2006-426: FROM "HOW STUFF WORKS" TO "HOW STUFF WORKS": A SYSTEMS APPROACH TO THE RELATIONSHIP OF STS AND "TECHNOLOGICAL LITERACY"

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Its [sic] not so important to pick the right name, as to not pick the wrong name.

--Rajaneesh Narula, "A Short Guide to Baby Names,"
The Astounding Importance of Triviality
Accessed September 30, 2005

I have a reputation as a pain in the ass when starting a project. . . .I think naming projects is critical to their continued success.

--Andy Lester, "On the Importance of Names"
February 15, 2004

I. Introduction

The opening sections of *Technically Speaking: Why All Americans Need to Know More about Technology* (2002), a joint publication of the National Research Council and the National Academy of Engineering, make it clear that the initiative called "technological literacy" is concerned with a sophisticated and heterogeneous combination of "knowledge, ways of thinking, and capabilities" and focused on ambitious goals: "To take full advantage of the benefits and to recognize, address, and even avoid some of the pitfalls of technology. . . [to help citizens] become better stewards of technological change".[1]

To borrow from the quote that begins this paper, it is unfortunate to see such a promising concept saddled with a name that gives so little insight into its character or potential—and that carries negative connotations and limitations that may undermine its chances for continuing success. Although *Technically Speaking* and many other publications concerned with technological literacy reveal well-formed intentions and sophisticated reasoning, it appears that the name was selected with little deliberation or reflection on its implications. This paper will argue that we need to **stop now** to rename the enterprise and to reflect on the numerous constituencies we will need to engage and system of heterogeneous elements we will need to bring together if we are to have an effective and productive interface between technical experts and those without technical expertise, both in academia and in the public sphere.

In particular, this paper (1) focuses on the complementary goals of science, technology, and society (STS) scholars and the advocates of technological literacy, (2) articulates the specific ways in which the term "literacy" is an inaccurate label for the enterprise, and (3) explores the obstacles to and prerequisites for building the interdisciplinary scholarly community required to achieve the goals of what we now term "technological literacy." One of the key steps will be to realize that "how stuff works" (that is, how devices work and things are made) is only one—though obviously a key—component of understanding "how STUFF works" (that is, becoming "better stewards of technological change").

II. The Complementary Goals of Science, Technology, and Society (STS) and Technological Literacy

Comparing the stated goals of the field of science, technology, and society (STS) with those of technological literacy reveals that the two sets of goals are both overlapping and complementary.

Goals and Definitions of STS

My home department of STS describes the field in terms of "understanding the complex interactions of science, technology, and society" (www.sts.virginia.edu). Figure 1 duplicates the descriptions from several different institutions. As figure 1 demonstrates, a common theme in descriptions of STS is that it is an integrative, interdisciplinary field. As the description from the University of Alberta illustrates, STS is fairly new, an "emerging field of academic study." The definition used by MIT captures a central aspect of the identity of STS: it has emerged to address a distinctive set of historical circumstances that MIT characterizes as "an unprecedented and momentous integration of science, technology, and society." This sense of responsiveness to the historical moment is shared by most researchers and educators in the field of STS. The MIT description also emphasizes the relevance of STS to the contemporary world, asserting that STS is "crucial to understanding major events of our time (war and conflict, the economy, health, the environment) and to addressing these and other major public issues (privacy, democracy, education)." The Stanford STS description captures another role of STS, facilitating interdisciplinary dialogue: "STS provides an arena for dialogue among students of engineering, humanities, natural sciences and social sciences—a common ground where important cross-disciplinary studies transcending the gaps between the technical and non-technical fields are not merely envisioned but practiced." Finally, the University of Alberta description captures the notion of STS examining "science and technology as social and cultural phenomena."

Technological Literacy as Defined by the Engineering Community

The definition of technological literacy as it appears on the NAE technological literacy web page (www.nae.edu/nae/techlithome.nsf) clearly echoes the definitions and goals of STS: "Technological literacy [is] a broad understanding of the human-designed world and our place in it. . . an essential quality for all people who live in the increasingly technology-driven 21st century." This definition emphasizes technological literacy as a multidimensional set of three interrelated dimensions (capabilities, knowledge, and ways of acting and thinking) and is portrayed graphically in figure 2. Figure 3 presents a list of characteristics of a technologically literate person. Like the goals and definitions of STS, this list of characteristics emphasizes and reflects the interdisciplinary, heterogeneous, and integrative nature of the enterprise.

The discussion of the three dimensions emphasizes that they will be developed at different levels for different purposes in different individuals at different times. Like STS, the NAE/NRC statement of goals focuses on the importance of the historical moment and of public participation and democracy: "The argument for technological literacy is fundamentally about providing citizens with the tools to participate fully and confidently in the world around them. . . .[and is] essential for people living in a modern nation like the United States".[2] It also highlights

the case-driven nature of technological literacy. Depending on particular technology-based decision or debate in question, the specific knowledge needed will vary considerably, another feature shared with STS.

Figure 1: Definitions of STS*

Welcome to our subject guide on STS. This guide is intended for use by students, staff and faculty at the University of Alberta with an interest in STS, an **emerging field of academic study**, **interdisciplinary** in nature, that examines **science and technology as social and cultural phenomena.**

http://www.ualberta.ca/~slis/guides/scitech/kmc.htm
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The Program in Science, Technology, and Society (STS) at the Massachusetts Institute of Technology attempts to increase **understanding of the human-built world**. In this world, **science and technology have broken through the walls of industry and of the laboratory to become an inextricable and determining element of nature, culture, and history**. The STS Program was founded at MIT in 1976 to address this **unprecedented and momentous integration of science, technology, and society.** Faculty and students in the Program address two basic, interrelated questions: how did science and technology evolve as human activities, and what role do they play in the larger civilization? The STS perspective is **crucial to understanding major events of our time (war and conflict, the economy, health, the environment) and to addressing these and other major public issues (privacy, democracy, education).**

http://web.mit.edu/sts/info/index-css.html

Stanford's Program in Science, Technology, and Society (STS) offers undergraduates **integrated studies** of the natures and relationship of science, technology, and engineering, and of the social relations of science and technology. STS provides an **arena for dialogue** among students of engineering, humanities, natural sciences and social sciences--a **common ground where important cross-disciplinary studies transcending the gaps between the technical and non-technical fields are not merely envisioned, but practiced.**
http://www.stanford.edu/group/STS/about.html

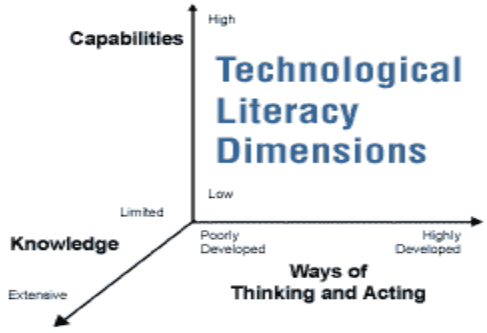
*Emphasis added.

Figure 2. The Three Interrelated Dimensions of Technological Literacy

http://www.nae.edu/nae/techlithome.nsf/weblinks/KGRG-569LNP?OpenDocument

Technological literacy can be thought of a comprising three interrelated dimensions that help describe the characteristics of a technologically literate person.

Dimensions of Technological Literacy



Technological literacy encompasses three interdependent dimensions: (1) knowledge; (2) ways of thinking and acting; and (3) capabilities. These dimensions can be placed along a continuum-from low to high, poorly developed to well developed, limited to extensive.

Every individual has a unique combination of knowledge, ways of thinking and acting, and capabilities that will change over time with education and life experience. The characteristics of a technologically literate person can be described along these dimensions.

Different job and life circumstances require different levels and types of literacy. For example, a state legislator involved in a debate about the merits of constructing new power plants to meet future electricity demand ought to understand at a fairly sophisticated level the technological concepts of trade-offs, constraints, and systems. He or she must also understand enough details about power generation to sort through conflicting claims by utility companies, environmental lobbyists, and other stakeholder groups. The average consumer pondering the purchase of a new digital television may be well served by a more basic understanding of the technology - for example, the differences between digital and analog signals - and a smaller set of critical thinking skills.

In practice, it is impossible to separate the dimensions from one another. It is hard to imagine a person with technological capability who does not also know something about the workings of technology, or a person who can think critically about a technological issue who does not also have some knowledge of technology and science. So, although the three-dimensional framework about technological literacy can be helpful in thinking and talking, it is important to remember these dimensions are arbitrary divisions.

Some Important Differences in Emphasis

Just as the definitions of STS tend to emphasize "science and technology as social and cultural phenomena" and thus bear the imprint of having originated in a community of humanists and social scientists, the list of traits of a technologically literate person bears the imprint of its engineering origins. Examples in this category include (1) understanding "basic engineering concepts and terms," (2) being "familiar with the nature and limitations of the engineering design process," (3) "hands-on skills," and (4) the ability to "identify and fix simple mechanical or technological problems at home or at work." The last two items in this list would clearly fall outside the professional expertise of most STS scholars and thus could not likely be taught by them. They also are not typically emphasized or even explicitly discussed by STS scholars, but I believe that most STS scholars would recognize their relevance to achieving the large-scale goals of STS.

Figure 3. Characteristics of a Technologically Literate Person as Defined by NAE

http://www.nae.edu/nae/techlithome.nsf/weblinks/KGRG-55SQ37?OpenDocument

A technologically literate person has knowledge of technology and is capable of using it effectively to accomplish various tasks. He or she can think critically about technological issues and act accordingly.

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 shapes human history and people shape technology.
- Knows that all technologies entail risk, some that can be anticipated and some that cannot.
- 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.

Ways of Thinking and Acting

- Asks pertinent questions, of self and others, regarding the benefits and risks of technologies.
- Seeks information about new technologies.
- Participates, when appropriate, in decisions about the development and use of technology.

Capabilities

- Has a range of hands-on skills, such as using a computer for word processing and surfing the Internet and operating a variety of home and office appliances.
- Can identify and fix simple mechanical or technological problems at home or work.
- Can apply basic mathematical concepts related to probability, scale, and estimation to make informed judgments about technological risks and benefits.

A Comprehensive View that Highlights Both Great Potential and Gaps in Knowledge

The similarity between the aims of STS and technological literacy leads to two important conclusions: (1) the differences in emphasis contribute to a broader view of the enterprise if we combine the two visions into a comprehensive picture of the goals and elements that most be brought together to achieve success and (2) there is great potential for fruitful collaboration as well as creative tension between the two groups.

A complete system that allows experts and non-experts to communicate successfully and act in meaningful ways will require diverse kinds of knowledge and the ability to find and assimilate new knowledge. But it will also require forums and mechanisms for decision-making that are essential to democratic management of technology but do not currently exist. As the editors of *Technically Speaking* express it, "From a philosophical point of view, democratic principles imply that decisions affecting many people or the entire society should be made with as much public involvement as possible. As people gain confidence in their ability to ask questions and think critically about technological developments, they are likely to participate more in making decisions."[3] Bugliarello adds, "Ultimately, the most important function of technological literacy is to make citizens more clearly conscious of the role of technology in preserving the other elements of their culture, and not allowing a gap to be created between technological savvy and the wise use of that savvy."[4]

Even if we had large numbers of citizens with all the traits defined above, it is not clear where the majority of people would be exercise their abilities except in their limited roles as consumers. In sum, we have significant structural and organizational gaps. As Emmanuel Mesthene pointed out in *Technological Change* (1970):

> Most of the consequences of technology that are causing concern at the present time. . . .are there in large measure because it has not been anybody's explicit business to foresee and anticipate them. They have fallen between the stools of innumerable individual decisions to develop individual technologies for individual purposes without anyone—any organization or agency—around to give explicit attention to what all these decisions add up to for society as a whole and for people as human beings.[5]

It is certainly true that some progress has been made through the establishment of organizations such as the Environmental Protection Agency (EPA) and the Occupational Safety and Health Administration (OSHA), but the mechanisms of democratic decision-making with regard to technology do not yet exist. Filling in these gaps will require a systems approach that recognizes the full range of expertise that will need to be brought to bear.

III. Why "Literacy" Is an Inaccurate Label for the Enterprise as a Whole

The first reason "literacy" is an inaccurate label arises from an important difference in scale that is captured in the distinction between "How Stuff Works" and "How STUFF Works," that is, between an "understanding of how things work or how to build some things"[6] versus an understanding of large-scale technological systems as implied by the idea of taking "full advantage of the benefits and [recognizing, addressing, and even avoiding] some of the pitfalls of technology"[7] The tension between these two scales of reference is reflected in George

Bugliarello's description of a "struggle" between two different conceptions of technological literacy and "efforts to elevate technological literacy to encompass a higher and broader level of understanding of the entire technological process and its role in society".[8] Although it is clear that the NAE/NRC perspective reflects a broad conception, "literacy" carries a connotation of a narrower concern with devices and processes that is inconsistent with the broader, heterogeneous forms of knowledge required to achieve the goals of both groups. The narrower conception also has the disadvantage of obscuring differences in the kind of curriculum envisioned and the range of expertise and collaboration that will be required to develop it.

The second reason "literacy" is inaccurate is that it suggests a relatively low skill level, as in the basic abilities to read and write. Perhaps even more damaging to the cause, "**il**literate" suggests not only the lack of basic skills that are fundamental to citizenship and personhood, but also a lack of culture. When it is used in relation to college students or adult citizens, "literacy" suggests remediation. The message conveyed by these connotations is certainly not the one intended by any advocates of technological literacy with whom I have had contact. It is also true that the use of the terminology within the engineering community has somewhat rehabilitated the meaning in the direction of the broad definitions promoted by the NRC/NAE. But these facts do not eliminate the negative potential of "literacy" terminology.

A brief passage from the technological literacy web site provides some insight into the origins of the term and the impulse to define the term broadly.

> One useful way to think about technological literacy is as a component of the more general, or "cultural," literacy popularized by educational theorist E.D. Hirsch, Jr. Hirsch pointed out that literate people in every society and every culture share a body of knowledge that enables them to communicate with each other and make sense of the world around them. . . .Technological literacy is a much richer concept than computer literacy, although the two are often confused.
> http://www.nae.edu/nae/techlithome.nsf/weblinks/KGRG-55SQ37?OpenDocument

This explanation reflects an attempt to broaden the meaning of "technological literacy" but it fails to reveal a key feature of Hirsch's thinking: he was concerned primarily with the knowledge that students should acquire in elementary and high school education, knowledge that would be the *means* to participation in democratic discourse but not an end in itself. Hirsch's work was revolutionary in the sense that it included scientific and technological information as an essential component of "cultural literacy." And while it was very much on target in identifying scientific and technological knowledge as being essential given the roles of science and technology in our world, the approach Hirsch suggested did not readily account for the dynamic character of the specific technical knowledge required for full participation in a technological society.

By Hirsch's definition, even most engineers would not qualify as technically literate in engineering fields not related to their own. And, as Young, Cole, and Denton recognize in "Improving Technological Literacy" (2002), "Even engineers, who have traditionally been considered experts in technology, may not have the training or experience necessary to think about the social, political, and ethical implications of their work and so may not be technologically literate".[9]

In sum, the terminology "literacy" is condescending and may repel potential allies and collaborators. The discourse of literacy suggests that the technical experts will "talk down" to the "lay audience" in order to bring them "up to snuff." The common terminology "lay audience" suggests a power relationship in which the technical experts offer some equivalent of salvation to the unwashed masses. It may well not be accurate to infer that the technical community is approaching its audience in a spirit of "talking down," but it not unreasonable for the audience to make such an inference. Perhaps more importantly, these kinds of negative inferences will not help achieve the desired goals. Thus, there is a significant misfit between the dominant meaning of "literacy" and the set of sophisticated skills and cutting edge thinking that both the STS community and the advocates of technological literacy have in mind.

Much Ado about Nothing?

This concern over terminology may well come across as classic "wet blanket" behavior in the eyes of advocates of technological literacy who have designed exciting courses and feel a strong sense of urgency about moving forward. It is exciting to see the NAE take such an active interest in technological literacy, and the overall interest seems to be growing, as witnessed by the development of the technological literacy constituency committee. Many excellent courses have been taught under the title "technological literacy," and the faculty who teach them bring great enthusiasm to the effort and generally find that their courses are very well received by students. It seems clear that the effort to achieve technological literacy has called for a considerable amount of pedagogical creativity and brought to light a number of very important questions that are of interest to scholars and practitioners alike.

I would also argue that there will never be better time than now to choose a new name. Both Andy Lester's discussion of the importance of names (2004) and our own experience remind us that the best names are not only accurate but appropriately evocative in the sense that they produce a positive reaction. A name is not just a label by which we designate something or the words by which a thing or person is distinctively referred to. Thoughtfully and creatively chosen names can convey an image that captures the positive values motivating the enterprise and that can inspire the full range of constituencies needed to achieve the goals of the enterprise. It is in meeting this last criterion—inspiring the full range of constituencies—that the terminology of "technological literacy" falls most clearly short. From my perspective, the most promising alternative candidate to date is "technological savvy," which has actually been used in some discussions of technological literacy and has the advantage of suggesting sophistication rather than deficiency. As a slang term, it may not seem suitable as the name for a course or an academic field, but, as a marketing strategy, it has many strengths.

IV. Conclusion: Prerequisites for Building the Interdisciplinary Scholarly Community Required to Achieve the Goals of What We Now Call "Technological Literacy"

This problem of naming highlights a very important characteristic of the effort on which we are embarking. We are seeking to create something that has never existed before rather than attempting to resurrect or recreate something that once existed but has somehow been lost. This effort will require both intellectual and organizational innovation, beginning within but spreading

beyond the academic community. It will require the expertise of engineers, humanists and social scientists, public servants, and corporate leaders. It is probably a mistake to imagine that it can be contained by a disciplinary name. From a pedagogical point of view, it is best understood as consisting of a wide variety of types of courses and other educational experiences. From a scholarly point of view, it will require us to bring our intellectual resources to bear on some of the most important problems of our time. Such an undertaking both requires and deserves a name that will evoke the ideals that motivate the effort and that will be conducive to continuing success.

Bibliography

Bugliarello, George. "Reflections on Technological Literacy," *Bulletin of Science, Technology, and Society*, Vol. 20, No. 2, pp. 83-89 (2002). Retrieved from: http://web.poly.edu/administration/articles/reflect_on_liter.cfm

Hirsch, E. D., Jr. and James Trefil. *Cultural Literacy: What Every American Needs to Know*. New York: Houghton Mifflin, 1987.

Lester, Andy. "On the Importance of Names." *Lamp: The Open Source Web Platform*, February 15, 2004. Available: http://www.oreillynet.com/onlamp/blog/2004/02/on_the_importance_of_names.html

Mesthene, Emmanuel G. *Technological Change: Its Impact on Man and Society*. Cambridge, Mass.: Harvard University Press, 1970.

Pearson, Greg and A. Thomas Young, ed. *Technically Speaking: Why All Americans Need to Know More about Technology*. Washington, D.C.: National Academy Press, 2002.

Young, A. Thomas, Jonathan R. Role, and Denice Denton, "Improving Technological Literacy," *Issues in Science and Technology Online*, Summer 2002. Available: http://www.issues.org/issues/18.4/young.htm

[1] Pearson and Young, p. 2.
[2] Pearson and Young, p. 12.
[3] Pearson and Young, p. 4.
[4] Bugliarello, p. 23.
[5] Mesthene, p. 40.
[6] Bugliarello, p. 2.
[7] Pearson and Young, p. 2.
[8] Pearson and Young, p. 3.
[9] Young, Cole, and Denton, p. 15.