliances; be able to identify and fix simple mechanical or technological problems at home or work; and use a design-thinking process to solve a problem at home, in school, or in the workplace.

The committee that drafted *Technically Speaking* was aiming high. It is hard to imagine any single person, even an engineer, possessing all of the traits associated with technological literacy. ITEA's K-12 standards are similarly ambitious, containing 20 standards and hundreds of grade-level benchmarks. It is thus helpful to refer to Figure 1, which suggests each of technological literacy's elements occurs along a continuum. For any person at any particular time, literacy will be some combination of these different aspects, and that will change with age, experience, and circumstances. A number of other models for thinking about literacy related to technology have been proposed (e.g., 11).

Importantly, technological literacy is not the same as technical competence. Some individuals (e.g., plumbers, automobile mechanics, computer programmers, airplane pilots) may be very competent in the use of one or more specific technologies but may not be technologically literate. Although technological literacy includes an element of hands-on ability, this does not necessarily imply a high level of practical, or technical, skill. And, conversely, having technical competency does not guarantee one understands technology in the ways suggested by the authors of *Technically Speaking*.

Any discussion of technological literacy would be incomplete without mention of scientific literacy. Technological and scientific literacy are interdependent. Scientific understanding is the basis of much of technology, and so it makes sense that a technologically literate person must know some science. This connection is called out in

ITEA's standards. Conversely, technology both embodies and, in some cases, makes possible new scientific knowledge. Thus, someone who is scientifically literate must have some degree of technological savvy, enough at least to recognize the dependence of much of scientific research on technological tools. This relationship is described in some detail in the two sets of national science education standards.

Benefits of Technological Literacy

There are a number of benefits to technological literacy, both for individuals and the nation as a whole. For instance, someone who is broadly knowledgeable and capable when it comes to technology may be able to contribute more (and compete more effectively) in the workplace than someone without those traits. Employers today are seeking workers who can identify and solve problems, who see issues within a broad context, and who are comfortable with complexity. The study of technology can encourage all of these qualities. A person who understands the basics of technology and can think critically about risks, benefits, and trade-offs will be a more savvy consumer. The world is full of products and services that promise to make people's lives easier, more enjoyable, more efficient, or healthier, and more and more of these products appear every year. A technologically literate person cannot know how each new technology works, its advantages and disadvantages, how to operate it, and so on, but he or she can learn enough about a product to put it to good use or to choose not to use it.

Anyone in a position to make decisions affecting large numbers of people, such as a government policy maker or business leader, will benefit from a fuller understanding of technology, particularly the notions of trade-offs and unintended consequences. Leaders who are able to take these ideas into account in their decision making will be more liable to manage technological developments in ways that maximize the benefits to humankind and minimize the negative impacts.

Of course, citizens of all stripes face decisions in their own lives that affect or are affected by technology. Is a local referendum on issuing bonds for the construction of a new power plant a wise use of taxpayer dollars? Does a plan to locate a new waste incinerator within several miles of one's home pose serious health risks, as opponents of the initiative may claim? How should one react to efforts by local government to place surveillance cameras in high-crime areas of the city? Technologically literate people may disagree on the best answers to these and other technology-related questions, but they will be much better able to discuss them in an informed manner.

Technological Literacy in the United States

People come to know something about technology in at least three ways. For many if not most Americans, the predominant mode is through personal experience. So-called incidental learning occurs through contact with consumer goods (e.g., computers, electronic goods, tools, self-assembly products); in do-it-yourself projects, where one is designing a solution to a specific problem; and by information gleaned from various media, including television, radio, movies, books, magazines, newspapers, and, increasingly, the Internet.

Technological literacy also can be encouraged more formally in schools, where it is taught either as a discrete subject or integrated into other academic areas, such as science, mathematics, or social studies/history. In K-12 education, the principal formal pathway is through technology education. With only about 30,000 teachers nationwide, however, and only one-third of states requiring students to take such courses by high school [12], technology education cannot at this time be considered a mainstream subject in U.S. education. Aspects of technological literacy, especially the element of design thinking, can be included in efforts aimed at introducing K-12 students to engineering. Project Lead the Way (www.pltw.org) may be the largest and best known of these initiatives, but there are many others that are having an impact. In post-secondary education, technological literacy has been the stated or implied goal of STS (science technology society) programs, and programs on the history and philosophy of technology. A small number of engineering faculty around the country have developed courses intended to introduce non-engineering students to fundamental ideas in technology and engineering [13].

Children and adults can acquire technologically literate through a variety of informal learning opportunities, such as visits to science centers and museums. In the last several years, for example, the Boston Museum of Science has taken an active role in promoting technological literacy. The museum is developing curricula and teacher education projects consistent with state learning standards that include a technology/engineering strand [14]. Other museums, such as the Tech Museum of Innovation in San Jose and the Oregon Museum of Science and Industry, have developed programming in line with the goals of technological literacy. Children can also experience hands-on design activities and technology-related problem solving through extracurricular contests, including the Toshiba/NSTA ExploraVision Awards program (www.exploravision.org), the FIRST Robotics Competition (www.usfirst.org) and FIRST LEGO League (www.firstlegoleague.org), and the National Engineering Design Challenge (www.jets.org/programs/nedc.cfm). A handful of community organizations, like the Boy and Girl Scouts, promote technological literacy activities among their members. In the case of the scouts, the initiative is a partnership with the Association of Mechanical Engineers.

How Technologically Literate Are We?

The case for technological literacy has in part been built on the assumption that the level of such literacy is suboptimal in the United States. The uncomfortable truth is that there are no hard data to support this claim. With the exception of the ITEA-sponsored Gallup polls and a handful of other assessments, there have been almost no attempts to actually measure such literacy--in children or adults. The authors of *Technically Speaking* recognized this problem and urged efforts to correct it. A recently completed project at the National Academies [15] attempts a partial fix by examining the challenges of assessment in this area and suggesting how test developers might overcome them. One of the most difficult tasks, according to the report, will be developing a conceptual model for technological literacy that appropriately combines its cognitive and content elements. A second challenge will be deciding what constitutes sufficient literacy, and that will depend to a great degree on the purpose of the assessment.

In 2005, the National Assessment Governing Board (NAGB), which oversees the National Assessment of Educational Progress, authorized a feasibility study of assessing technological literacy. Among other things, the study will look into the pros and cons of different assessment methods and collect considerable attitudinal data. The feasibility study is a very encouraging development that suggests the possibility of collecting national sample-based data on technological literacy among U.S. K–12 students. However, results of the study will not be known until at least 2012 because of the time required to develop a conceptual framework and conduct field tests of assessment items.

The Future of Technological Literacy

Interest in and awareness of technological literacy has grown significantly over the past 5 years, in part due to publication of ITEA's standards and *Technically Speaking*. But the concept is still below the radar screens of most educators, policy makers, and members of the public. Concerns about the United States' ability to compete in the global science and technology enterprise have focused renewed attention on K-12 education, especially science, mathematics, and engineering (e.g., 16), but technology education and technological literacy rarely enter into these discussions in a serious way. The current focus in American education on testing and accountability favors those subjects that are assessed over those that are not. In this respect, technological literacy remains outside the mainstream, though NAGB's assessment feasibility study could change that.

With a few exceptions, the engineering community has been mostly silent on the topic of technological literacy. For the most part, engineering educators and technology educators do not commingle, even though a case could be made that the two groups have much in common and much to gain by working together more closely [17]. Both groups, for example, are concerned about the "professional pipeline," their poor record on diversity, and public perceptions of their relevance. It is naïve to think that technological literacy would suddenly blossom if engineering were to promote the idea more vigorously. Yet it is hard to imagine how greater involvement by engineers would not help that cause.

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18. In fairness, there is a range of views about what constitutes computer literacy. Information technology "fluency," for example (9), suggests a broad interpretation similar to the model proposed in Technically Speaking, while educational technology standards developed for K-12 students (ISTE, 2000) are relatively narrowly focused on skills.