Improving Technological Literacy in the Schools

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Introduction

The systematic study of the past is crucial for full development of those who would shape the future. We here argue that historians of technology have a vital role to play in developing a curriculum for the schools that could help foster an atmosphere of innovation and invention among the next generation of engineers, scientists and researchers.

In this short article, we seek to accomplish three things. First, we speak of the importance of sorting out the conceptual problem of drawing too great a distinction between "science" and "technology," arguing that this is a necessary condition for thoroughgoing curricular reform. Second, we describe succinctly efforts now under way to enhance technological literacy in the K-12 system in the United States. Third, we suggest ways that historians of science and technology might contribute to these ongoing efforts.

Science *versus* Technology?

It has long been acknowledged that technological literacy is an important element of a comprehensively educated citizenry. Even those who do not work directly with technology have their lives fundamentally and irretrievably structured by basic, advanced and complicated technology. Yet, even though myriad efforts at the local, state, national and international level have been undertaken, "the majority of these initiatives have taken place within an educational system that for the most part does not recognize technology as an area of academic content in its own right." Technology education is needed, in other words, but it does not have its own place yet at the table of education.[1] Policymakers at the highest level often reinforce neglect of technological literacy when they speak of the need for science standards.

This should not be a surprise. When policymakers and educators alike continue to operate with a strong conceptual distinction between "science" and "technology" they are reiterating a longstanding distinction between science and technology, between "high" or "pure" science and "low" or "applied" technology. Yet, this distinction was unknown in the ancient world, where techne as "systematic treatment" stood on even footing with episteme, science: as late as the seventeenth century, Bacon could advocate an integrated approach-that scientists study the methods of craftsmen and craftsmen those of science.[2] With the development of highly specialized areas of scientific inquiry in the modern world, pure science came to be esteemed more highly than the "industrial arts," a series of practical matters. Part of our argument here is that efforts to improve scientific literacy in the schools will be significantly enhanced with an integrated approach, one that treats science and technology as aspects of a unified curriculum, rather than continuing to maintain what is effectively a mental vs. manual labor distinction, putting technology in the role of handmaiden in service of the "higher" scientific pursuits.

Fortunately, in the past twenty-five years, there has been a growing recognition by educational leaders that the division of science from technology is an educationally detrimental conceptual mistake. As the American Association for the Advancement of Science (AAAS) has written in an important statement, "Technology is even older than mathematics and science. Indeed, the latter may both have developed at first in response to the need to build things and solve practical problems, although discoveries in science and mathematics today often precede practical uses." Technology today "is becoming much more closely tied to mathematics and science and hence is an essential part of the scientific enterprise. Understanding technology and its connections to science and mathematics is therefore necessary for science literacy."[3] *Benchmarks* goes on to say that "unfortunately, technology does not have a place in the general curriculum, so academic students fail to learn about technology or develop engineering problem-solving skills. Furthermore, the technology taught in technology-education classes (formerly industrial arts, and before that, 'shop') is often so singlemindedly vocational that teachers fail to teach about technology in social or scientific contexts."[4]

Let us call these the divisive and the integrated approaches to science and technology. The divisive viewpoint was hegemonic in the American educational community from the 1950s to about 1980. But it came under criticism in the early 1980s, as educators and policymakers from across the spectrum began to realize the damaging effects of holding fast to the rigid distinction between scientific and technological education. The National Science Foundation issued a significant study, *Educating Americans for the 21st Century*, emphasizing the need for a more integrated scientific and technological curriculum.[5] A major 1984 meeting organized by the Exxon Education Foundation concurred. Chaired by Paul DeHart Hurd (Stanford) and including such participants as F. James Rutherford of the AAAS and Fred Hechinger of the *New York Times*, the meeting underlined the importance of integrating science and technology education. The Exxon group lauded the NSF's goals of increasing the technological component of school education and establishing "scientific and technological literacy" as goals for all students. "These two recommendations stand in marked contrast to the approach to science education supported by the National Science Foundation (NSF) and accepted by the educational community from 1950 until about 1980. During that period, attention was focused almost exclusively on the educational needs of students aspiring to scientific and engineering careers, and technology was deliberately downplayed."[6]

A sea change in the understanding of educational administrators and leaders was taking place in the early 1980s. The new, integrated approach is championed by the American Association for the Advancement of Science (AAAS), which has advanced a long-range plan for integrated science-technology education reform in their Benchmarks for Science Literacy, the Project 2061 report. "By 'science,' Project 2061 means basic and applied natural and social science, basic and applied mathematics, and engineering and technology, *and their interconnections-which is to say the scientific enterprise as a whole*. The basic point is that the ideas and practice of science, mathematics, and technology are so closely intertwined that we do not see how education in any one of them can be undertaken well in isolation from the others."[7]

Efforts of the International Technological Technology Education Association (ITEA)

The International Technology Education Association (ITEA), a private body, is a leader in the effort to advance technological literacy. The ITEA has played a primary role in establishing K-12 standards. Following the trend toward developing content standards, the ITEA published *Technology for All Americans: A Rationale and Structure for the Study of Technology*.[8] Establishing a philosophical orientation and organizational structure for technological literacy in America's public schools, this document was followed by *Standards for Technological Literacy: Content for the Study of Technology (STL)*, in 2000. STL defines technological literacy as one's "ability to use, manage, assess, and understand technology."[9] This document passed successfully through a formal review by the National Research Council (NRC), and has been endorsed by the National Academy of Engineering (NAE). As part of their effort backing the ITEA's technological literacy standards, the NAE has published *Technically Speaking: Why All Americans Need to Know More About Technology*, which makes a compelling case for the need for technological literacy.[10]

Broad public support exists for including the study of technology in the K-12 curriculum. In a 2001 Gallup Poll on "What Americans Know About Technology" fully 97 percent of respondents believe the study of technology should be included in school curriculum, and 61 percent believe that the evaluation of technological literacy should be part of high school requirements.[11]

In 2003, the ITEA published a companion document to *STL, Advancing Excellence in Technological Literacy: Student Assessment, Professional Development, and Program Standards (AETL)*.[12] Supporting the effort to improve technological literacy for all students, this publication provides means of assessing students, as well as recommendations of quality programs of professional development for teachers, and enhanced education programs to ensure the delivery of quality technological literacy curriculum in the K-12 system.

Efforts by State Educational Systems

Significant, one might say unprecedented, efforts are underway to integrate technology education into the school experience throughout the United States. There are "major movements being made at the local level for establishing technology education as an important subject in the pre-college program." One survey found that as of 2001, fourteen American states required some form of technology education, six additional states had technology education under school district control, two states awaited pending legislation. Sixteen other states made technology education elective. The largest states-California, New York, Florida, Illinois, Texas, Michigan, Ohio-all have required, or will soon require, technology education at the state level. As of 2000, more than 38,000 technology education teachers were at work in American schools. In addition, regular subject teachers will also teach from these standards. The existence of state-level standards will necessitate a revolution in curriculum and teacher education in the coming years.[13]

The Massachusetts Department of Education undertook consideration of K-12 technology education in several iterations leading to the March 2001 *Massachusetts Science and Technology/Engineering Curriculum Framework*. It defines technology as "1) Human innovation in action that involves the generation of knowledge and processes to develop systems that solve problems and extend human capabilities; 2) The innovation, change, or modification of the natural environment to satisfy perceived human needs and wants."[14]

In Ohio, the process of developing a set of standards in technology education and literacy began only in 1997. The State Board of Education and the Ohio Board of Regents (administering public higher education) created a Joint Council which established common expectations for educational outcomes, which they divided into six content areas-the arts, English language arts, technologies, mathematics, science and social studies. These content areas are in the process of being fleshed out by writing teams. The documents that these bodies are writing contain or will contain standards for all schools in the content areas, curricular recommendations, and will be used as a basis for the assessment and ranking of the performance of the schools.

It is a salutary development that Ohio's science standards include technology as an integral element. Unfortunately, when educators speak of "technology" as subservient to "science," they continue to operate under the historic conceptual separation of science from technology. It is as if the integrated approach advocated by the AAAS has not yet been accepted in the states, where standards documents are being written. The Ohio science standards define "technology" as "human innovation and action that involves the generation of knowledge and processes to develop systems that solve problems and extend human capabilities. The innovation, change, or modification of the natural environment to satisfy perceived human needs and wants."[15] The problem is that this broad, inclusive, innovation-focused definition of "technology" is undermined when the standards report then speaks of technology as a servant of science. Technology is something that is "used" in service of science. The high-low distinction between science and technology continues to be maintained. Thus, at the state level, the old divisive worldview still prevails.[16]

What we see in the current phase of drafting state standards is that both content of the standards *and* the curricular approach to teaching them are relatively new developments and open to discussion. There is a wing of the standards movement that sees it as a back to basics emphasis pure and simple. Other educators recognize that innovative hands-on curriculum, ironically, may be the best way to teach basic competencies.

Private Initiatives Fostering Innovative Thinking

In the context of declining public funding for innovative educational programs since the late 1970s, it is not surprising that much of the most innovative work in technology education has been undertaken by private entities, often funded at least in part by public agencies. Such projects as Future Scientists and Engineers of America (NSF funded),[17] the Invention Innovation Centers Project (IICP) funded by the Ohio Space Grant Consortium (NASA),[18] or Intel's Design and Discovery Project[19] point the way to curricular innovations that could more effectively educate young people. At present there are 286 FSEA Clubs in elementary, middle and high schools, in sixteen states and Puerto Rico. Each club has approximately twenty-five members, so more than 7,000 students participate. The Ohio project has five sites operating or under development, with units in planning discussions at four additional sites.

These initiatives constitute an important expression of the view that basic standards are best taught when students' natural creativity is enhanced. Some of these educational experiments recognize after-school hours as often wasted discretionary time for many young people.[20] The Ohio project, for instance, seeks to engage students in resource rich invention/innovation centers, where their natural curiosity is the starting point for their inquiries. The centers make available a wide array of materials and artifacts, and the expertise and competencies of mentors-professionals, retirees, craft workers and others from the local community. Ideally, the centers are also clearinghouses for the most effective techniques of problem-solving, such as TRIZ, Talents Unlimited, or Shlesinger's Themes and Keys Approach.[21] Student participants in these centers engage in creative problem-solving projects, often arriving at fascinatingly novel solutions to problems.[22] They get a chance to practice problem-solving skills. As the Project 2061 report put it, "If students are expected to apply ideas in novel situations, then they must practice applying them in novel situations."[23]

Importantly, basic skills are also fostered for students engaged in such inquiries. There is no zero-sum trade-off between creative problem-solving in innovation centers and the development of basic skills competency. Rather, students' interest-driven inquiries in the centers pique their interest in geography or mathematics or social history, in part because students see the relevance of standard skills to their problem-solving inquiries. When students desire to learn, their learning is a hundred times richer and more effective, than when they are bored and merely going through the motions.

Historians and Curricular Reform in the K-12 System

Historians of technology can suggest to teachers, mentors and students the breadth and historical depth of technology, including technics (products of technology), and techniques, (processes). A comprehensive, historically-grounded curricular approach to technology, technics and techniques will help all students correct common misconceptions about technology, such as the understandable but mistaken narrowing, in the present context, of "technology" to "information technology." Computers in the classroom are of course but the most recent technological innovation in a long, varied history.

The structure of incentives for historians of technology, as for other scholars in an academic, higher education setting, hardly promotes teaching and writing directed at the audience of K-12 educators. Yet, incentives could be offered to foster a dialogue between historians of science and technology and educators in the K-12 system. Granting agencies such as the National Science Foundation and private philanthropic bodies such as the Ford Foundation, Spencer, and others, could provide incentives for historians of science and technology to direct some of their scholarly energies toward this audience of K-12 educators. With sufficient money and time, busy academics could be enlisted to work on curricular reform initiatives with the K-12 system. Partnerships between institutions of higher education and the schools could be fostered by public or private granting agencies. The condition of public education is sufficiently fragmented and challenged today that policymakers can fairly easily be convinced that such partnerships should be a public policy priority. At the very least, pilot programs of curricular innovation could be developed. We hope that a dialogue between historians of science and technology and technology educators in the K-12 system can be fostered.

Endnotes

1. National Academy of Engineering, Assessing Technological Literacy in the United States, [Proposal to the National Science Foundation (n.d., 2001?)], 1.
2. The distinction between science and technology was not drawn by Aristotle. As Terence Irwin, who provides an extraordinarily careful translation of Aristotle, Nichomachean Ethics (Indianapolis: Hackett, 1999), 347, puts it, for Aristotle, science, ep?st?μ?, was "any systematically organized, rationally justifiable and teachable, body of doctrine or instructions. [Sciences], therefore, include crafts such as medicine or gymnastics, and exclude pursuits that proceed by mere experience." The high regard in which Aristotle held te??? is indicated by its inclusion with ep?st?μ?, f????s?? [prudence], s?f?a [wisdom], and ???? [understanding] as the five ways of grasping a???e?a, the unrevealed, or truth. Arist., NE 1139b [in Irwin, trans., p. 88]. In classical Greek, te??? referred to artful conception or creation, or to systematic treatment, particularly in rhetoric. The technology word, strictly speaking, te???????a, refers to systematic treatment, often of grammar or rhetoric, as in Philodemus, Voluminia Rhetorica, a first century BC work. It must be recalled that rhetoric was the art of the statesman, highly esteemed in the classical polis. "Science" and "technology" are still fundamentally united in the work of the influential fourth century AD neoplatonist Iamblichus, that is, fully six hundred years after the death of Aristotle. In the Middle Ages, the "seven (liberal) sciences" could be used interchangably for the "seven liberal arts." The Oxford English Dictionary, q.v. "science," says that the distinction between science [ep?st?μ?] and art [te???] is the difference between concern for theoretical truth and for "methods for effecting certain results," but sciences have always had their practical side. With the separation of technology from science, bearing implicit denigration of the former as merely "practical or industrial arts," a high-low distinction has been imposed: This is a modern distinction, dating perhaps from the seventeenth century.
3. American Association for the Advancement of Science, Benchmarks for Science Literacy: Project 2061 (New York: Oxford University Press, 1993), 323.
4. AAAS, Benchmarks, 323.
5. Educating Americans for the 21st Century (Washington: NSF, 1983). Impetus for the standards movement was provided by U.S. Secretary of Education Terrell H. Bell's creation of the National Commission on Excellence in Education in 1981. The often-cited report of this commission, A Nation at Risk, was published in 1983. See www.ed.gov/pubs/NatAtRisk/intro.html. The report recommended adoption of more rigorous and measurable standards in schools, colleges and universities.
6. Science Education in the United States: Essential Steps for Achieving Fundamental Improvement: A Report on a Meeting of Educational Leaders Hosted by the Exxon Education Foundation, January 17-20, 1984 (New York: Exxon Education Foundation, 1984), 5.
7. AAAS, Benchmarks, 321-2, emphasis supplied. The year 2061 is the next arrival in Earth orbit of Halley's comet. The AAAS chose that date to name its science-technology-mathematics reform effort to underscore the long-term nature of the reform process. We view these standards as an exemplary vision of the comprehensive nature of the reforms that are required.
8. ITEA, Technology for All Americans: A Rationale and Structure for the Study of Technology (Reston, VA: ITEA, 1996).

9. ITEA, Standards for Technological Literacy: Content for the Study of Technology (Reston, VA: ITEA, 2000), 7.
10. National Academy of Engineering and National Research Council, Technically speaking: Why all Americans need to know more about technology, ed. A. Pearson and T. Young (Washington: National Academy Press, 2002).
11. The poll results can be read at , then select "Publications."
12. ITEA, Advancing excellence in technological literacy: Student assessment, professional development, and program standards (Reston, VA: ITEA, 2003).
13. Pamela B. Newberry, "Technology Education in the U.S.: A Status Report," The Technology Teacher, September 2001, 6. The article provides a concise summary of responses to a survey on technology education, including the existence of technology education in state frameworks, whether technology education is required in curriculum, and the numbers of technology education teachers, broken down by state.
14. The Commonwealth of Massachusetts, Department of Education, Science and Technology/Engineering Curriculum Framework (Malden, MA: Massachusetts Department of Education, March 1, 2001), 131.
15. Ohio Department of Education, Center for Curriculum and Assessment, Academic Content Standards, K-12 Science (Columbus, OH: Ohio Department of Education, 2003), p. 300.
16. For instance, the Ohio Department of Education, Center for Curriculum and Assessment, Academic Content Standards, K-12 Science (Columbus, OH: Ohio Department of Education, 2003) and the separately published technology standards.
17. See for information on the Future Scientists and Engineers of America.
18. Materials on Ohio's Invention Innovation Centers Project (IICP) are available from perusek@wcoil.com.
19. See for information on the Design and Discovery program.
20. Leading voices in the after-school movement include: The Carnegie Council on Adolescent Development; Mott Foundation; National Center for Community Education; U.S. Department of Education's 21st Century Community Learning Centers Project; J.C. Penny Foundation; Nellie Mae Education Foundation; and the National Institute on Out of School Time at the Wellesley Center for Women. See for instance, the useful "Fact Sheet on School-Age Children's Out-of-School Time," January 2000, at .
21. Genrich Altshuller, The Innovation Algorithm: TRIZ, Systematic Innovation and Technical Creativity, trans. Lev Shulyak and Steven Rodman (Worcester, MA: Technical Innovation Center, 2000); Genrich Altshuller, And Suddenly the Inventor Appeared: TRIZ, the Theory of Inventive Problem Solving, trans. Lev Shulyak (Worcester, MA: Technical Innovation Center, 1996). More information on TRIZ is available at www.triz.org; B. E. Shlesinger, Jr., How to Invent: A Text for Teachers and Students (New York: IFI/Plenum, 1978); Talents Unlimited (Mobile, AL: Talents Unlimited, 1995).
22. As John Dewey wrote, "...where children are engaged in doing things and in discussing what arises in the course of their doing, it is found, even with comparatively indifferent modes of instruction, that children's inquiries are spontaneous and numerous, and the proposals of solution advanced, varied, and ingenious." John Dewey, Democracy and Education (New York: Free Press, 1916), 156.
23. American Association for the Advancement of Science, Project 2061, Benchmarks for Science Literacy (New York: Oxford University Press, 1993), 198-9.