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The Two Cultures Revisited

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The gulf in understanding between scientists and nonscientists may be traceable to an educational system that neglects the historical importance of scientific and technological developments.

I want to speak this morning about the recent past and the immediate future of science, technology, and society in twenty-first century America. Science and technology policy would appear to be in a state of crisis. There are many indicators that a crisis does exist in the partnership between the federal government and the American research universities - that the terms of the partnership are increasingly being questioned and reexamined. Even if it should turn out that this is not, in fact, the case, so many knowledgeable and informed members of the academic, scientific, and engineering communities believe that this is so that the perception of crisis is real in its consequences. It is probably not a matter of hyperbole to suggest that we are witnessing a number of fundamental changes in the relationship between the federal government and the scientific and technology research community. There are apt to be material changes in the national system of innovation in the years ahead.

To me this moment of crisis appears ironical. After all, each of us is aware of the extraordinary half-century of scientific and technological growth and achievement that we have witnessed in the United States. This 50 years of extraordinary growth in knowledge, in terms of its diversity, sheer volume and unquestionable quality, as well as its impact on our culture and everyday life, is perhaps unmatched since that glorious Newtonian period of scientific and technological development in seventeenth century England. Yet, we confront in a wide array of places the emergence of strong antiscience and antitechnology movements--and not only among the limited number of fringe players, but also among some very serious philosophers, poets, social scientists, and politicians.

Part of the explanation for these sentiments, I believe, lies in the American public's own ambivalence toward science and technology. Why is it that we in this country admire scientific genius and technological inventiveness, and can become truly obsessed by the fruits of science and technology, yet are so abysmally ignorant of facts and processes of scientific and technological discovery? Americans benefit in virtually every area of life from the fruits of these discoveries. The list of significant advances, in such areas as telecommunications, lasers, photonic systems, computer technology, synthetic materials, and biotechnology is long and constantly growing. 1

Not all of these scientific and technological advances have been entirely for industrial or health gain; many supported changes in leisure time activities, from video games to new materials for tennis rackets and golf clubs. Indeed, science and technology have changed dramatically the nature of American culture and, in many ways, redefined the locus of what Schumpeter called "conspicuous consumption." Many reasonably well-to-do Americans have come to think of health as a middle-class consumer good that can be bought and from which

we can expect straight-forward returns from our investments.

For all of its appreciation of science and technology--to say nothing of its massive purchasing of the products of scientific and technological advances--the American public remains strikingly scientifically illiterate. Gerald Holton, one of our most distinguished physicists and historian of science, notes in his exceptionally powerful recent essays on science and antiscience that "Public literacy [in the United States] is now at a level where 'half the adults questioned did not know that it took one year for the Earth to orbit the Sun.' Less than 7 percent of U.S. adults can be called scientifically literate by the most generous definition, only 13 percent have at least a minimum level of understanding of the process of science, and 40 percent disagree with the statement 'astrology is not at all scientific'" (Holton, 1993, p. 147).

Teacher Attrition, Qualifications

Furthermore, Holton says, our schools no longer are attracting young people who might correct this problem. '"We are losing thirteen mathematics and science teachers for each one entering the profession.' Only the following percentages of teachers meet the minimum established standards for course work preparation at the high school level: 29 percent in biology, 31 percent in chemistry, 12 percent in physics. . . . 'In the most recent international science assessments, in comparison with students in 12 other countries, our high school students finished 9th in physics, 11th in chemistry, and last in biology. . . . In mathematics, our top 13 percent generally fell into the bottom 25 percent in comparison with other countries'" (Holton, 1993, pp. 147-148). 2

The limited knowledge of the public--or even what William James called "acquaintance with knowledge"--is neither, as one might expect, monopolized by the poorly educated or found only among certain social classes, nor is it confined to individuals in a limited numbers of occupations. Most members of Congress with whom I have spoken in the past few years about national investments in science and technology, who by the way tend to hold generally positive views of the social and economic benefits of such investments, are almost wholly uninformed about the process of growth of knowledge and discovery, about the diffusion of knowledge, of the process of technology transfer, of the historical links between fundamental discoveries and practical applications.

Widespread ignorance and illiteracy is, of course, not without its consequences. Out of the ocean of illiteracy flow ideas that challenge fundamental aspects of modern culture. One of the best examples of this is the recent challenges to the world of science produced by the extraordinary Czech poet, playwright, and political leader, Vaclav Havel. Havel identifies the mental apparatus associated with scientific thinking (its "rational and cognitive thinking," its "depersonalized objectivity," its belief that "there is a there out there") as a root cause of many of the true evils and atrocities that have marked the twentieth century's political history, from World War I to Nazism and Communist authoritarianism. Havel's attack on the epistemology of science is direct and unsparing:

> Traditional science, with its usual coolness, can describe the different ways we might destroy ourselves, but it cannot offer us truly effective and practicable instructions on how to avert them. . . . The world today is a world in which generality, objectivity and universality are in crisis . . . Many of the traditional mechanisms of democracy created and developed and conserved in the modern era are so linked to the cult of objectivity and statistical averages that they can annul human individuality. . . . [Ours is] an epoch which denies the binding importance of personal experience--including the experience of mystery and of the absolute--and displaces the personally experienced absolute as the measure of the world with a new, man-made absolute, devoid of mystery, free of the 'whims' of subjectivity and, as such, impersonal and

> inhuman. It is the absolute of so-called objectivity: the objective, rational cognition of the scientific model of the world. Modern science, constructing its universally valid image of the world, thus crashes through the bounds of the natural world which it can understand only as a prison of prejudices from which we must break out into the light of objectively verified truth. . . . With that, of course, it abolishes as mere fiction even the innermost foundation of our natural world; it kills God and takes his place on the vacant throne, so that henceforth it would be science which would hold the order of being in its hand as its sole legitimate guardian and be the legitimate arbiter of all relevant truth . . . (Quoted in Holton, 1993, pp. 175-177)

This powerful rhetoric, even if terribly incomplete and distorted, resonates in many quarters these days, including many of the best humanities and social science departments at some of our most prominent universities.

The level of American illiteracy about science and technology is disturbing not only because of the fertile ground it prepares for those antagonistic toward modern science and technology, but also because we seem to be doing very little in our educational system to reverse the trend. Educators, including scientists and engineers, have not stepped up to the challenge of constructing a strong program for increasing scientific literacy. They have not assumed that educating the American public about the processes and fruits of discovery is one of their fundamental roles.

C. P. Snow, in his now famous 1959 Rede Lecture on "Two Cultures," identified the wide gap that existed between the two worlds in which he lived--the world of writers, artists, and other literary intellectuals, and the world of science. Snow's analysis of the gulf between the two cultures suggested that literary intellectuals were in many ways more ignorant about science and its foundations than were scientists about literature. Notwithstanding Jerome Wiesner's reflection, "Better two cultures than none," Snow's analysis, which, of course, focused more on British than American society, remains cogent. He wrote:

> It is obvious that between the two [cultures], as one moves through intellectual society from the physicists to the literary intellectuals, there are all kinds of tones of feeling on the way. But I believe the pole of total incomprehension of science radiates its influence on all the rest. That total incomprehension gives, much more pervasively than we realize, living in it, an unscientific flavour to the whole 'traditional' culture, and that unscientific flavour is often, much more than we admit, on the point of turning anti-scientific. The feelings of one pole become the anti-feelings of the other. If the scientists have the future in their bones, then the traditional culture responds by wishing the future did not exist. It is the traditional culture, to an extent remarkably little diminished by the emergence of the scientific one, which manages the western world . . . [t]his polarization is sheer loss to us all. To us as people, and to our society. It is at the same time practical and intellectual and creative loss. . . . In our society (that is advanced western society) we have lost even the pretense of a common culture. Persons educated with the greatest intensity we know can no longer communicate with each other on the plane of their major intellectual concern. This is serious for our creative, intellectual, and above all, our normal life. It is leading us to interpret the past wrongly, to misjudge the present, and to deny our hopes of the future. It is making it difficult or impossible for us to take good action. . . .

> There is only one way out of all this: it is, of course, by rethinking our education. (Snow, 1959, Pp. 11, 16, 60)

It seems to me that the divide between the two cultures is as pronounced today as it was in 1959, despite our awareness of the problem and despite the achievements of American science and technology, from the first manned space flight to the identification of genes that cause cancer. Despite the glorious history of science and technology under the model originally proposed by Vannevar Bush 50 years ago, we have failed as a culture to teach the most elementary aspects of the process of scientific growth and the mechanisms that enable technology and science to interact to the practical benefit of the society. Why is this still true today? Why have we strayed so far from the time in our Republic's history when the likes of Franklin and Jefferson revealed through their writing and discourse a profound knowledge about, and interest in, science and technology, as well as an ability to articulate reasons why knowledge of science and technology was a necessary aspect of developing a firm foundation for a precarious democracy? (See Cohen, 1995.) When we try to understand why we need to construct a new rationale for science and technology in the national interest, part of the reason lies in the absence of substantial knowledge about the achievements and failures of science and technology among the leaders of the nation.

Curious about what might partially sustain the divide between "the two cultures" and, derivatively, the level of scientific illiteracy in this country, I have recently begun a review of the way science and technology is represented in leading American history books, texts, and curricula. Some years ago, John Heilbron and Daniel Kevles (1988) carried out a similar study. Here are some rather unsystematic, preliminary results. [3]

One consequence of the current structure of education in America is that youngsters are labeled as scientifically "able" or "talented" at an early age. Most often this labeling is based upon how rapidly students can obtain correct answers to questions when the answers are already known. Most of our very talented students come to believe that they have little aptitude for science or engineering and so turn their attention to other subjects--history, the social sciences, the arts and literature--eventually moving into professions far removed from the sciences and engineering. Many never take a science course after they have completed the final requirement in high school. What they know about science and technology must, then, come from the various news media and from whatever teaching they may receive in American history during high school, college, or graduate school.

The Teaching of American History

Given the extraordinary contributions of science and technology to contemporary culture and the economic well-being of Americans--as perhaps the major cause of social and institutional change in contemporary society--one might expect some significant representation of the development of science and technology, and the processes of scientific discovery, in the works that describe recent American history. To explore what actually exists in those works, I asked three distinguished historians at Columbia to give me the titles of the leading books in American history covering the period from World War II to the present. I also obtained the titles of some leading American history textbooks that were used in colleges and high school courses on the subject. Finally, I examined the course offerings at the top 10 departments of history, according to rankings in the recent National Research Council (NRC) (1995) evaluation of graduate Ph.D. programs for courses focusing on science and technology. In examining references and discussions of science and technology in these historical works, I wanted some comparative reference points. So, I chose also to examine the works in light of the attention they give to several other themes, including religion, popular culture, and the counterculture.

In recounting my findings, let me emphasize that the historians whose work I have reviewed are leaders in their field; they have exceptional ability and a demonstrated record of publishing important books. And yet, to say that there is a paucity of references to and discussions of science and technology in the works could only be considered on inspection to be a gross understatement.

For example, in Michael Barone's (1990) *Our Country: The Shaping of American from Roosevelt to Reagan*, there is not a single reference to science and technology topics in the index. There is space devoted to the "upheavals" of the 1960s and some references to popular culture and counterculture, including Elvis Presley, premarital sex, and recreational drug use. There is some discussion of changing family patterns, such as lower fertility, more contraception, more divorce, and the declining authority of men in the family. But you won't find discussions of the discovery of the double-helix by Watson and Crick or, for that matter, any aspect of the biological revolution, or of the plate tectonics revolution, or of the development of the laser, or of the transformational effects of computer and telecommunications on American society. Indeed, for the uninitiated young student examining the half-century of the American scientific revolution, science and technology doesn't exist.

William Chafe's (1986) exceptional work, well-known and widely used by colleges and high schools, *The Unfinished Journey: American Since World War II*, offers another example of the striking neglect of the subject. In one chapter, Chafe has a two-page discussion of technological breakthroughs that were important for industrial development of aerospace, chemicals, and electronics, and he does say "the government served as a primary sponsor" for these breakthroughs--but that is all he says. He mentions the importance of the new computer technology and quotes Daniel Bell as having said, "The knowledge revolution transformed the occupational structure of the country" (p. 320). That is it for science and technology during the post-war period. Chafe provides the reader with more material on television and popular culture (almost nine pages) than on science and technology.

William Leuchtenburg (1983), one of my former colleagues at Columbia, has but one indexed reference to research and development in his major work, *A Troubled Feast: American Society Since 1945*. I'm afraid that reference must suffice for both technology and science. There is a brief section (pp. 40-41) devoted to a discussion of medical achievements, including five lines about antibiotics and a picture of a child receiving a polio shot, and a page and a half on computers, automation, and R&D generally (pp. 44-45). At one point, Herbert Simon is quoted saying that the computer represents "an advance in man's thinking processes as radical as the invention of writing" (p. 44). Leuchtenburg's discussion of technology advances attributes many of them to research going on at institutions like MIT and Caltech. He does devote an entire chapter to "The Consumer Culture" and another to the counterculture, called "The Greening of America," in which he discusses such topics as drugs, generational conflict, anti-consumerism, the reduction of sex differences, and pacifism.

No more than one more example is needed to bring the central message home: that the young members of our society who become lawyers, businessmen, or members of Congress are surely not learning about the scientific and technology revolution in their reading of the best texts produced by American historians. James T. Patterson (1996), in his recently published 829-page megabook *Great Expectations: The United States, 1945-1974* does in fact have 13 references to technology in his index, grouped by decade. There is one reference to the National Institutes of Health (NIH) as well. But almost all of these references are simply cursory, without any effort to develop in the young reader an understanding of the processes of discovery, of technology transfer, or of the ways in which science and technology have helped bring about the economic and social transformation of modern American society in the post-war period. There is a 12-line discussion of the effects of research and development on productivity and the expansion of various kinds of industry; there is a two-page discussion of advances in medical science, including the role of NIH, tranquilizers, vaccines (especially polio vaccine); and another half-page mention of technological breakthroughs, including Xeroxing,

heart transplants, and the moon walk. In contrast, there is a whole chapter on "Mass Consumer Culture," much of which is devoted to popular culture.

I won't belabor the point further but only note that other important works, including Frederick F. Siegel's (1984) *Troubled Journey: From Pearl Harbor to Ronald Reagan* and Lawrence S. Wittner's (1978) *Cold War America: From Hiroshima to Watergate* include little, if anything, on our subject. Even the 6th edition of John A. Garraty's and Robert A. McCaughey's (1991) long-standing, best-selling text for high school courses in American history, *The American Nation: A History of the United States Since 1865*, has only two references to science, and those are to the study of science in the late 1800s. As for technology, there are references to the Manhattan Project, DDT, and television, and one page devoted to the development of plastics, nuclear power, and computers--a good part of which stresses the adverse impacts of new technology. A brief reference to the space program under Kennedy, then under Reagan, can be found, but there is nothing on the developments of biomedicine.

Why is there so little to be found? Part of the answer may lie in the training that American historians receive at major graduate schools in the nation. In fact, here the answer is not quite as clear as in the examination of the output of leading American historians. The top 10 history departments, according to the NRC assessment (National Research Council, 1995), are Yale, Berkeley, Princeton, Harvard, Columbia, UCLA, Stanford, Chicago, Johns Hopkins, and Wisconsin at Madison. 4 Most of these departments offer courses of some kind in the history of science and medicine; few devote much attention to technology. A number of these universities have separate departments or programs that focus on the history, philosophy, and, less often, the sociology of science. Harvard has a long-standing commitment to the history of science since the days of George Sarton, and Chicago, Stanford, Hopkins, and Wisconsin have what appear to be substantial offerings. Robert K. Merton, the putative father of the sociology of science, began his work at Harvard and later developed the specialty at Columbia. In short, there have been and continue to be many high-quality books and articles published on the history, sociology, and philosophy of science.

What remains unclear, however, is how much of the work at these major departments and programs is directed only toward highly self-selected students who are interested in science and technology - many of whom come with backgrounds in science--but who are not part of the mainstream programs of American history at the university. Are these course offerings part of the standard curricula of these graduate programs? Are all students of contemporary American history who will be teaching the subject and writing books about it required to study the influence of science and technology on American society? Even more particularly, are they asked to understand in an elementary way the nature of discovery and the forces that shape technological growth and development? The answers are negative. Unless the history and sociology of science and technology are, indeed, truly integrated into the core curriculum of American history graduate students, the teachers of the next generation of Americans are apt to be as scientifically illiterate as those in the classroom today. 5 Yet, from what I can gather, there is little interaction between graduate students in departments of history, that is, those graduate students who will eventually teach American history and write the books and articles read by the next generation of students, and the graduate students in small science-related departments operating on the periphery of the larger history departments.

A Self-Fulfilling Prophecy

I wonder how often in discussions within academic departments about the need for new young faculty, the possibility of an appointment of a person who specializes in the recent history of science and technology even reaches the table. Almost never, I would conjecture. Moreover, American historians feel understandably very reluctant to discuss science and technology in their classes, texts, or scholarly books, because they are acutely aware of how their training is inadequate to the task. Since these faculty and the students that come after them receive such dismal training in the history of American science and technology at the elementary and secondary levels, as well as at more advanced stages of training, publishers and authors feel (probably correctly) that there is no "market" for discussions of science and technology in new textbooks or books about recent American history. Conditions for a self-fulfilling prophecy fall into place--conditions that reinforce the existing definition of the situation.

It would not surprise me if 100 years from now, historians of America in the post-World War II period devote far more attention to the role of science and technology in making the American nation a global power, the wealthiest nation in the world during the second half of the twentieth century, and the undisputed leader in the production of pathbreaking scientific and technological discoveries. Today, you surely would not get that impression from reading the best books narrating the critical forces in our nation's recent history.

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Notes

1. I have benefited here from discussions and correspondence with Gerald Holton, who has written with extraordinary force and grace about problems with scientific literacy, the recent rise in "antiscience," and the absence of effective teaching of science and technology in American schools.

2. One might argue that it is a waste of national resources to train Ph.D.'s to teach in secondary school settings, but it seems to me that a strong counterargument to this position can be developed. One of our problems in graduate education is that we have led all Ph.D. students at the major universities to believe that they can expect positions at similarly situated places. This is, of course, a practical impossibility. We have got to change the nature of expectations or reduce the size of these programs. There were times in the past when Ph.D.'s did populate secondary schools, in somewhat greater numbers than today, and they do have places in some of the better private secondary schools. The need is substantial and means ought to be found to provide incentives for well-trained young scientists to migrate to the school system rather than to unrelated occupations.

3. Dr. Elinor Barber, affiliated with the Provost's Office at Columbia, helped collect the basic data reported here.

4. Although not included in the top 10 rankings, MIT, Cal Tech, Georgia Tech, UC/San Diego, Rensselaer Polytechnic Institute, and the Illinois Institute of Technology have significant academic programs focusing on science and technology.

5. An important project at MIT, sponsored by the Sloan Foundation, is underway. It is an effort by a set of highly regarded American historians to create a textbook of American history that integrates fully and adequately the role of science and technology in the development of the nation. It is not a specialized text, but a standard work that will attempt to correct some of the problems discussed here.

About the Author

Jonathan R. Cole is provost, Columbia University. This paper is adapted from remarks he made 3 October during the symposium Industry-University-Government Cooperation for U.S. Technological Leadership in the 21st Century, part of the 1996 NAE Annual Meeting.