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ABSTRACT

The science-technology-society (STS) movement is emerging at the collegiate level. In elementary and secondary school science, social studies, and industrial arts classes, there is a growing awareness of the need for students to learn about technology and the methods by which it can be directed, made more appropriate, and controlled. This issue of "Theory Into Practice" is the first part of a two-part series that explores methods for approaching the integrated instruction of STS. Authors in this document review the history of science, technology, and social studies education, consider how various disciplines can contribute to the study of this emerging field, and discuss factors influencing the teaching of STS. A conceptualization of STS is introduced in the lead article by Melvin Kranzberg, one of the early proponents of an integrative study of science, technology, and society. In the following three articles, Paul DeHart Hurd, Karen F. Zuga, and Fred Splittgerber take a retrospective look at science, technology and social studies education, respectively, reviewing the history of those fields and related STS themes. The remaining articles address issues that influence people's perceptions of STS and ways in which STS instruction could be approached. Arthur G. Wirth, Merry M. Merryfield, and Jerry Kowal focus on concerns related to the reorganization of work, global perspectives, and a curricular approach to human values, respectively. Articles by Carolyn Carter, Rodger W. Bybee, and Peter A. Rubba discuss access to knowledge, the policy-practice gap, and teacher education. While describing and evaluating the STS movement, these articles point out the nature of the subject matter fields involved and identify potential areas of both cooperation and conflict. (PR)

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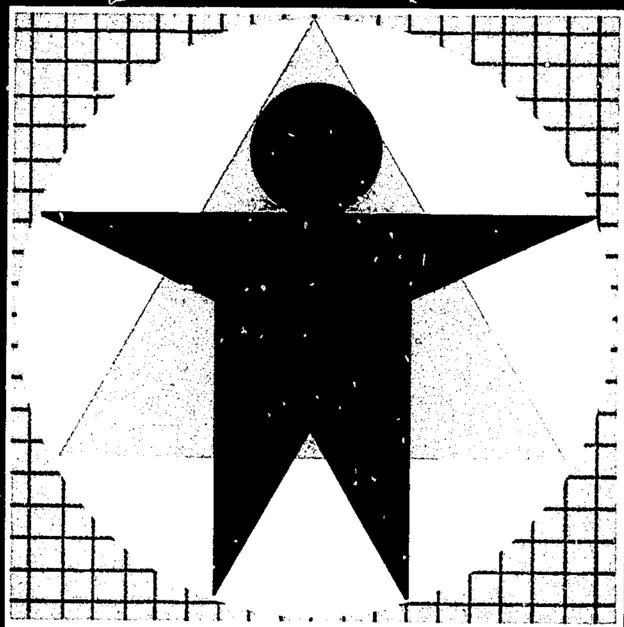

SCIENCE, TECHNOLOGY, SOCIETY: CHALLENGES

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Volume XXX, Number 4, Autumn 1991

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THE OHIO STATE UNIVERSITY

Theory Into Practice

Guest Editors: M. Eugene Gilliom, Stanley L. Helgeson, and Karen F. Zuga

Editorial Staffing Changes: Timothy E. Heron has served as a *TIP* associate editor since 1984. He is now accepting new responsibilities, which caused him to resign from the editorial staff. Tim has left his mark on *TIP* over the past 7 years. This note publicly records our gratitude for his contributions.

The vacancy created by Tim's resignation has been filled by the appointment of Robert Donmoyer, associate professor of educational policy and leadership. His qualifications and experience assure us of continued quality counsel from this position. Welcome, Robert—D.G.L.

Prior to This Issue

The gestation period for *Theory Into Practice* issues varies. This issue and the related one that will follow it have been in process about as long as any.

These two issues grew out of an increasing awareness that technology is growing exponentially. As a result, our world is becoming more what we make it than what we inherited. Unfortunately, this development has been making its presence felt everywhere except perhaps in our schools. In this regard, Ernest Boyer, in *A Report on Secondary Education in America* in 1983, said, "We are frankly disappointed that none of the schools we visited required a study of technology. More disturbing still is the current inclination to equate technology with computers . . . . The great urgency is not 'computer literacy' but 'technological literacy,' the need for students to see how society is being reshaped by our inventions, just as tools of earlier eras changed the course of history."

Groups and individuals have been at work to add a study of technology to courses and, more rarely, to curricula. Most notably, at the collegiate level, a science-technology-society (STS) movement is emerging, though primarily in smaller liberal arts institutions. At the elementary and secondary levels, a growing number of teachers of industrial arts have been changing their focus from industrial literacy to technological literacy. And in both science and social studies education, there is a growing awareness of the need for students to learn about technology and the methods by which it can be directed, made more appropriate, and controlled, if they are to adequately perform their societal duties to protect spaceship earth in the face of rapid technological development.

But most evident is the growing mismatch between what traditional liberal education offers and what modern learners need. This mismatch calls for restructuring and reconstructing education. *TIP* is providing this series of two issues on the themes of (a) challenges and (b) opportunities in the subject areas of science, technology, and social studies in order to help stimulate change.

The "knee-jerk response" to the need for change is widely evident and not likely to solve the problem. Technology, the "T" in the STS formulation, is not something that can be taught effectively by non-technologists alone. By the same token, technologists, the relative newcomers to the STS grouping, will likely achieve greater effectiveness and acceptance if they breach the walls that typically enclose respective subject matter areas.

The planning for this series of two issues goes back to 1988, when two small group meetings of specialists in science, technology, and social studies were held. These meetings led to a lengthier and larger session in May 1989. This, in turn, led to the identification of guest editors and the submission of a proposal to the editorial board, the following July, for a two-issue series. During the next 6 months, authors were identified and detailed planning for the organization and content of the issues began.

Early on, it was recognized that more communication among and between editors and authors would be required for these issues than for most. We were seeking to break authors out of their traditional subject matter "closets" and to challenge them to seriously consider ways and means of integrating and cooperating. The conventional behavior is to follow the dictates of respective disciplines. Our educational traditions make the goal of joint effort difficult to achieve, and the history of efforts to work across disciplines is disheartening, rather than encouraging.

Because of fears that each group would speak only to members of their respective disciplines, funds were requested from The Ohio State University College of Education to bring together all of the guest editors, authors, and editorial staff for a 3-day conference. Funds were granted, and the meetings were held February 21-23, 1990. Participants were requested to consider possibilities for restructuring the totality of both issues and to listen to and discuss each other's preliminary ideas in order to achieve greater collegiality of ideas and efforts. The participants welcomed what for most was a unique opportunity to share ideas during the developmental phases of their manuscripts, rather than upon their completion.

As the reader of these issues, you can be the judge of the extent to which we have achieved greater awareness of common goals and have identified opportunities for increasing student achievement and making subject matter more relevant. If you find us lacking, it will help confirm the difficulties facing those who would change education. Surely you will find herein evidence of the forces inhibiting increased STS integration, but we hope you will also find more reasons for optimism than for despair. As John Goodlad stated at the Educational Press Association conference at the National Press Club (June 7, 1990), "Fundamental change demands a new beginning, new adaptation to what exists. We can and must improve the schools we have, but the ones we need do not yet exist."

DGL

This Issue

Science-technology-society (STS) is a multidisciplinary curriculum initiative that has become increasingly visible on college and university campuses during the past 20 years. Likewise, an interest in STS has been growing gradually in elementary and secondary education. More and more teachers across the country are collaborating to offer interdisciplinary courses in science, technology, and social studies, and new initiatives are being launched at the national level in Great Britain and the United States.

An outgrowth of the STS effort is the cooperative involvement of scholars from a variety of disciplines in new and productive efforts. University scholars from political science, engineering, anthropology, sociology, history, physics, chemistry, and psychology, for example, have joined together to pursue questions and problems related to the role of science and technology in modern society. This groundbreaking effort has been challenging, and the scholars involved are still working to identify an accepted structure for the study of STS. A recent conference at Cornell, which marked the 20th anniversary of the STS program there, led to this observation by Dorothy Nelkin:

> STS is still struggling with a framework and mission. Is its purpose to promote science, advance science, and frame policy that will advance scientific and technological development? Or is it a form of criticism focused on assessing and analyzing and critiquing science and technology decisions? Is it theoretical analysis of science as an extension of the sociology of knowledge and in effect a search for an understanding of science and society dimensions? Or is it a policy field intended to engineer solutions to such dilemmas and to design new policies? (Lepkowski, 1989, p. 14)

The diversity of purpose embedded in this quotation reflects major challenges facing both scholars and teachers who embark on a study of STS in universities and schools. That is, exactly what is this emerging STS initiative? What are its theoretical underpinnings? What is its future?

With the two-part series being launched with this issue, *Theory Into Practice* has departed from its usual practice of publishing individual, self-contained theme issues. Rather, *TIP*'s focus on STS spans two issues related to this movement. This issue focuses on "Science-Technology-Society: Challenges," while the Winter 1992 issue will address "Science-Technology-Society: Opportunities."

The two-part series explores the overall role of the schools in developing in students an understanding of the relationships among science, technology, and society. In this issue, the authors review the history of science, technology, and social studies education, consider how various disciplines can contribute to the study of this emerging field, and discuss factors influencing the teaching of STS. The articles have grown out of a collaborative effort by authors and editors from the fields of science, technology, and social studies education.

A conceptualization of STS is introduced in the lead article by Melvin Kranzberg, one of the early proponents of an integrative study of science, technology, and society. In the following three articles, Hurd, Zuga, and Splittgerber take a retrospective look at science, technology, and social studies education, respectively, reviewing the history of those fields and related STS themes.

The remaining articles address issues that influence people's perceptions of STS and ways in which STS instruction could be approached. Wirth, Merryfield, and Kowal focus on concerns related to the reorganization of work, global perspectives, and a curricular approach to human values, respectively. Articles by Carter, Bybee, and Rubba discuss access to knowledge, the policy-practice gap, and teacher education.

While describing and evaluating the STS movement, these articles effectively point out the nature of the subject matter fields involved and identify potential areas of both cooperation and conflict. That we do not all view the world through the same lens is borne out rather refreshingly by the authors in this issue. They have written from a variety of perspectives, and have supported the implementation of the STS movement in different ways, ranging from an interdisciplinary approach, to the integration of STS themes into existing subject matter, to the assumption that STS is the province of a particular discipline. Clearly, the articles provide insight into the difficulties of conceptualizing a standard approach to STS and provide us with a wide array of challenges and stimulation for further thought.

M. Eugene Gilliom
Stanley L. Helgeson
Karen F. Zuga

Guest Editors

Reference

Lepkowski, W. (1989, March). Scholars ponder the goals of science, technology and society programs. *Chemical & Engineering News, 67*(12), 14-15.

Melvin Kranzberg

Science-Technology-Society: It's as Simple as XYZ!

We live in a scientific and technological age. It is called that, not because all of us are scientists and engineers, and certainly not because everyone can understand the intricacies of science or the workings of the technological devices that are an integral part of our daily living, but rather because we are aware that science, technology, and society (STS) are intermeshed with one another, affecting our lives in many different ways.

Yet we have become so accustomed to our scientific technology that we sometimes take it for granted, failing to realize how unique and significant it is until a storm causes the lights to go out, briefly altering our daily living pattern, or until a critical problem, such as a potential energy crisis created by political developments in far-off lands, threatens international peace. But such examples show that science and technology are inextricably connected with the human condition, from minor, everyday items to matters of grave concern for human survival.

Although serious study of STS interactions is of recent vintage, their interrelationships go far back in history; indeed, to prehistoric times, for our human species probably could not have evolved or survived without the tools of technology. Our prehuman forebears were too weak and puny to fight nature with only their hands and teeth. The lion was stronger, the horse was faster, the giraffe could reach higher; but tools served as extensions of human hands and amplifiers of muscle power, enabling humans to adjust to an almost infinite number of operations in virtually any environment. Thus modern physiology, psychology, evolutionary biology, and anthropology all combine to demonstrate that *homo sapiens* (humans as thinkers) cannot be distinguished from *homo faber* (humans as makers). Hence we now realize that humans could not have become thinkers had they not also been makers (Leroi-Gourhan, 1969; Oakley, 1972; Volti, 1988; Washburn, 1960).

Anthropologists and archeologists have found evidence that as soon as humans began to think, they began thinking about the whys and wherefores of nature (Braidwood, 1975; Childe, 1946; Clarke, 1970; Sarton, 1952). Science, whether in the form of magic, superstition, or religion, was a means whereby human beings sought to understand the meaning and workings of the natural universe and, with the aid of technology, how to bend nature to their will. Thus technology and science, in addition to playing a major role in shaping our modern world, are among the most basic of human cultural characteristics. As Paul Gray (1988), former president of the Massachusetts Institute of Technology, stated, "Engineering and science are not esoteric quests by an elite few, but are, instead, humanistic ventures inspired by native

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human curiosity about the world and desire to make it better."

Characteristics of Science and Technology

To avoid the philosophical and linguistic complexities of epistemology and other "ologies," I give my students simple working definitions of science and technology. I tell them that science is concerned with "knowing why," that is, comprehending underlying physical and natural principles, while technology is concerned with "knowing how," how to make things and do things. But "why" is involved in technology too: *Why* do technologists want to make things and do things?—to make life better and easier, to satisfy a variety of human needs and wants. That requires "knowledgable doing," an integration of theory and practice (Lux, 1981).

Not surprisingly, relations between science and technology have changed over the course of the centuries. What began as two separate fields—one to explain nature and the other to alter and control it—started coming together when (a) technology had advanced to the point where technical practitioners realized that they must make greater use of mathematical tools and scientific findings in order to make nature and machines do their bidding, and (b) when scientists increasingly began employing technical instrumentation to further their study of nature.

Only a century ago, technology was viewed as "applied science." At that time, scientific explorations in magnetism and electricity had given rise to the new field of electrical engineering, and chemical and pharmaceutical studies had opened up still other technical areas. At the same time, older technical fields, such as civil and mechanical engineering, advanced to a point where they required more exact mathematical measurement than the old "rule of thumb" and more awareness of the scientific bases of materials and thermodynamics.

In the present century, scientists began utilizing more sophisticated technological instruments to view the inner workings of the atom and to peer into outer space. Commenting on how physics and biology laboratories had become reliant on ingenious technical devices and instrumentation, the late Derek Price (1984) implied that modern science could be seen as a kind of applied technology. That notion is demonstrated by elaborate atom-smashing mechanisms and the delicate tools of genetic engineering, as well as the hospital operating room, which is an electronic engineer's "playpen" as well as a surgeon's workplace. Although scientists and engineers may still proclaim the differences between them, the distinctions are rapidly disappearing as the theory-practice of science and the theory-practice of technology become increasingly interwoven.

The Role of Society in STS

So far I have concentrated on the interconnectedness of science and technology, but where and how does society come into the picture? The fact is that society has never been out of the picture. Science and technology are very human activities and, as such, they are an inherent part of our social milieu. Society includes all sorts of human activities, thoughts, values, and hopes, and our social environment extends from our immediate family to our neighbors, our country, and, nowadays, largely as a result of the applications of science and technology, to the whole world.

Also included within our social ecology are our institutions, both public and private. Similarly, our culture, our arts and entertainment, and our religious and philosophical concepts about the meaning of life form part of our sociocultural ecology. And they too are affected by—and affect—our science and technology.

This has led Cutcliffe (1990) to state that science and technology "are complex enterprises taking place in specific social contexts shaped by, and in turn shaping, human values as reflected and refracted in cultural, political, and economic institutions" (p. 363). Since the sociocultural environment differs from place to place and changes from time to time, the sociocultural context in which scientific and technological thoughts and actions occur reflects those changes (Cutcliffe, 1990).

Yet many people regard science and technology as exogenous forces that alter life and society independently of any social forces. They view scientists as isolated individuals working in an "ivory laboratory," disdainful of the elements of everyday life. Inventors are viewed as "heroic" (albeit sometimes eccentric) figures who are largely unaffected by the world around them. Only within the past 3 decades has the scholarly community come to realize that technology can be understood only in terms of its sociocultural context (Cutcliffe & Post, 1989) and that technical artifacts are products of "social constructivism," that is, interactions—including conflict and competition, and sometimes cooperation—among inventors, scientists, engineers, business executives, and public forces of various kinds (Bijker, Hughes, & Pinch, 1987).

That is why this article is entitled, "STS: It's as Simple as XYZ," a turn-around of the phrase, "as easy as ABC." For in dealing with science-technology-society interactions, one must take so many elements into consideration that one uses up the entire "alphabet" of social and human capabilities, hopes, and fears.

In enumerating some of the complications involved in science-technology-society interactions, this article concentrates on the role of technology in history, my field of special interest. However, the same or similar problems arise in considering scientific interactions, especially since science and technology have become so interconnected in today's world.

Technology-Society Interactions

Although technology is a very human activity that affects, and is affected by, many elements of our social and natural environment, we constantly encounter people who regard technology as something divorced from the essence of humanity. My humanist friends ask: What is human about a monkey wrench, a lathe, a computer? The characteristic of technology that repels them is what they term the "inhumanity" of technology's objects, for example, the industrial robots that they fear will make human beings expendable, or the "anti-humanity" of technology's byproducts, such as the pollution that threatens our environment. In brief, they regard technology as something mechanical.

But machines are not something apart from humanity. Instead, all technical processes and products are the result of the human creative imagination and human skills, hands and mind working together. Behind every machine I see a face, indeed, many faces: the worker, the scientist, the engineer, the businessperson, and sometimes the general or admiral.

Furthermore, the significance of technology lies in its use by human beings and sometimes, alas, its misuse and abuse. While we can point to many wonderful contributions that human applications of technology have made to society, the old adage that "every cloud has a silver lining" might also be turned around to read, "every silver lining has a cloud." Technology's impact upon the social and natural ecology makes many sensitive individuals fear that this very human activity—technology—has grown so large that it threatens to engulf or even destroy the human race.

One of the intellectual clichés of our time is that technology has become "autonomous" and is pursued for its own sake, without regard for human needs (Winner, 1977). Thus, in a startling reversal, machines become the masters of humans. In philosophical terms, this is the doctrine of technological determinism; namely, that technology is the prime factor in shaping our values, institutions, and other elements of our society.

Not all scholars accept this notion of technological omnipotence. The late Lynn White (1962), a great medieval historian and historian of technology, said, "A technical device merely opens a door; it does not compel one to enter" (p. 28). In White's view, technology is simply an enabling mechanism, a means humans are free to employ or not, as they see fit. But the question then arises as to whether we can always distinguish between means and ends, and if the means do not sometimes determine the ends. True, one is not compelled to enter White's open door, but an open door is an invitation. Besides, who decides which doors to open? And once we have entered the room, are not our future directions guided by the contours of the corridor into which we have stepped? Equally important, once we have crossed the threshold, can we turn back?

Frankly, we historians do not know the answer to this question of technological determinism; ours is a relatively new discipline. We are still working on the problem, and we might never reach agreement on an answer. Yet we do know several things, which I summarize under the label of "Kranzberg's First Law," discussed in the following section.

Unintended Effects

Kranzberg's First Law reads as follows: Technology is neither good nor bad, nor is it neutral (Kranzberg, 1986b). This refers to the fact that technology's interaction with the social ecology is such that technical developments frequently have social and human consequences that go far beyond the immediate purposes of the technical devices themselves. Thus the same technology can have quite different effects when introduced into different contexts, under different circumstances, or when "overused." Many technical applications that seemed to be boons to society when first introduced became threats with widespread use.

For example, DDT was employed to raise agricultural productivity and to eliminate disease-carrying pests. Then it was discovered that DDT not only did that, but also threatened ecological systems, including the food chain of birds, fish, and eventually people. So the Western industrialized nations banned DDT. We could afford to do so, because our high technological level enabled us to use alternative means of pest control to achieve the same results at a slightly higher cost.

Other nations, however, were not so well placed. They felt they had to use any technological advance they could afford if it handled a current problem, irrespective of possible side-effects in the future. Hence India continued to employ DDT despite its drawbacks, because it was not economically feasible for India to change to an insecticide that was less persistent than DDT and would require spraying every few weeks instead of just twice a year. According to World Health Organization statistics, the use of DDT in the 1950s and 1960s reduced the incidence of malaria in India from 100 million cases a year to only 15,000 cases and reduced the death rate from 750,000 to only 1,500 per year (Kranzberg, 1986b, p. 546). Is it surprising, then, that the Indians viewed DDT differently from the Western industrialized nations, and continued its use rather than banning it? Here is a case where the same technology can answer questions differently, depending on the socio-ecological context into which it is introduced and the problem it is designed to solve.

The importance of sociocultural elements in shaping the acceptance and use of technological devices, sometimes in a manner far different from the original hopes of those who made the devices, can also be seen in the history of a major component of American life in the 20th century: the automobile. At the turn of this century, the automobile was extolled as the solution to the pollution, safety, and congestion problems posed by horse-drawn transportation. That was a time when in New York City alone horses deposited some 2½ million pounds of manure and 60,000 gallons of urine each day (Flink, 1988, p. 136). The automobile promised relief from these problems but, as we know, the large-scale use of the auto brought back pollution, congestion, and safety problems in heightened and altered form.

Another example of how the use of technology sometimes has unanticipated social consequences is shown by the experience of Henry Ford. Although he did not invent the automobile, Ford devised manufacturing means that made it affordable for the common person. Since Ford's auto made it cheap and easy for the farmer to deliver goods to the city and return to the small-town farm, Ford hoped to preserve the country village (Marcus & Segal, 1989). But instead of fulfilling his notion of a small-town paradise, large-scale use of the auto doomed the rural town, leading eventually to today's megalopolis of suburbia and exurbia—just the kind of development Ford hated. True, he achieved the reality of an affordable auto, but his larger vision of small-town America was eventually overthrown by the technical device he hoped would preserve it.

Unexpected Benefits

Sometimes technology interacts with society to produce unexpected benefits. This is particularly manifest in the field of education, where technological developments both demanded and made possible more education for larger segments of society.

In order to play a productive role in the increasingly complex industrial world that came into being in the 19th century, workers had to learn how to read and write. Although printing had been invented 4 centuries earlier, books were expensive and literacy remained limited to a small, elite group. Technology gave people an incentive to learn reading and writing because more complex production methods required larger numbers to become educated.

At the same time, improvements in printing techniques and materials made printed works cheaper and more available to the masses. But most important was technology's indirect contribution to the spread of literacy by making it possible for the public to have the time and means to become educated. We can see this at work in American history.

Some 2 centuries ago, Thomas Jefferson, who believed in both education and equality, proposed an educational master plan for the state of Virginia that allowed access to higher education for only a select few (Kranzberg, 1986a). This was not because Jefferson was an elitist, but because the low productivity of the agrarian society of his time could spare only a handful of people for educational pursuits. Children had to work in the fields as soon as they were old enough to help their parents, and in towns they were apprenticed as craftworkers at an early age. Only when technical advances in agriculture and industry had expanded the availability of food and goods was it possible to delay the entrance of children into the work force and provide them with schooling. The figures tell the story.

In 1800 the average American attended school only 82 days in an entire lifetime, and by 1840 this had grown to only 208 days (Kranzberg, 1986a, p. 240). But as industrialization increased, the state entered into the educational business. Elementary schooling (and later, secondary schooling) was made compulsory. This was not because local and state governments thought in terms of "high culture." Rather, reading and writing were necessary to meet the commercial and industrial needs of the time, and governments responded to that need. Indeed, the Morrill Act of 1862, providing for land-grant colleges aimed at education in agricultural and mechanical fields, was a big step in democratizing higher education (Boorstin, 1973).

However, real educational progress in the United States is quite recent. Only 6 percent of American children graduated from high school in 1900, and only one out of every eight Americans at work in 1930 had ever attended high school. By 1980, however, two-thirds of the entire population were high school graduates. Indeed, by then the United States had committed itself to making higher education available to all, sometimes irrespective of people's ability to take advantage of it. Thus, although in 1930 only about 4 percent of the appropriate age group attended college, in 1970 the figure was about 50 percent. In 1970 only 13 percent of the adult labor force had college degrees, but a dozen years later that figure had risen to 20 percent (Ferris, 1969; U.S. Bureau of the Census, 1976).

In brief, we have democratized higher education. Only a rich society, made so by technological advances in agriculture and industry, could afford to do so. As a result, great numbers of today's Americans have an education equivalent to that of yesterday's small upper class.

Those critics who claim that technological advance is ruining our planet and bringing suffering to humankind should take a closer look at the pragmatic realities. If modern technology is so harmful to both humans and nature, how can we account for the fact that the standard of living is higher in the industrialized portions of the world than in those where technology lags behind? Why are the citizens in the industrial nations better fed and longer-lived? Why is more being done to protect the environment in the technologically-advanced nations than in those still at a primitive technological level (Kranzberg, Elkana, & Tadmor, 1989)? Can this be ascribed to mere coincidence? Or, rather, does it not indicate the presence of linkages between technological level and other elements of society that make it essential to study technology-society interrelationships?

Why Study STS

While technology alone cannot solve society's problems, the material needs of society will also not be met by cursing technology. This does not mean, however, that a group of technocrats or a scientific-technological elite should make decisions for the future directions of our scientific-technological research and its applications. Many of the problems facing society involve not only technology, but also human values, social organization, environmental concerns, economic resources, political decisions, and a host of other factors. These are "interface problems," that is, the interface between technology and society, and they can only be solved—if they can be solved at all—by the application of scientific knowledge, technical expertise, social understanding, and humane compassion.

These interface problems—the kernel of STS studies—have another feature in common: Scientists and engineers cannot solve them alone, yet they cannot be resolved without the aid of scientific-technological expertise. Unlike earlier times when society had no choice but to pursue traditional technical methods, our modern, sophisticated technology provides different options, opening up various paths we can follow.

Scientific-technological advances will not guarantee that we will use our technical prowess for the common weal, for science and technology are *not* autonomous. They function within a sociocultural matrix. Our value system, as embodied in our religious and political ideologies and in our institutional structure, including our banking and business corporations and our government, will determine which of the many technological options we will select.

However, the fact that our modern technology gives us options does not mean that, like spoiled children, we can have everything we want. We need to make tradeoffs.

In our daily lives we constantly make tradeoffs, choosing among various goods—or avoiding evils—as they present themselves. For example, we forego a vacation this year so that we can make a down payment on a new car, or we postpone the new car until next year, so that we can take a vacation this year. In a sense, we practice Jeremy Bentham's early 19th-century "calculus of pain and plenty" in deciding which of several options we will choose for spending our time and money. We trade one "good" for another, or if some bad things seem inevitable, we endeavor to choose the least of the evils besetting us.

That same problem of tradeoffs will affect our choice of the many technological options open to us. We must select those that promise the most good with the least-possible harmful effects. While it is hard enough to make such choices as individuals, it is even more difficult to reach a social consensus.

Questions of societal risk and technological choices also involve value notions and ethical judgments. We cannot solve individual parts of problems when coping with "mushy" sociotechnical issues; instead, we must look at the whole in order to make the necessary and difficult tradeoffs between technological possibilities and conflicting socioeconomic pressures—and still have the results conform to our value system.

STS and Education

Inasmuch as many of the problems facing the world have a technological as well as a human component, we are faced with a tremendous educational problem. For one thing, scientists and engineers need some understanding of the social and human factors affecting their work. But an even more challenging task is to teach all students—including liberal arts and other students—something about science and technology. This does not mean that all students must become scientists and engineers, but all must develop "technological literacy," that is, some understanding of our technological age.

After all, the purpose of an education is not only to train students for a career, but also to challenge them to think about the meaning and purpose of life, their role in both the cosmic and human scheme of things, and their relationship toward their immediate neighbors and toward the larger global society. These perspectives have long been included in the subject matter of the liberal arts and of education in general. But the world has changed, which is why the humanities and social sciences must also change. They must become involved in STS issues in order to help students understand the world in which they live.

Understanding the interactions of technology with society is furthered by knowing the principles and operations of the technology itself. And that puts a special burden on those involved in technical education. For in a technological society there is need for technical knowledge and skills of many different kinds to serve society's needs. As John Gardner, former secretary of health, education, and welfare, once stated, referring to the ties between the intellectual aspirations of a society and its material and mechanical foundations, "Our ideas won't hold water if we allow our plumbing to leak."

During the past 2 decades there was a growing belief that the introduction of automation in our factories and offices would change the nature of the workforce. Our futurists told us that computerized robots in manufacturing would mean that we would no longer need skilled workers, except for maintenance and repair of robots. A few computer specialists would take care of computer-aided design and manufacturing, and computerized devices would similarly take over routinized office and service tasks. How wrong they were (Guile, 1985)!

Now we realize that our workers require more general education and more technical schooling if they are to function in an increasingly high-tech society. As Zuboff (1988) said, "Smart machines require smart workers."

Instead of doing away with skilled handcraft workers, as did the substitution of machinery for human labor in the early stages of the Industrial Revolution, we are again requiring highly-skilled workers. Both their minds and their skills must be developed, and that is why technological education, which many people mistakenly downgraded as being unnecessary in a high-tech age, is more necessary than ever before. Of course, technology education must change in response to changes in the technology, and technology educators are in the process of doing exactly that: preparing people for tomorrow's workplace, not yesterday's.

But we must also educate all Americans, not just our scientists and technical personnel, about the interactions of science and technology with each other and with society. More and more, people want to have some control over their destinies, and inasmuch as an advancing science and technology have a great deal to do with shaping the future, people want to have some control over them. In order to exercise that control intelligently, people must have some knowledge of science-technology-society interactions.

For democracy is more than freedom. It is also responsibility, and, in this case, it is responsibility to make our technological choices for the future with a reasonable regard for other people and for our descendants on Spaceship Earth.

Conclusion

In my discussion of science-technology interactions with both the social and physical environment, I have mentioned both good and bad effects. That is because working with STS issues, like science and technology themselves, is a very human activity. Hence it reflects human hopes and fears, dreams and nightmares.

We are not helpless victims of our technology. Indeed we live in a world that has been shaped by humans, and that has occurred with the aid of technology. If humans can make our world, they can surely remake it. In that remaking process, a wise and foresighted use of science and technology becomes imperative—and that can only be achieved by taking full cognizance of science-technology-society interactions.

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tip

Fred Splittgerber

Science-Technology-Society Themes in Social Studies: Historical Perspectives

Social studies programs as they exist today are in part a result of what has happened in the sciences over the past decades and centuries. As we investigate the legacy of science-technology-society (STS) themes in social studies, it becomes apparent that scientific and technological advances have made a significant impact on individuals, societies, and civilizations. In fact, Hickman, Patrick, and Bybee (1987) have documented that this country's founding and institutions can be traced directly to the legacy of Newton's idea on natural order from the Enlightenment.

Newton's idea on natural order, which provided an ordered way to view the universe and explained the order of events through natural law, was proposed as the conceptual framework for organizing an ideal society during the 17th and 18th centuries. The evolution of Newton's thesis resulted in his treatise on natural law serving as the organizational framework for the Constitution and institutions of the United States.

Since the founding of this country, the interactions among institutions, constitutional principles, and scientific and technological developments have increased dramatically. At the present time, a stable society is difficult to maintain, with the rapid rate of social change that has resulted from scientific and technological advances. Studying the implications of these societal changes continues to be an essential part of the social studies curriculum. Therefore, a primary reason for including STS topics in social studies is that these themes are essential to maintain the heritage of freedom gained from the Enlightenment.

Another reason for including STS topics in social studies is based on the premise that modern societies aspiring to be democratic require citizens who are informed about and have some understanding of complex scientific and technological issues. The incorporation of STS topics in social studies is in response to this premise and addresses the continuing need to develop a reasoned commitment among students to the interrelated ideas of scientific inquiry and a constitutional democracy that ultimately provides the basis for a civilization (Patrick, 1987).

However, the importance of citizens understanding the impact of STS topics in a democratic society does not guarantee easy integration into the social studies curriculum. Incorporation of STS topics into social studies is increasingly difficult to accomplish due in part to the complex and rapid advancements occurring in science and technology. The other major difficulty is the need for understanding the comprehensive knowledge base social studies educators must utilize in examining STS topics. Although there is disagreement over what knowledge is important in explaining scientific and

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technological advances, this issue should not be a valid reason for excluding STS topics in social studies.

In summary, because of tremendous technological and scientific changes that have occurred throughout this country's history, the argument has been made repeatedly that social studies should play a major role in the development of STS topics (Patrick, 1987). By integrating STS topics and materials into the curriculum, social studies is fulfilling part of its mission to develop responsible citizens with an understanding of scientific and technological knowledge and skills required in a democratic society.

The Growth of Public Education and Social Studies

Although it is acknowledged today that an understanding of scientific and technological advancements is essential to exercising effective citizenship, prior to 1900 the social studies curriculum was based on the teaching of history and civil government. History was directed toward teaching patriotism and civil government and stressed the inculcation of respect for the Constitution and the national government. Goals and objectives were dictated in large part by the admission requirements of colleges. In the continuing debate from 1890 to 1918 over whether the colleges and universities or the public schools were to control the curriculum, science and technology issues do not appear to have been a major concern (Gross & Zeleny, 1958).

There is ample evidence to suggest that the social studies curriculum did not come into existence overnight. The emergence of the social studies as an alternative or replacement for history and civil government began in 1893 with the Committee of Ten (Tryon, 1935) and ended with the 1916 Social Studies Committee Report (National Education Association, 1916). In the Committee of Ten report, specific recommendations were made for the field including the use of the term social studies (Tryon, 1935).

The social studies program as we know it today evolved during the decades from 1900 to 1920. In 1916, the National Education Association (NEA) Report of the Committee on Social Studies of the Commission on the Reorganization of Secondary Education was disseminated. This report defined social studies as those subjects related directly to the organization and development of a human society and to people as members of social groups. The term social studies was included in the title of the report and was used to describe the curriculum content of the various social science disciplines.

In addition, the NEA report (1916) recognized John Dewey's concern for the needs of all youth by recommending that the real problems and issues of life be studied from a multidisciplinary viewpoint in a course entitled "Problems of Democracy." The course recommendations included no mention of specific topics from science and technology, but existing societal issues were recognized as a major focus. During this period, democratic values and community spirit were viewed as social studies' major goals (Barr, Barth, & Shermis, 1977).

Dewey's impact on the formation of the social studies curriculum must be noted as a part of the STS legacy in social studies. Dewey (1939) maintained that "empirical sciences now offer the best type of intellectual organization which can be found in any field" (p. 22). He commented that "the only freedom that is of enduring importance is the freedom of intelligence, that is to say, freedom of observation and judgment exercised in behalf of purposes that are intrinsically worthwhile" (p. 69). Dewey stated that the "scientific method is the only authentic means at our command for getting at the significance of our everyday experiences of the world in which we live" (p. 111).

In Dewey's monumental book, *Democracy and Education* (1921/1944), he clarified his views on science, society, curriculum, and education. Dewey maintained that a "democratic society is peculiarly dependent for its maintenance" upon a curriculum that is "broadly human" (p. 192). Education in a democratic society is responsible for presenting learning experiences "relevant to the problems of living together" (p. 192). Dewey left a legacy of many ideas applicable to STS today: inquiry, the scientific method, knowledge learned through experience, and education for citizenship.

The Core Subjects and Progressive Education

As the term social studies gained support in the 1920s and during the progressive education movement in the 1930s, programs in many schools switched from a subject-centered to a problem-centered social studies curriculum. In 1921, the National Council for the Social Studies (NCSS) was organized as an affiliate of the NEA Department of Social Studies. A decade later (1931), the first NCSS yearbook was published. A chapter in the first edition on the fusion of social studies for junior high schools had some relationship to science and society topics; however, the section on research had no mention of STS topics being investigated (NCSS, 1931).

During this same period, the Commission on the Social Studies issued a report entitled Conclusions and Recommendations (1934), sponsored by the American Historical Society (cited in Barr et al., 1977). The commission was composed of eminent scholars from education, psychology, history, and geography, but no scientists or technologists were included. Although the commission published 16 other volumes between 1932 and 1941, it was never able to make a definitive statement concerning the curriculum or definition of social studies (Barr et al., 1977).

A more pressing concern for the nation was the impact of the depression on industry, employment, and poverty. In spite of the depression, however, technology and technical problems encouraged and stimulated scientific investigations. With the advent of World War II, tremendous changes occurred in science and technology, including the development of atomic energy and improved transportation and communications. Many of the major scientific discoveries during this period were the result of research conducted in European universities (Cummings, 1957). In fact, concern for this nation's ability to compete in a scientific race with Europe and Asia led to the establishment in 1950 of the National Science Foundation (NSF). When the feasibility of including the social sciences in the NSF was discussed during the hearings on the pending bill, Congress decided that research in this area should not be supported with federal funds (Cummings, 1957).

The Cold War, Citizenship, and STS Themes

The Cold War followed World War II, with large defense and armament expenditures and the ominous threat of a nuclear war. The arms and space races resulted in the commitment of scarce resources to the development and production of scientific and technological instruments of destruction. One positive aspect of the space race, however, was that it helped to generate a revolution in science research and space exploration. In response to criticisms of the schools' failure to provide technological and scientific knowledge following Soviet achievements in space exploration in the late 1950s, academic excellence and citizenship education again became major goals of American education. During this period, a growing awareness of the significance of STS issues became one of the forces for instituting curricular change in public education and social studies (Barr et al., 1977).

The NCSS published a yearbook entitled *Science and the Social Studies* (Cummings, 1957) immediately prior to the launching of Sputnik I. The yearbook made it clear that the sciences and the social sciences were interdependent and could not be separated when analyzing the curriculum or the impact of science on the progress of technology, agriculture, health, and war. The yearbook suggested that "an understanding of science is an essential part of the irreducible minimum of education" required of every responsible citizen (Cummings, 1957, p. 27).

Social studies teachers were challenged to accept part of the responsibility for the development of scientific understanding and were urged to recognize that their education in science and technology must be strengthened. Cummings, the yearbook editor, indicated that social studies teachers did not have the responsibility to "develop research scholars in the physical and biological sciences," but should focus the attention of their classes on people and their problems in society rather than on abstract scientific theories or specialized technological applications (pp. 5-7).

In order to assist social studies teachers with course content and methods, the yearbook recommended guidelines for (a) integrating science into American culture, (b) understanding how scientists have contributed to discoveries and formulation of new knowledge, (c) studying the role of science and technology as one of the important aspects of modern citizenship, and (d) reducing delays in taking action on dangerous scientific and technological problems. It was pointed out that once these guidelines were addressed, common problems facing social studies teachers and social scientists could be examined. Although the specific contents and guidelines were general in the yearbook, the rationale and need for STS topics in social studes were recognized.

Research and Development and the "New" Curricula

The political discontent of the 1960s resulted in renewed interest in relevant curricula. The struggle for the cultivation of excellence in education and the promotion of equal rights helped shape the politics of the decade but did not improve the awareness of STS topics. Social science objectives included references to racial equality, integration, cultural pluralism, multi-ethnic studies, and sexual equality. Although the decade was marred by violence growing out of racial protest and the Vietnam war, a new national goal to improve education through intense research and development activities was instituted in all subject areas (Barr et al., 1977).

In 1963, the social studies received major federal funding for Project Social Studies. The purpose of these funds was to reform the social studies in both content areas and teaching methodology. Often referred to as the "new social studies," Project Social Studies was directed at: (a) broadening of social studies concepts from all social sciences; (b) stressing concepts and generalizations; (c) encouraging greater variety of classroom teaching strategies, including discovery, inquiry, and inductive approaches; (d) investigating learning theories as well as what is learned; and (e) differentiating staff and organizational patterns (Barr et al., 1977).

In addition, the National Science Foundation funded *Man: A Course of Study* (*MACOS*), one of the most significant STS projects combining science and social studies (Dow, 1975). *MACOS* was designed for fifth and sixth grades and included films, booklets, records, maps, games, and other materials. *MACOS* was first marketed in 1969 and by 1975 was reported being used in 1,700 schools in 47 states (Weber, 1975, p. 81).

The course content of *MACOS* dealt with the nature of humans as a species and the forces that molded and continued to shape their humanity. Three questions recurred throughout the course: "What is human about human beings? How did they get that way? How can they be made more so?" (Bruner, 1966, p. 74). In order to answer these questions, students investigated human and animal life styles that were significant to human social behavior, social organization, and the management of childhood, parenthood, and culture. These concepts were achieved through a detailed study of the life cycles of salmon, herring gulls, baboons, and Netsilik Eskimos.

MACOS was criticized during the 1975-1976 Congressional hearings after NSF had requested $210,000 for teacher training and other promotions. The controversy was centered on the claim that the course exposed young children to "adultery, bestiality, cannibalism, infanticide, and senilicide" (Weber, 1975, p. 81). In response to these allegations, Dow (1975) maintained that children were introduced to a concept of humankind as a unique species that possessed "language, the capacity for complex social organization, the ability to alter [one's] surroundings through technology, the prolonged investment by both male and female in the care of the young, and the capacity to explain the world through storytelling, mythology, belief systems, art, literature, and the growing power of modern science" (p. 79).

Dow concluded that the course afforded the children the opportunity to examine the benefits of their culture against the traditional folkways of a hunter gatherer culture. In contrast, Weber (1975) argued that (a) many of the events and topics are too controversial to be presented to young children, (b) 10-year-olds are too young to face these controversial and perplexing questions about humans and society, and (c) young children would appear to be indoctrinated in the beliefs of "cultural relativism" and "environmental determinism" as the scientific explanation of humankind's place in society (Weber, p. 82).

Bruner gave his reflections on the *MACOS* controversy in his book, *In Search of Mind: Essays in Autobiography* (1983). Bruner maintained that the course first came under attack from right wing groups such as the John Birch Society and creationists who opposed the teaching of evolution. What ensued was the harassment of school districts followed by attacks from several members of Congress. The media campaign that followed led Congress to cut off the funding of *MACOS*.

Bruner (1983) classified the demise of *MACOS* as a result of a "storm of anti-intellectualism, primitive patriotism, and 'back-to-basics' " (p. 196). He maintained that *MACOS* became too controversial because the program delved into an "inquiry of what makes human beings human" (p. 198). Bruner maintained that the study of the nature of humans cannot be addressed in the schools without reconsidering how schools reflect society. He stated, "If I had it all to do over again, and if I knew how, I would put my energies into reexamining how schools express the agenda of the society and how that agenda is formulated and how translated by schools. That, it seems to me, would be the properly subversive way to proceed" (p. 198).

In summary, while STS issues were addressed through *MACOS* by integrating the disciplines of the natural sciences and social studies, the lasting impact of the program was minimized by the failure of the project to gain widespread implementation due to the public controversy over the nature of the course content. Finally, the push for equality, excellence in education, and STS themes during the decade largely was ignored because the nation's attention was focused on racial protest and violence related to integrating universities, public schools, and public places.

Citizenship, "Basics," and Competencies

Although the first energy crisis occurred during the 1970s, social studies educators did not appear to recognize the importance of STS themes during this period. In many colleges, however, STS materials became a major area of study. In the same decade, the NCSS established a science and society committee, which sponsored a bulletin on science-related social topics entitled *Science and Society: Knowing, Teaching, Learning,* (Charles & Samples, 1978) and a special section for the journal Social Education entitled "Science and Technology for a Global Society," (Wood, 1979b). These publications and the NCSS committee represented an initial recognition of the need to address STS themes.

In the Foreword to the bulletin, *Science and Society,* Anna Ochoa, the president of the NCSS, indicated that the publication "symbolizes a significant point of departure for the NCSS. For the first time, we are devoting a major publication to the integration of two discrete components of traditional curricula: science and social studies" (Ochoa, 1978, p. v). She suggested that several "powerful assumptions permeate the bulletin. One of these is that every person has her or his unique view of reality, and therefore of the essential relationships within and between nature and culture. Further, nature and culture are inextricably intertwined" (p. v).

In setting the tone for the bulletin, the editors maintained that each person is affected by the scientific, technological, and cultural issues that impact on their daily lives. The editors implied that social studies educators have a responsibility to address the ethical issues confronting all humans today in a science and technology oriented world (Charles & Samples, 1978).

The bulletin, written by some of America's leading scholars in the sciences, psychology, and social studies, presented a well organized argument for holistic and integrated teaching of science-related social issues. The first two sections dealt with questions of perceptions and human responsibility by exploring ethical concerns faced by individuals, groups, and society and the relationship of ethics and values to the maintenance of a scientific and technological society. The third section explored concepts that could be taught in the classrooms, such as inquiry and decision making. In the fourth section, the personal challenges for future survival were presented but with few suggestions of how to teach these concerns. In retrospect, the bulletin appeared to be more of a philosophical statement of the rationale and reasons for teaching science and technology in the social studies than a publication designed to assist classroom teachers in moving from a set of theoretical constructs to the actual implementation of STS themes.

In her introduction to the special section in *Social Education*, Jayne Wood (1979a) suggested that tremendous progress had been accomplished by science and technology in changing our daily lives and the relationships among nations in fields such as medicine, agriculture, and areospace. However, a set of critical global problems had developed that could not be solved without scientific and technological cooperation on national and global levels. Wood suggested that because science and technology had been unable to solve many [illegible]ous problems in the past, their role in resolving present concerns had come into question. Woods noted that social studies could "provide a particularly appropriate context in which to raise the question of to what ends science and technology should be used" (p. 421).

The articles in the special issue addressed critical STS themes such as technology and human choices; the role of the United States in the development of science and technology; the impact of technology on women and poverty; and STS teaching strategies, resources, and materials. It is the first publication by the NCSS to use the STS theme in the content and titles of articles.

While awareness of the need for STS themes was growing in the NCSS, STS topics had not become a major focus of high school and middle school social studies curriculum. Although instructional strategies highlighting STS themes had begun to make their way into public school social studies curricula, the pressure for the "basics" had reduced the emphasis and funding of social studies and science programs with STS themes. Because of the knowledge base required to teach STS topics and the controversial nature of STS themes dealing with ethical and value choices, social studies teachers appear to have treated STS topics as information—de-emphasizing in-depth discussions on content and value choices. Also, the outcome of the controversy over continued funding for *MACOS* raised additional questions about the values and ethics of STS topics, which further restricted the implementation of STS themes in social studies (Marker, 1987).

Expansion of the STS Framework in Social Studies

The decade of the 1980s has seen increased interest by the NCSS in issues surrounding STS topics. The term STS was not officially adopted by the NCSS in its guidelines until the current guideline revisions were approved and published in the spring of 1990 (Heath et al., 1990). Under the leadership of the science and society committee, "Guidelines for Energy Education in Social Studies" (Allen, 1981) and "Guidelines for Teaching Science-Related Social Issues" (Otto et al., 1983) were published. During 1990, the revised STS guidelines entitled "Teaching About Science, Technology and Society in Social Studies: Education for Citizenship in the 21st Century" were published (Heath et al., 1990).

The energy guidelines proposed basing an energy program on student interests, utilizing active participation strategies (a cooperative model of learning through active involvement of students, teachers, and community). The content was to focus on consumption patterns of energy use and an understanding of the interrelatedness of energy concepts to society's conservation of scarce resources (Allen , 1981). These guidelines were widely disseminated by the NCSS and used as a focus of STS discussions on the conservation of energy in social studies.

The "Guidelines for Teaching Science-Related Social Issues" (Otto et al., 1983) did not emphasize technology except in the opening sentence of the document. Any reference to technology was omitted from these guidelines because the NCSS board of directors assigned the responsibility for technology issues to the instructional media and technology committee rather than the science and society committee. As a result of this decision, the guidelines were general in their approach and focused on methodology and science-related issues in society rather than on the interrelatedness of science, technology, and society themes and the effects of STS topics on the lives of citizens in a global society.

The revised "Teaching About Science, Technology and Society in Social Studies" (Heath et al., 1990) made substantive changes. A comparison between the previous guidelines and the revised guidelines reflected an awareness of the increasing need for technological knowledge in our society and the interrelationships among science, technology, and society and their widespread effects on the lives of citizens in a global society. Other changes in the revised guidelines included the recognition of an expanded body of data regarding the teaching of STS topics in social studies and a stronger emphasis on civic participation. This commitment to citizen participation also was reflected in the definition of STS education as "the understanding of how science and technology shape and are shaped by society, the problems and opportunities they create, and how citizens can relate most effectively to them" (p. 189).

The revised guidelines further suggested that STS topics should include criteria for lesson selection based on the social contexts in which they operate, STS concepts, and social influences. Other topics included value positions of groups and individuals as sources of unity or conflict, attitudes and beliefs regarding science and technology, civic responsibility of an individual, and effects of values and ethics on the formation of public policy (Heath et al., 1990). The focus in the revised guidelines was on criteria that distinguished STS lessons and topics from other lessons, identification of civic action plans for STS issues, and the utilization of models and frameworks for identifying and analyzing STS topics. The guidelines proposed the implementation of STS topics through infusion into existing courses, extension of existing units of study, and creation of separate courses of study. Finally, criteria were suggested for evaluating the effectiveness of STS topics on student learning.

In summary, the revised guidelines were more comprehensive than the previous version and addressed several major STS concerns. For example, additional emphasis was placed on civic responsibility in responding to complex scientific and technological questions facing a global society. Finally, the importance of attitudes and beliefs as sources of unity or conflict and the effect of values and ethics on the formation of public policy were emphasized in the revised guidelines.

STS Values and Ethics in Social Studies

The way in which STS values and ethics should be treated in the social studies has raised more controversy in the field in recent years than any other topic. STS values and ethics have been discussed by numerous school boards and parent and citizen groups and have been debated in professional bulletins, journals, and papers (see, for example, Charles & Samples, 1978; Hawkins, 1977; Hickman et al., 1987; Patrick & Remy, 1985; Wartofsky, 1980).

The debate continues over what STS values should be taught for the development of good citizens. The difficulty in selecting certain values arises from the fact that we live in a pluralistic society with many diverse political persuasions, religious beliefs, and ethnic groups. Analyzing the consequences of various STS value positions has posed a threat to some parents and religious and ethnic groups. However, in a pluralistic society, it is essential that differing viewpoints on values and attitudes are discussed and understood.

Some proposed guidelines for addressing STS values and attitudes in a pluralistic society include (a) a recognition that knowledge is never complete, changes constantly, and operates under an evolving set of laws; (b) an assumption that persons who engage in science remain open-minded, base their knowledge on empirical knowledge, and encourage patience and perseverance even if it means criticism; and (c) a realization that citizenship principles recognize cultural diversity, foster participation of citizens in policy decisions, promote equal opportunity, and encourage the dignity and worth of the individual as a responsible member of society (Hickman et al., 1987). If STS values cannot be reviewed and discussed as to the consequences of various alternatives, the result may be indoctrination and the loss of freedom.

In summary, scientists, social studies educators, and citizens must continue to search for the freedom to express ideas and pursue ideas in science and technology. Ethical questions must be raised about the limits and possibilities of science and technology in a society. Every teacher, student, and citizen must continue to ask important questions about the moral and ethical implications of social issues in science and technology.

Future Challenges

Educating citizens on STS topics appears to face three major challenges (Patrick & Remy, 1985). The first is to insure that all citizens are informed about complex social issues related to science and technology. The second challenge for social studies teachers is to integrate the distinct fields of knowledge on STS topics into the social studies curriculum. The third challenge is to resist the censure of STS topics that contradict current political and religious beliefs.

During the 1980s, progress was made in the recognition and development of STS topics in the NCSS from the energy guidelines to the current STS guidelines. The National Council for the Social Studies must intensify its leadership in promoting STS themes in social studies. At the present time, widespread recognition and adoption of STS materials has not occurred in social studies classrooms (Heath et al., 1990). Current efforts by the NCSS to promote STS materials in the public schools will not be successful unless social studies educators themselves comprehend why STS topics are an important part of the curriculum and understand how to incorporate STS materials into the curriculum.

Several alternative strategies for bringing STS content into the social studies curriculum have been proposed (Remy, 1990). These strategies are: (a) infusion into existing courses, (b) extension of existing units, and (c) creation of a separate course of study. The first strategy, infusion, permits the insertion of STS material into existing social studies lessons. However, in adding STS material it may be difficult to decide what should be omitted from the current content coverage of standard courses. Yet, because the time allocated on the elementary level for teaching social studies content is limited, infusing the material into existing courses may be the only realistic way of implementing STS topics into elementary schools.

The second strategy adds distinct STS topics and content to the existing units of traditional social studies courses. One potential problem with adding content in this fashion is that the treatment of STS topics could still be superficial due to lack of adequate time remaining for presenting STS materials.

The third strategy involves the creation of separate courses utilizing interdisciplinary or multidisciplinary content. A major advantage of this approach is that these courses can provide in-depth concepts on various interdisciplinary STS topics. The disadvantages of separate courses are that these courses could take away time from the traditional social studies courses, and complex concepts from the various academic disciplines might be difficult for teachers to integrate.

Another major factor is the lack of a well-defined conceptual framework for the development of interdisciplinary STS topics. Also, teachers tend to think of STS topics in terms of subjects rather than interdisciplinary concepts. Because there is no conceptual framework upon which to build an interdisciplinary curriculum, students find themselves studying content removed from its original context, and few teachers possess the broad knowledge base to integrate the disciplines. The result is that students flounder in poorly organized courses because the teachers are overwhelmed with demands for explaining complex STS concepts (Marker, 1987).

While each option has several advantages, the current alternative of integrating the STS content into existing courses appears easiest for teachers to accomplish. However, introducing STS topics into the curriculum requires that one realize that the time available for teaching social studies is restricted, and teachers already find it difficult to cover the required social studies content.

Recent studies of textbooks have indicated that coverage of STS issues in social studies is inadequate. Investigations into the coverage of STS materials in high-school world and American history textbooks, for example, found minimal coverage of science in the development of civilization (Patrick, 1980, 1982). A study of four United States history textbooks conducted by Heilbron and Kevles (1988) revealed that the books omitted sources, authors, and the context of scientific and technological events in favor of discussions of social and economic impact. The lack of textbook coverage must be corrected if STS materials are to be integrated successfully into social studies classrooms.

Conclusion

Throughout the 20th century, because of tremendous technological and scientific changes, the argument has been made repeatedly that social studies should play a major role in the development of STS topics. By integrating STS topics and materials into the classroom, social studies is fulfilling part of its mission to develop responsible citizens with an understanding of scientific and technological knowledge and skills required to maintain a democratic society.

Social studies' focus on STS issues must alert citizens to the scientific, technological, and societal impact made on individuals, institutions, and nations of the world. STS topics must go beyond just the concern for past and current social issues by broadening students' awareness of the future challenges caused by scientific achievements and emerging technologies. All avenues for bringing about the implementation of STS themes in social studies must be explored. The NCSS must continue to direct its organizational efforts toward integrating STS topics into the social studies curriculum. Preservation of individual freedoms and democratic principles in the 21st century may well depend on every citizen understanding the significance of scientific and technological developments.

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Paul DeHart Hurd

Closing the Educational Gaps Between Science, Technology, and Society

From the very beginning of modern science in the 1600s, the place of science in the education of pre-college students has been questioned. This issue has been argued for centuries, but never as vigorously as at the present time. The National Commission on Excellence in Education perceived today's school science curriculum as promoting a "rising tide of mediocrity" and "placing the nation at risk" (National Commission, 1983, p. 5). The commission called for a reconceptualization of instructional goals and the invention of a new curriculum suitable for modern times.

Throughout history and currently, school science courses have been organized and taught as mirror images of research disciplines found in universities, such as biology, chemistry, geology, and physics. Typically, learning goals include knowing the structure and basic principles of each discipline. Students are expected to acquire the vocabulary and language scientists use to communicate with other researchers. Learning activities are designed to encourage students "to think like a scientist" and to acquire the mathematical and observational skills essential for doing so. The primary goal of science teaching in the upper grades has traditionally been to prepare students for college and a career in science.

This mode of science teaching has been challenged throughout the history of public education in the United States. The alternate view is to consider achievements in science in terms of benefiting the common good and fostering the welfare of individuals. Instructional goals are seen as developing an understanding of the natural world and the acquisition of intellectual skills for living and participating in a culture that is increasingly characterized by achievements in science and technology. The central goal for an education in the sciences in the 1990s is perceived as enculturation or scientific literacy. Over the past 200 years, the debate on the social nature of science has ripened into an educational vision that brings science, technology, and society (STS) into a common discipline. The current reform movement in science teaching calls for instructional goals and a supporting curriculum taught in a social and personal context.

The purpose of this article is to present historical perspectives that have led to the rationale for an STS context for the teaching of school science. To make it possible for the reader to examine the course of thinking leading to the modern concept of STS, the language of the original authors is used in most instances, rather than a historical account written in the present (see Best, 1983, pp. 1-55).

Modern Science and Society

The introduction of modern science into western civilization around 1500 led Francis Bacon to write in 1620 as follows: "The ideal of

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human service is the ultimate goal of scientific effort," to the end of equipping the intellect for a "better and more perfect use of human reason." The subject matter selected to achieve this end should be that "which has the most for the welfare of man [sic]" (Dick, 1955, pp. 441, 487). These comments represent a context for an education in science that has persisted to this day, though rarely with a supporting science curriculum in schools.

One of the first Americans to recognize the potential significance of science in the affairs of our nation was Benjamin Franklin. In 1743 Franklin proposed the organization of an American Philosophy Society "to promote useful knowledge . . . and improve the common stock of knowledge" among people (Franklin, 1743, plate 3). He proposed a library to house a collection of scientific "experience, observations, and experiments . . . which, if well-examined, pursued, and improved, might produce discoveries to the advantage of some or all the British plantations, or to the benefit of [humankind] in general" (plate 3).

Thomas Jefferson in 1798, when vice president of the United States, noted that little practical science was being taught in elementary and secondary school science courses. Jefferson viewed the "sciences as keys to the treasures of nature . . . hands must be trained to use them wisely" (de Nemours, 1923, pp. 55, 159). He felt the major purpose of education in the sciences should be to enhance the progress of the country as a developing nation.

Jefferson invited his friend DuPont de Nemours, a medical doctor and minister of agriculture in France, to survey the teaching of science in U.S. schools and to make recommendations for improvement. De Nemours reported that teachers at all grade levels stated there were no textbooks that related science to the practical affairs of the nation. Jefferson asked Congress to appropriate money to write new science textbooks stressing "natural history and mechanics," beginning with the first grade; Congress refused. Thus the first effort to generate a science-technology-society curriculum died.

A New Context for Science in Universities

Stephen Van Rensselaer, a politician and an army general, founded in 1824 the institution of higher education that today bears his name. He was convinced that a university that considers the applications of "science to the common purposes of life" and fosters "the application of experimental chemistry, philosophy, and natural history to agriculture, domestic economy, the arts, and manufacturing" was essential for a more productive economy (Eddy, 1956, p. 10).

In 1861 a committee of Boston citizens, representing the associated institutions of science and arts, thought the time had arrived to consider "the happy influence of scientific culture on the industry and the civilization of nations . . . [and] for the cooperation of intelligent culture with industrial pursuits," recognizing that "material prosperity and intellectual advancement are inseparably associated." Furthermore, "to secure the great industrial and educational levels alluded to, it is proposed to establish . . . an institution devoted to practical arts and sciences, to be called the Massachusetts Institute of Technology, having the triple organization of a society of arts, a museum or conservatory of arts, and a school of industrial science and art" (Committee, 1861, pp. 3-5). The committee not only defined an institutional structure, but also a rationale, curriculum goals, and instructional strategies for a science-technology-society curriculum.

Another opportunity for a science-technology-society orientation in higher education was initiated in 1862 by the U.S. Congress with the passing of the Morrill Act. Colleges were to be established in each state "for the benefit of agriculture and the mechanic arts" (Eddy, 1956, p. xiii). In the years that followed, vocational agriculture became a school subject and continues to be focused on the practical applications of science and technology to economic endeavors.

A Philosopher on Science Teaching

One of the most quoted books on education and science teaching was written by Herbert Spencer, a British philosopher, in 1859. The central question of his essay was: "What knowledge is of most worth?" (Spencer, 1859, p. 5). Spencer deplored the lack of practical and useful knowledge in the school curriculum. He felt that whatever is chosen to teach should have "bearing on some part of life." He viewed the subject matter of school science courses as a collection of "dead facts" that "fail to make clear any appreciable efforts which they can produce on human welfare" (p. 14).

Spencer pointed out that nearly all aspects of industry, processes of living, and social development depend on science. However, "this order of knowledge, which is in great part ignored in our school courses, is the order of knowledge underlying the right performance of all the processes by which civilized life is made possible (p. 29). In addition to biology, chemistry, physics, and mathematics, Spencer pleaded for "yet one more science . . . bearing directly on industrial success—the Science of Society" (p. 90).

Spencer supported his position with a list of examples in which science, technology and society interact and also give rise to issues of human values. He noted that this approach to science education was likely not to occur due to the factual nature of school science curricula, "making the pupil a passive recipient of other's ideas, and not in the least teaching [the pupil] to be an active inquirer or self-instructor" (p. 47). The result is that once examinations are over, "the greater part of what has been learned, being unorganized, soon drops out of recollecting . . . what remains is mostly inert—the art of applying not having been cultivated; and there is but little power either of accurate observation or independent thinking" (p. 47).

The teaching of science as isolated facts, fragmentary and largely encyclopedic in character, persisted throughout the 19th century and on into the 20th (Noll, 1939, p. 5). The ability to describe natural phenomena was the recognized goal of science teaching. Student laboratory work was introduced for the first time as a method of science teaching in Girl's High and Normal School in Boston in 1865 (Downing, 1925, p. 23). From the beginning, laboratory "experiments" were confined to preprogrammed routines, requiring only that the student follow directions.

The Faculty Psychology Learning Theory

The aims of science changed somewhat in the 1870s with the rise of the "faculty psychology" learning theory. This theory viewed the mind as composed of distinct faculties or abilities, each of which could be trained by specific exercises. An example is the idea that memory can be improved by systematic drill in the memorization of factual information. Science, with its vast array of names, terms, and formulas, seemed ideal "not only to give mental discipline, but also to train the faculty of observation and to teach the scholar the experimental method of grappling with unsolved problems" (Clarke, 1880, p. 10).

This was a time of meticulous classification of plants and animals, of attention to details in laboratory experiments, and of complete systematization of knowledge. The fact that knowledge in this form was difficult for the learner to acquire was held to be in its favor—it possessed greater disciplinary value (Commission, 1938, p. 9). This notion persists today under the guise of such terms as "academic" and "rigor" in the reform of science teaching.

Spencer's idea of a science-technology-society curriculum disappeared by the end of the 19th century. There were, however, a few efforts to develop "practical science" course offerings (see, for example, *Practical Biology*, Huxley & Martin, 1880). The controversy between a discipline-bound school science curriculum and one oriented toward social progress continued on into the next century.

A Changing Culture

The 1890s brought about major changes in the U.S. culture. The country experienced a severe economic depression, the closing of the frontier and an end to free land, the beginning of a shift from an agricultural to an industrial society, and the beginning of mass migrations of people from Europe to the United States. The sum of these events and others was sufficient to foment calls for a reexamination of education in the United States.

The National Education Association responded to the demands for educational reform in 1892 by appointing a Committee of Ten to study school reform issues. After extensive deliberations, the subcommittee on science recommended that two years of science, one biological and one physical, be required of all high school students. The rationale underlying these courses was that they should prepare students for the "duties of life." Instructional objectives were defined as imparting information and training the powers of accurate observation, memory, and expression, along with developing skills in reasoning and logical investigation. The purpose of laboratory work was defined as "finding a relationship between facts and laws." The committee emphasized that "there should be no difference in the treatment of physics, chemistry and astronomy for those going to college or scientific schools, and those going to neither" (NEA, 1894, pp. 118-124).

Detailed outlines of model courses were developed for teaching physical geography, physics, botany, zoology, astronomy, meteorology, chemistry, geology, anatomy, physiology, and hygiene. Most of these courses were envisaged as half-year subjects. The course outlines had no references to technology although it was already evident that the United States was entering an industrial age. The outlines were formulated by scientists from universities. They chose to continue the prevailing discipline-bound, career oriented concept of school science not only as preparation for college but also for general education.

A New Science Era

Significant advancements in science and technology characterized the onset of the 20th century. A new era of science emerged from a host of discoveries in genetics, physics, chemistry, and the control of disease. A new phase of industrial development emerged in which scientists were employed in industry to produce or improve technological innovations.

Industrialization brought about demands for skilled workers. These workers would need more education and a new kind of education in the sciences. Science education issues for schools and colleges were argued anew. The debate centered on appropriate science requirements for college bound and non-college bound high school students, and between academic science and applied science (Bieglow, 1906; Caldwell, 1909; Galloway, 1910; Linville, 1909).

Courses were developed in which physics principles were derived from spring driven toys (Mann, 1906). Also common were courses in civic biology and additions to chemistry textbooks on such topics as methods of manufacturing sulfuric and nitric acids, smelting iron ores, mining sulfur, and assaying gold. These courses were developed primarily to attract more high school students into the science courses of universities by demonstrating the technological uses of science. These new courses were viewed by scientists as an educational fad and were soon replaced by diluted or simplified versions of college and university science courses (Hurd, 1949).

Another effort to stimulate more student interest in taking science subjects occurred in the years around 1915, when courses were developed in household chemistry, household physics, and girls' physics and chemistry. More ecology and environmental topics were added to biology courses. In all of these subjects, practical and technological applications of science were featured (Hurd, 1949).

Science Enrollment Concerns

In 1915 a course titled "general science," designed for use in the ninth grade, was widely taught throughout the United States. The course sought to relate science and technology with topics on the automobile, airplane, telegraph, radio, steam engine, farm machinery, health and safety (particularly in using electrical household appliances)—a panorama of technological developments characterizing the American scene at the time. The developers of general science felt the course would stimulate increased enrollment in high school science, especially in the physical sciences. It did not, although it did become the most successful innovative science course at the time in terms of student interest and enrollments.

The rapid growth of science and technology in the decade 1910-1920 was such as to bring into question the goals and subject matter of high school science courses. In 1913 the U.S. Bureau of Education appointed a committee to make recommendations for the reorganization of science in secondary schools in terms of the needs of pupils and those of society ("Reorganization," 1920, p. 22).

The committee perceived the values of science study as (a) "the development of interests, habits, and abilities . . . that have real significance" in people's lives and (b) the development of direct, effective, and satisfying methods of solving problems related to common needs and everyday life. The committee emphasized that the "body of facts and principles taught find their value and significance in the home, school, and community and in an intelligent understanding of the conditions, institutions, demands, and opportunities of modern life" (pp. 14-15).

The committee recognized the tensions that have existed between the school's responsibility for preparing students for the practice of science and that of a citizen's education in the sciences. The committee's response was that "the dualism that would classify subjects as cultural or non-cultural, as humanistic or scientific, as aesthetic or materialistic, with an implication of the inferiority of the latter to the former, is rapidly dying out" (p. 15).

The committee recommended changes in the point of view that shaped the traditional science courses of biology, chemistry, and physics and which were perceived as remote from human experience and welfare, neglecting connections with society—the "home, farm, and industries . . . and the pupil personally" (p. 15). Throughout the report, there was a clear indication that science, technology, society, and the individual should provide the framework for precollege education in the sciences. In the years following the report, except for general science, high school science courses remained unchanged by the recommendations.

New Social Tensions

The 1930s were characterized by a severe economic depression, the mechanization of farming, and increased automation in factories. The effect was a decrease in the demand for unskilled labor, which led to mass unemployment. These events, particularly those of the workplace, created a negative image of science and technology and their value to society. The teaching of science in schools again became a major issue of debate.

The U.S. Commission of Education appointed a commission to study the condition of science instruction in U.S. schools and to report the finding to the secretary of the interior. Outside of the courses in general science, commission members found little agreement among teachers on what should be the objectives of science teaching (Beauchamp, 1932, p. 8). Where goals existed, they were defined in terms of a science discipline and not from a social, economic, or personal perspective. Teachers identified themselves as instructors of physics, chemistry, or biology, not of science.

Laboratory work in courses was found to have become "an end in itself," formal and routine. Due to economic pressures, most schools were reducing the traditional 2-hour laboratory period to 1 hour and were recommending more demonstrations. No connections between science, technology, and society were found, although science and technology were seen to be at the root of the economic depression and social and economic changes.

In 1932 the National Society for the Study of Education appointed a committee to examine the role of science in education and to publish the findings. The committee took the following positions:

- Science teaching should contribute to "life enrichment through participation in a democratic social order."
- "The process of learning involves the integration of facts and experiences . . . leading to ideas."
- "The principles and generalizations [of science] that ramify most widely into human affairs" should be the focus of science teaching.
- Courses should be organized into units that represent major problems of everyday life and provide opportunities to utilize science in one's own life experience.
- Laboratory work should be viewed as an integral part of problem solving.

Although the committee viewed science in a social and personal context, the impact of technology on human affairs was not mentioned (Powers, 1932). The immediate effect of this report was to stimulate extensive research on identifying the principles of science most common in human experience and the skills and attitudes associated with scientific problem solving (Curtis, 1939, p. viii).

A commission was appointed in 1932 by the Progressive Education Association to study "the educational processes and goals relevant to the needs of the learners as they interact with their social medium in situations which confront young people in the home, school, community and the wider social science" (Thayer, 1938, p. v). The commission defined objectives for science teaching in the following categories (Thayer, 1938, pp. 59-291):

- personal living
- immediate personal-social relations
- social-civic relationships
- economic relations

To accommodate these objectives in human actions, the elements of critical thinking and a more flexible cognitive concept than scientific problem solving would need to be developed. These educational goals reflected the changing ethos of science regarding social implications that emerged in the 1930s (Bernal, 1939). The theme of science, technology, and society permeated the report and is considered in each of the goal categories.

Whatever influence the science-technology-society view of the 1930s had on school sciences was quickly obscured by the advent of World War II. During the war years, the prevailing view in science education was that school science courses should be oriented toward the education of technical resources—engineers and scientists.

Scientists and Educators in Conflict

In 1945 the concept of a social approach to science education was rekindled by a Harvard University report titled *General Education in a Free Society* (Buck, 1945). The Harvard Committee argued that science education should relate to the problems of human society.

> The facts of science and the experiences of the laboratory no longer can stand by themselves, since they no longer represent simple, spontaneous, and practical elements directly related to the life of the student. As they become further removed from the student's experience, more subtle, more abstract, the facts must be learned in another context, cultural, historical and philosophical. Only such broader perspectives can give point and lasting value to scientific information and experience for the general student. (pp. 155-156)

Furthermore, "science is not to be divorced from technology. Science and technology develop in parallel, each fructifying the other" (Buck, 1945, p. 150). The Harvard Committee perceived the student's own way of life and personal relation to the immediate environment to be the most critical integrative elements of the curriculum.

To achieve these ends requires an emphasis upon broad integrative elements both in subject matter and modes of thought that influence human thinking and welfare. The nature of these integrative science principles is amplified in the work of Margeneau and associates (Margeneau, 1972).

Following the close of World War II, the place of science and education in the sciences came under federal scrutiny. A report prepared at the request of President Franklin Roosevelt defined a policy that America's peacetime future in health, economy, and military security required the continuous deployment of new scientific knowledge to assure social progress. To implement this policy, however, would require at all educational levels—schools, colleges, and universities—"the complete revision and updating of course content in physics, mathematics, chemistry, and biology . . . including new textbooks and teaching aids and the introduction of imaginative and stimulating new equipment" (Bush, 1945, p. xvii). A President's Scientific Research Board was formed, and in conjunction with the American Association for the Advancement of Science Cooperative Committee, issued a report identifying a developing shortage of scientific researchers, technical workers, and qualified science teachers in the United States (Steelman, 1947).

The Bush and Steelman reports led to the formation in 1950 of the National Science Foundation (NSF), which was directed to improve the quality and quantity of science education in schools, colleges, and universities (England, 1982, p. 228). During the 1950s and 1960s, NSF financed the development of a series of precollege "course content improvement projects," with the broad directive of better preparing precollege students to engage in "real science" with opportunities to "think like scientists" (England, 1982, pp. 227-254). Financial support and the responsibility for preparing new, innovative textbooks were limited to research oriented scientists from disciplines represented in school science curricula. The place of science in society and as a cultural factor as well as the interaction of science and technology were sometimes mentioned as examples in the new texts, but were not substantively dealt with.

The overarching framework for the textbooks was: (a) science as a mode of quantitative inquiry; (b) the structure of various scientific disciplines; and (c) a "hands on" laboratory approach to science teaching. All goals and objectives were defined in terms of the structure of a particular discipline, leaving no place to consider integrative concepts of science and technology or those of science, technology, and society.

The career or professional approach to science teaching did not appeal to most students; they found the courses too detailed and technical, with too much to memorize. From the 1960s to the 1990s, the career oriented NSF courses declined in usage by schools (Klopfer & Champagne, 1990).

A report to President Eisenhower in 1959, *Education for the Age of Science* (President's, 1959), took a position somewhat between those of the professional scientists who fostered an education for the practice of science and those who stressed science in the context of its social, cultural, and personal impacts. The president's report noted that not only should modern education "sharpen the intellectual capacities and curiosities of each new generation . . . it must also produce citizens and leaders who will know how to use the knowledge and tools to advance social and cultural life" (p. 1).

In 1960 eighty science teachers and educators plus a half dozen scientists, with the sponsorship of the National Society for the Study of Education, published a volume titled *Rethinking Science Education* (Barnard, 1960). The writers based their essays on the roles of science and technology in liberal education, using a preliminary report of an AAAS Committee on "social aspects of science" (AAAS, 1957). They agreed that the time had come for a reform of science education. However, there was no agreement on what should be the nature of a society oriented science curriculum.

A Re-emergence of the STS Educational View

The NSF innovative science curricula of the 1950s and 1960s effectively blocked efforts to provide a science-technology-society context for precollege science teaching, judging from the science textbooks now most widely used in schools. In colleges and universities, STS curricula have been restored with new vigor and philosophical insights. In 1978 the American Association for the Advancement of Science published a resource directory of college and university programs and courses in the fields of ethics and values in science and technology (AAAS, 1978). Over 1000 colleges and universities were found to be offering courses, and sometimes undergraduate majors, related to science, technology, and values. Hundreds more were offering courses on topics that involved a consideration of science and technology concepts such as the natural environment, urban studies, agriculture and society, and biotechnology and the law.

The 1990s began with a greater support from the science community on matters involving an integrated view of science, technology, society, and human values than at any time in the past. Several factors are contributing to the renewal of STS as a valid context for a citizen's education in the sciences: (a) research in the sciences, which is increasingly focused on resolving social problems, for example, control of diseases, crop improvement, environmental safety, and new sources of energy, rather than in the development and refinement of new theories not likely to have immediate practical implications, (b) gradual shifting of research centers from universities to industry and agencies of the federal government, with less than 40 percent of researchers currently located in universities; (c) philosophical considerations of science as social knowledge; and (d) general acceptance of science and technology as an integrated system. A number of new journals and newsletters provide a means for national and international discussions on the problems and issues related to STS education (see, for example, the journals, *Science, Technology, and Human Values, Agriculture and Human Values, Issues in Science and Technology* (National Academy of Sciences), *Bulletin of Science, Technology, and Society,* and newsletters, *Science, Technology and Society, Teachers Clearinghouse for Science and Society Education,* and the newsletter of the National Association for Science, Technology and Society).

Educational Reform in the Sciences

Since the 1970s, hundreds of national panels, commissions, and committees have called for the reform of education in the sciences There is widespread agreement that the traditional discipline-bound science curriculum with the principal goal of preparing students for the practice of science is outmoded in terms of the ethos of modern science, the nation's economy, and citizens' education (see, for example, Hurd, 1984, 1985, 1986, 1989).

The NSF Advisory Committee for Science Education in 1970 recommended that NSF modify its traditional commitment to science career education for all students and place more "emphasis on the understanding of science and technology by those who are not, and do not expect to be, professional scientists and technologists" (Report, 1970, p. iii). The committee stressed one overriding goal for the future: "to educate scientists who will be at home in society and to educate a society that will be at home with science" (p. iii).

The science education reform issue was brought to a focus in 1983 with a report by the National Commission on Excellence in Education titled: *A Nation At Risk: The Imperative for Educational Reform*. The commission recommended that

> the teaching of science in high school provide graduates with an introduction to: (a) the concepts, laws, and processes of the physical and biological sciences; (b) the methods of scientific inquiry and reasoning; (c) the application of scientific knowledge to everyday life; and (d) the social and environmental implications of scientific and technological development. (National Commission, 1983, p. 25)

The National Council on Science and Technology Education of the American Association for the Advancement of Science takes the position that science and technology be taught to the end that it benefits society and the lives of students. The council's view is stated as follows: "The terms and circumstances of human existence can be expected to change radically during the next human lifespan. Science, mathematics and technology will be the center of that change—causing it, shaping it and responding to it. Therefore, they will be essential to the education of today's children for tomorrow's world" (AAAS, 1989, foreword).

In 1990 NSF announced new guidelines for the improvement of science curriculum and instruction "for all students, not just for students moving toward careers in technical fields." The aim is "to boost science literacy and citizen understanding of science related issues . . . the influence of technology on the physical world and the human condition—at every educational level." Science instruction "must deal with improving critical thinking and habits of mind developing better understanding of the contributions of science to the lives of individuals and societies, and generating stronger student commitment to positive value systems and ethical conduct" (NSF, 1990, p. 1).

The Future

After nearly 200 years of debate within the scientific and educational communities as to what a citizen's education in science and technology ought to be, we now find substantial agreement. The current educational reform movement is calling for a reconceptualization of science teaching to bring it into harmony with the ethos of modern science and technology. This effort is envisaged as not simply a reform of science teaching but a renascence, a new vision for science courses.

It is expected these new courses would be invented with a full recognition of recent developments in the cognitive sciences, putting students more in control of their own learning (Resnick, 1983, pp. 477-448). The new curriculum is to be future oriented, not in the sense of predicting a future, but rather in providing students with the knowledge and habits of thought for shaping and managing a favorable future for human survival and a desired quality of life.

The intent of this article has been to show that the current STS goals for science education are deeply embedded in our culture and have been for the past 200 years. Today, we argue anew the place of science and technology in our society and what they should mean for the welfare of the individual and the nation. The current reform movement in science teaching, backed this time by hundreds of national reports and political forces, is yet another plea for the teaching of science and technology in the context of society and social needs (see Hurd, 1984, 1985, 1986, 1989).

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Karen F. Zuga

The Technology Education Experience and What It Can Contribute to STS

As technology educators begin to participate in discussions and programs about science, technology and society (STS), they will have much experience to contribute. As technology education has evolved, examples of STS-related curricula can be found. However, technology educators are encapsulated by their experiences with technology, and their attitudes about technology will influence their decisions about appropriate content and study.

Contemporary technology education has been shaped by curriculum efforts and political associations. This article presents a short history of technology education with a discussion of contemporary technology education programs in order to illustrate the common thoughts and experiences of technology educators. This discussion leads to several of the ways in which technology educators can contribute to the study of STS.

Evolution of Technology Education

Technology education has evolved over the past 100 years from a variety of educational programs concerned with the study of industry and technology and from the influence of association with a variety of fields. The history of technology education reveals liaisons with vocational educators, elementary educators, and more recently, engineering technology and business educators. Moreover, contemporary technology educators maintain all of these liaisons today. As a result, technology education as a subject matter in the schools has a complex pattern of mission, content, and delivery throughout the United States. It is a field of study in continuous transition. Contemporary technology educators have often had very different experiences and maintain a variety of liaisons due to local and national policies.

Efforts designed to apply principles of theory through practice provided the bases from which the field drew, united, and evolved. Late 19th century educational programs in Scandinavia, Russia, Germany, and the United States coalesced here after the turn of the century to create the field of study called the industrial arts (Bennett, 1937; Smith, 1981). The educational ideas that influenced early industrial arts educators related to several purposes. Vocational education as a purpose was present, but general education as a purpose was prominent. In addition, the level of education at which industrial arts was being practiced began in the elementary school and extended through secondary education.

Drawing upon the technology and terminology of the 19th century, the study of industrial arts focused on the knowledge, skills, and attitudes of craftspersons. In that, era, when wood, metal, textiles, and ceramics dominated the materials in use, industrial arts was a suitable term for conveying what we mean today

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by the term technology. During the first half of the 20th century, the hallmark definition of industrial arts was created. Industrial arts was to be "a study of the changes made by [humans] in the forms of materials to increase their values, and of the problems of life related to these changes" (Bonser & Mossman, 1923, p. 5). The dominant focus, however, was often on the first half of the definition. As our use of technology evolved, industrial arts education began to evolve by increasing the special curriculum topics related to materials and processes.

Finally, in 1947, a group of industrial arts educators introduced the need to "reflect technology" within the curriculum (Warner et al., 1947), and a period of curriculum experimentation ensued. With major innovations occurring in technology, the traditional organization of knowledge restricted the ability to accurately represent technological processes in industrial arts education. The explosion of knowledge with respect to materials and processes also created curriculum difficulties involving logical organization and timeliness. The field had been based on providing instruction about individual use of materials and processes, a task that was becoming more difficult to achieve as mass production in industry was evolving. Nonetheless, technology educators of that era and the present were and are immersed in the tradition of teaching about the changes made in materials through processes in order to (a) fulfill human needs and wants and (b) explore the related social problems. Technology educators view laboratory practice as fundamental to contemporary technology education.

The mid-20th century discomfort with industrial arts curricula began to force several innovations. At this time, the concept of studying technology from a broader systems perspective involving a taxonomy of processes was introduced through the Industrial Arts Curriculum Project (IACP) (Towers, Lux, & Ray, 1966). Other curriculum projects of the time sought to reorganize curriculum by similar taxonomic designs, in addition to learner-centered, social functions and problem solving designs (Face & Flug, 1965; Maley, 1973; Yoho, 1969). Professionals in the field, although steeped in the tradition of materials and processes instruction, began to grapple with alternative forms of curriculum organization.

Contemporary Technology Education

Contemporary technology educators bear the influence of the past on their beliefs and practices. Technology education is still grounded in laboratory practice and largely involves instruction about how people change materials through processes in order to address social needs, wants, and problems. However, the influence of looking at technological systems has been strong. Today, technology educators tend to organize their courses around the human adaptive systems (De Vore, 1980) of manufacturing, construction, communication, and transportation (Snyder & Hales, 1981), with some adding a category for energy and power utilization (Illinois State Board of Education, 1984). Within these areas, content is selected with a systems model based on inputs, processes, and outputs (Hacker & Barden, 1988; Towers et al., 1966). Technology educators continue to struggle with maintaining fidelity to applied practice while seeking a broader scope of knowledge regarding technology.

With the introduction of a systems approach to the study of industrial arts through the IACP (Towers et al., 1966), efforts to introduce societal issues into the study of technology education continued. In the study of industrial technology, defined as manufacturing and construction in the IACP, the organization, management, and control of work through production was incorporated as content. The educational programs that resulted from the IACP placed equal emphasis on the organization, production, and control of the manufacturing and construction industries (Lux & Ray, 1970, 1971). Other less successful, but noteworthy, contemporary programs also were incorporating similar concepts into the study of industrial technology during the same time period (Face & Flug, 1965; Yoho, 1969).

As technology education curriculum continued to evolve, the evolution of the study of energy and power from the study of automobile mechanics provided a fertile ground for incorporating science, technology, and society into technology education courses. Incorporating the concerns of technologists through topics related to sources of energy, converting energy to power, and determining the efficiency and safety of the process, technology educators began to explore and teach about the scientific principles involved in these processes, the effects of these processes on the environment, and the social debate over the current and future use of energy (Schwaller, 1980). Energy and power courses tended to incorporate science, technology, and society from the perspective of the technology educator by organizing and selecting curriculum content from technical processes.

Related to energy and power courses, but developed for an entirely different purpose, a "Principles of Technology" program was adopted by some technology educators (Hammer & Thode, 1989; Sherer, 1986). This interdisciplinary program was organized by selecting concepts from physics and incorporating mathematics and examples of how technicians use this information. It was developed for technician training, but has interested technology educators who like the applied nature of the course. The difference between this program and an energy and power course is in the derivation of the conceptual outline of content. Energy and power courses have tended to focus on concepts of technology, and the "Principles of Technology" program has focused on science concepts.

Recently, Maley (1987, 1989) has attempted to blend science and mathematics with traditional project activities from technology education. This approach focused on the topics normally selected for curriculum in technology education and incorporated related concepts from science and mathematics. For example, a technological device such as a windmill is identified as a topic of study, and the function, design, and construction of a windmill are related to the science concepts of friction, energy conservation, and Bernoulli's Principle, and the mathematics concepts of using formulas to calculate distance, volume of air, and mass.

Within the context of technology education, many technology educators are experimenting with incorporating science and social studies concepts and issues. However, it is through their interest in and knowledge about technology, especially knowledge of materials, processes, and human adaptive systems, that technology educators derive their conceptual structures and then incorporate related and relevant information from other disciplines. Technology educators have always been concerned with how people modify their environment through the use of materials and processes, the efficiency of the use of materials and processes, the aesthetics of the results, and the morality of those actions. Understanding these actions and making "wise" choices from the growing number of options available today has led technology educators to recognize the need to incorporate information about science and society.

Potential Contributions to STS

Technology educators have much to offer in partnership with science and social studies educators with respect to the conceptualization of STS. Recent curriculum reorganization in technology education has caused the delineation and organization of a body of knowledge about technology deemed appropriate for elementary and secondary education. Moreover, the hallmark project method of instruction, involving technical problem solving, provides a sound basis for accessing the knowledge, skills, and values related to technology. The effort to define STS and a means of integrating relevant instruction about STS could benefit from the recent experience and efforts of technology educators.

Uniting Content and Process

Early biases in academe that separated knowing from doing on the strength of Greek philosophy and tradition still influence us today (Hickman, 1990). The Greeks separated the educated class from the servant class through a division of labor and a differential form of education. Citizens were educated to be thinkers while servants were educated to be doers, forever instilling in western culture an artificial dichotomy that separated thinking and doing (Bennett, 1926; Waetjen, 1989). Although many have argued the fallacy of this notion (Dewey, 1916, 1938; Hickman, 1990; Woodward, 1898), the attitude prevails today in educational ideas such as "back to the basics" and in the educational prescriptions of Adler (1982), Ravitch (1985), and others.

The message from the academic rationalists has been that the study of technology does not belong in the school; it is for job training, and such activity cannot help to educate liberally. Countering this attitude, educators who have seen the power of knowledge applied to activity and the pervasive effects of our use of technology in this society have struggled to promote, initiate, and provide sound educational programs about technology for liberal education. Their point is that people create and use technology to modify their environment, that this is the major activity of western civilization, that efficient practice involves knowing and doing, and that liberally educated children ought to study and know about technology in order to make wise personal and collective decisions about the use and control of technology (Boyer, 1983).

Fired by these ideas, technology educators have been working to create a comprehensive study of technology that is based in application, is integrative of all disciplines, and helps people to wisely and efficiently alter our environment. Technology educators believe that providing opportunities for students to solve technical problems through the study of human adaptive systems allows students to apply principles of science and mathematics while also clarifying values about our use of technology, thereby making technology education a true liberal study (Waetjen, 1989). These beliefs have led to a structuring of the knowledge of technology for the purpose of instruction.

Structuring Technological Knowledge

Technology educators will be able to contribute a view of the organization and structure of the knowledge of technology to the study of STS. Early in the history of the field, the concern for delimiting and organizing the knowledge was present. That concern has continued due to the dynamic nature of technological knowledge.

Early industrial arts educators recognized the many ways in which technological knowledge could be organized. Classifying industries, manipulative processes, self-expression, historic sequence of industrial development, materials, and uses of products (Bonser & Mossman, 1923) were all recognized ways of organizing technological knowledge. Organizing curriculum by materials such as woods, metals, and plastics and processes such as drawing, graphic arts, and automotive mechanics served until mid-century.

Interest in reflecting a more accurate conceptualization of technology led several industrial arts educators to search for both appropriate content and the best way of structuring that content (De Vore, 1980; Olson, 1963; Towers et al., 1966; Yoho, 1969). The quality, explicitness, and operational adequacy of the curriculum proposals varied. To this day, some of the most detailed and explicit content structures exist in *The Rationale and Structure of Industrial Arts Subject Matter* (Towers et al., 1966) and the *Illinois Plan for Industrial Education* (Illinois State Board of Education, 1984).

The variety of curriculum proposals developed during this period created a need for a synthesis of ideas that would lead to a consensus on the part of technology educators about appropriate content for instruction. This was achieved in a synthesis document that reported the results of a series of curriculum negotiations held at the beginning of the 1980s. That synthesis focused on curriculum organization by manufacturing, construction, communication, and transportation as human adaptive systems (Snyder & Hales, 1981).

Due to the rapid evolution of technological knowledge and the low usage of textbooks in technology education, technology educators continue to place a priority on the ability to identify and structure appropriate knowledge for instruction. As we move from an industrial to an information society, new technological systems, processes, materials, and societal problems will force technology educators to continually modify the substance of instruction and, possibly, curriculum plans. These evolutionary conditions cause technology educators to rely on many sources of curriculum materials and their abilities to synthesize technological information, thereby placing textbooks in minor roles with respect to content selection.

As a result of our continual revision of technological means and the need to reflect this in technology education curriculum, technology educators will contribute experience and knowledge about organizing the subject matter of technology to STS programs in elementary and secondary education.

Integrating the Disciplines

Because the concern for selecting and structuring knowledge about technology has been a tradition in the field, technology educators also have a basic understanding of the roles of science, technology, and society in the STS equation. The relationships have been acknowledged since the first manual training programs were created (Woodward, 1898). The distinction of science as a study of our environment and technology as a study of how people alter the environment has also been recognized (De Vore, 1980; Lux, 1984). Of the differences, Lux (1984) states:

> Science is a study of what is. Technology is a study of what might be and how to bring it about. . . . As a school subject, science offers a systematic study of knowledge about nature, while technology is a systematic study of how people alter nature to make it of more use or value. . . . *Knowledge* (ology) of *practice* (techn) is technology. Thus, in science one can study wave phenomena, but for technology to be something different, it must demand something else. It requires, for example, that one harness wave energy for a useful purpose. (p. 18)

Technology educators are not likely to confuse the purposes of scientific, technological, and societal inquiry, and they understand the relationships among and between science, social studies, and technology. How we create and use technology is a societal decision. The way we use technology creates new meaning in both scientific and social endeavors (Hickman, 1990; Ihde, 1990).

Application as a Means of Instruction

From the beginning of the earliest efforts to study technology, educators who were involved in this activity were aware of the role application plays in making content meaningful. Of application Woodward (1898), a manual training advocate near the turn of the century, wrote, "Science and mathematics profit from a better understanding of *forms, materials*, and *processes*, and from the readiness with which their principles may be illustrated" (p. 133). Industrial arts advocates reiterated, "The primary purpose of the hand work is to help to make meaning clear and to give a reality of personal experience. This makes for permanence of both interest and the possession of values derived as ideas and attitudes or habits" (Bonser & Mossman, 1923, p. 16).

Application through the study of the occupations for general educational purposes was advocated by progressive educators such as Dewey, who in 1938 wrote:

> In the degree in which intelligent observation is transferred from the relation of means to ends to the more complex question of the relation of means to one another, the idea of cause and effect becomes prominent and explicit. The final justification of shops, kitchens, and so on in the school is not just that they afford opportunity for activity, but that they provide opportunity for the *kind* of activity or for the acquisition of mechanical skills which leads students to attend to the relation of means and ends, and then to consideration of the way things interact with one another to produce definite effects. It is the same in principle as the ground for laboratories in scientific research. (pp. 84-85)

Laboratory practice has been fundamental to the study of technology, whether the emphasis has been on materials and processes or the study of the human adaptive systems. The activities conducted in technology education labs have been created to illustrate the relationships of means to ends, of content to practice, and of our use of technology to social problems. Whether students create prototype products, retrofit vehicles for energy efficiency, operate small manufacturing businesses, construct modern housing modules, or actively research, design, and test materials and processes, the activity is to be illustrative of our technology and the consequences of our use of a given technology.

As noted above, Dewey (1938) compared the purpose of shops and kitchens in schools to the purpose of scientific research laboratories. While most educators support a variety of educational laboratories in schools, few discuss the unique activities that take place in those laboratories. Much of the activity in research and school science laboratories involves making observations of phenomena in order to understand and demonstrate hypotheses, theories, and laws. In technology education laboratories, the activity unites theory and practice through action in order to modify and create usable products. The difference may be subtle, but it denotes the uniqueness of technology. Theory without practice or practice without theory cannot be technology (D.G. Lux, personal communication, February 15, 1990).

Theory and practice as making and doing has been and remains central to technology education and has always been attempted in order to unite knowing and doing in an effort to develop valuing. The expertise of integrating content and practice in a technological application is one of the major contributions technology educators will make to STS educational programs.

Summary

As we plan and implement STS programs in schools with teams of teachers, we need to search for the relationships within our respective disciplines as well as our focus upon our own subject matter. Technology educators bring a knowledge of the disciplinary structure of technology, the realization of relationships among science, social studies, and technology education, and a history of uniting theory and practice through laboratory activity.

Technology educators, however, are steeped in the traditions of their field. They view the creation and utilization of technology as an effort that is distinct from science. Because of this predominant view, technology educators do not tend to combine science and technology as if it were one subject or discipline. This is not an example of dualistic thinking by technology educators, for the way in which technology education is conducted by uniting theory and practice illustrates the opposite. Technology educators are able to contribute a clear definition and understanding of technology without muddying the waters.

The differences between science as it is studied and taught in colleges of science and engineering as it is studied and taught in colleges of engineering are understood by technology educators. The fact that both faculties teach and conduct inquiry is not confused with the *purpose* of that teaching and conducting of inquiry. Yet, with this separation of the purposes of science and technology, technology educators understand well the focus on society in the STS equation. Working together with experts from science and social studies enables interdisciplinary study that reflects upon the connections between and among science, technology, and social studies, and helps us to address the questions concerning our pursuit of science and technology.

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Jerry Kowal

Science Technology, and Human Values: A Curricular Approach

The unfolding scenarios of our global future take on a variety of images as projections of the direction environmental stresses may lead our global community. Clark (1989) writes:

> The global pattern of light created by today's civilizations is not unlike the pattern of exuberant growth that develops soon after bacteria are introduced to a nutrient-rich petri dish. In the limited world of the petri dish, such growth is not sustainable. Sooner or later, as the bacterial populations deplete available resources and submerge in their own wastes, their initial blossoming is replaced by stagnation and collapse. (p. 47)

This harsh analogy need not be the path followed by humanity. While a wealth of challenges threaten our human condition and environmental stability, there are also a wealth of opportunities to improve on these concerns if comprehensive and creative thinking are employed. The human element is the greatest threat to the human condition and, at the same time, the greatest asset.

To alter current trends, significant changes must be made in the manner in which we manage our existence. The information and tools to make these changes can be obtained, but the will-to-change remains as the essential prerequisite for correcting our problems. How we act as a world culture to address human needs and meet the challenges of today and tomorrow depends on our ability and our willingness to view the world as interrelated and its inhabitants as interdependent.

What is essential in the college curriculum is an integrated format that links the disciplines and demonstrates their interconnectedness. In addition, critical thinking, problem solving, and human values are ingredients necessary to assess the human perspective. This article addresses the interrelationship between science and technology and considers how an interdisciplinary approach can be woven into an education program. It then provides an example of a college program that is applying the principles discussed.

The Science-Technology Relationship

Since our primitive beginnings, humans have sought to change the shape and form of materials, employing technology to protect themselves from exposure to the elements, provide for the cultivation of domestic crops and animals, control the effects of disease, and improve the mobility and communication potential among the world's peoples. While science has brought us understanding of the natural world, technology has brought us a means of control and adaptation. Our ability to grow and to thrive is essentially a result of our scientific understandings and the technological developments that have paralleled this growth in understanding.

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Our progress has not come without cost, however. The ability to survive and thrive has taken an immeasurable toll on the global environment. The same technology that has allowed us to reach high levels of development now threaten our very survival on earth. The science we have come to know and understand has apparently been addressed in isolation, beyond the interrelatedness of social, environmental, and economic systems.

Commoner (1974) and Berry (1977) have criticized scientists for a reductionist or specialist perspective that explores or limits understandings to isolated and narrow frames of reference rather than the broader contexts of systems and their interactions. Technology has often been identified as the cause of our problems. It is not technology that is at fault, however, but rather the human misuse of technical means. Many of our contemporary ills can be directly attributed to a lack of understanding of or concern for the effects of our actions on the various natural and fabricated systems in our world.

The environmental stresses that are threatening our planet have their roots in technology but are not caused by technology. People employ technology, both good and bad, to meet human wants and needs. As Ellul (1964) explains, technology can be defined as "techniques." We use various techniques as means to ends, with greater or lesser effects on natural and societal systems. Environmental sciences can assist us in the understanding of the natural world and the effects of technologies on natural systems, but science alone does not offer solutions.

Myers (1990) calls for a holistic form of science. This is "an expansive form of knowledge encompassing the four 'knowings': *the know-what of scientific inquiry; the know-how of technology; the know-who of social institutions; and the know-why of values*" (p. 56). In a comparable sense, the concept of "appropriate technology" requires that technologists and users of technologies select products and processes in light of economics and effects on social well-being, human health, and the environment (De Vore, 1980). It requires, further, that the products and processes be matched in scale to their end-use needs.

For example, chlorofluorocarbons (CFCs), used as spray-can propellants, could have first been considered appropriate as a technology for spray paints, hair spray, insecticides, etc. CFCs are inexpensive, nonreactive in the lower atmosphere, and nonreactive with spray-can contents. Further study, however, revealed that CFCs, although nonreactive and long lived at the tropospheric level, are reactive at the stratospheric level and diminish the protective layer of ozone that shields the earth from excess levels of ultraviolet radiation. From a human health and environmental perspective, CFCs are now inappropriate, as they threaten organisms and ecosystems. Although inexpensive and particularly effective for what they do, they are inappropriate on a broader scale, which cannot be ignored. This more comprehensive approach strives to view and respond to the relatedness of issues in the applications of technology.

General Education and the Common Core

Creating a college curriculum that links the disciplines while at the same time developing skills in critical thinking and problem solving is easier to support than to achieve. Our students need not only a rationale for these features but also a strategy for integrating these elements into the curriculum.

A preoccupation with facts and quantifiable outcomes has dominated instructional design in public institutions, in an attempt to equate quantity with quality. While academic content is important, many recognize that without an ability to clearly discern valued from unvalued outcomes, critically analyze situations, and develop problem-solving strategies, students are left with a collection of general knowledge issues they are unable to evaluate, integrate, or direct to appropriate ends.

When set in a broad-based, integrated format, issues in science and technology provide an excellent opportunity for the study of values, critical thinking, and problem solving. On the other hand, teaching science as a collection of facts, principles, and laws provides little opportunity for questioning or valuing. Taking what scientists say as indisputable is limiting and even dangerous. Jones and Zucker (1986) write:

> Facts taught out of human and social context leave important gaps in understanding that make application of scientific knowledge more difficult. (p. 41)

Understanding the realms of science and technology, along with their limits and linkages, will not only provide our citizenry with better understanding but will lead us to more effective solutions to problems. It then becomes the role of academic institutions to foster a curriculum that addresses integrated content while also placing emphasis on the study of values, critical thinking, and problem solving.

As disciplines strive to narrow their scope and develop more concentrated programs, the greater breadth of academic experience resides in the general education program. What constitutes an appropriate general education program, however, is an issue of great debate. More than a collection of courses, general education must represent a weave of disciplines and ideas. Boyer (1987) concludes:

> To achieve these ends, we suggest as one possible approach *the integrated core*. By the integrated core we mean a program of general education that introduces students not only to essential knowledge, but also to connections across the disciplines, and, in the end, to application of knowledge to life beyond the campus. The integrated core concerns itself with the universal experiences that are common to all people, with those shared activities without which human relationships are diminished and the quality of life reduced. (p. 91)

As used in this text, general education is curriculum based and consists of a core program and distribution requirements comprised of selected courses. The core curriculum, then, is what all students experience in common. It reflects the role and mission of the institution, and it intertwines content with the competencies, student attributes, and higher order abilities that provide students with the opportunity to know, to think, and to do. The core must be progressive (vertical) and provide for student growth throughout the undergraduate experience. Distinguishing general education from liberal education, Pedersen (1987) writes:

> "Liberal education" does not represent any particular academic disciplines or fields, whether they be history, music or science. Rather it characterizes a manner of viewing and knowing reality (what I will call a perceptual paradigm) that is highly individualistic and humanistic. (p. ix)

Within this context, general education is a distribution of courses from which students select a given subset; the core is a collection of courses that all students take in common; and liberal education is that which is gained by students as a result of the total experience. As students seek their more narrowed ends (majors), the liberal education component seeks to show connections between disciplines and provides opportunities for students to think, debate, and formulate their own conclusions.

It is not uncommon to find faculty and departments competing for access to general education course offerings. In an age of diminishing student pools and increased competition, the general education program is used as a means of access to potential majors. Instead, general education can be a shared opportunity to bring a broad foundation of educational continuity to students as well as to the faculty.

In a similar sense, if an institution in any way expects to tap all options for common learning, at no time should a simple dividing of the academic pie be considered. Long ago, Dewey (1938) warned:

> It is the business of an intelligent theory of education to ascertain the causes for the conflicts that exist and then, instead of taking one side or the other, to indicate a plan of operations proceeding from a level deeper and more inclusive than is represented by the practices and ideas of the contending parties.
>
> This formulation of the business of the philosophy of education does not mean that the latter should attempt to bring about compromise between opposed schools of thought, to find a via media, nor yet make an eclectic combination of points picked out hither and yon from all schools. It means the necessity of the introduction of a new order of conceptions leading to new modes of practice. (p. 5)

Following Dewey's reasoning, the task is not to design a general education program based on who yells the loudest or the longest or to use compromise as a rationale for curricular design. The basis of an appropriate rationale is centered on the student; how students learn, what is necessary for a cohesive educational experience, and how students can be best prepared for a future, which is at any given time, unknown. Boyer (1987) writes:

> General education is not complete until the subject matter of one discipline is made to touch another. Bridges between disciplines must be built, and the core program must be seen ultimately as relating the curriculum consequently to life. (p. 91)

Boyer further states:

> This nation and the world need well informed, inquisitive, open minded young people who are both productive and reflective, seeking answers to life's most important questions. Above all, we need educated men and women who not only pursue their own personal interests but are also prepared to fulfill their social and civic obligations. And it is during the undergraduate experience, perhaps more than at any other time, that these essential qualities of mind and character are refined. (p. 7)

To have meaning, such an educational program must be addressed in a real-world context, the context of futures in science and technology. The future in science, as Kranzberg (1968) suggests, affords limitless possibilities, and futures in technology require cautious advancement in light of social, ethical, and environmental restraints. Together these two disciplines provide a rich inventory of contemporary issues to support study in lifelong learning.

Thus, technology and the technological choices of today and tomorrow are necessary elements in the format of the common core. Almost every critical issue in our society has technological implications. Yet traditional programs in general education seldom include technology, the integration of science, technology, and other disciplines, or an emphasis on critical thinking, problem solving, and human values in the context of contemporary issues.

A Curricular Approach

The CORE curriculum at Western State College of Colorado addresses the issues discussed above in the broader sense of global imperatives. More specifically, the junior-level science and technology CORE course focuses on the human side of science and technology and interrelationships with other disciplines. Some of the goals of this program are specifically focused on critical thinking, problem solving, and human values in the context of integrated studies.

The science and technology CORE course has two major emphases. The first is the enhancement of desired student outcomes in (a) the competencies, (b) student attributes, and (c) higher order abilities. The second emphasis is to address the 12 specific goals of the course, which relate to the nature of science, technology, and the changing human condition (e.g., methods of scientific inquiry, costs and risks of alternative futures, moral and ethical issues in science and technology, and appropriate technological means).

The concepts are introduced and supported by events, issues, and future prospects, which are the topical and more content-oriented components of the course. The primary content varies and is ordered around the 12 goal statements. The variability of the content allows for new issues to be introduced as the need dictates, while maintaining the course goals as a foundation. The present class structure provides for a brief introduction on the nature of science and technology, followed by two 6-week clusters—one on environmental ethics (the greenhouse effect) and the other on evolutionary processes (human evolution and genetic engineering).

The content is delivered in large group sessions, while the discussions, analyses, quizzes, and assignments are handled in small breakout sessions. For example, the cluster on the greenhouse effect uses group lectures to address the nature of the atmosphere, industrialization, alternate technologies, mathematical modeling, and public policy. Each of these topics is delivered by an expert in the field. The cluster on evolutionary processes covers paradigms in scientific thinking, the fossil record, molecular genetics, and genetic engineering.

The course goals are addressed at several junctures in each of the clusters as dictated by the topics. In the remainder of this section, examples are given of some of the course goals and how they are carried out.

Course goal No. 3. *Students will understand that "truth," as such, does not exist in science but rather that scientific knowledge progresses in a historical context.*

Within the cluster on the greenhouse effect, students are exposed to the evidence that supports contemporary theories on the evolution of the atmosphere. Not only is it difficult to look backward and determine how our atmosphere evolved, but it is even more difficult to project how the atmosphere may change and what effects this will have on climate. Since science is tentative, what seems true today may not be so tomorrow. The many changing variables that are likely to have an effect on world climate must all be evaluated.

The use of mathematical models to substantiate claims and predict outcomes provides data necessary for good decision making. Public policy options can then be structured to reflect valid instances that are supported by the new-found data. Throughout the course, students review data and suggest options that may be initiated by weighing information to make quality choices. The use of models and the initiation of policy are used as a means of validation and eliciting an appropriate human response.

Course goal No. 6. *Students will be sensitive to the type of issues they will be called upon to consider in relation to scientific activities and technological endeavors as active members of this society. Decisions concerning genetic engineering, high-energy physics, energy and resource choices, behavioral control, etc., will require that students understand the process of inquiry and reasoning and be prepared to make value judgments.*

Having been grounded in basic genetics and understanding the general nature of the DNA molecule, students can account for genetic inconsistencies and their manifestation as genetic disorders. Cognizant of the genome project, whose goal is to map the entire human genome, students were asked to read "The End of Insurance," a scenario presented by Wright (1990). The basic premise of the article is that all persons seeking health insurance coverage would eventually be required to submit to a genetic analysis to determine whether or not they possessed any genetic maladies. Insurance premiums would be adjusted according to the results of these tests.

Students were required to address several aspects of this issue and to develop a policy for insurability based on their ethical perspectives. Value judgments were the principal elements of this assignment.

Course goal No. 11. *Students will be able to differentiate between "hard" and "soft" technologies and be sensitive to "appropriate" technological means.*

The concepts of hard and soft technologies were first described by Lovins (1976). Hard technologies represent the status quo—rapid expansion of centralized high technology power plants driven by nonrenewable fuels. Soft energy technologies, on the other hand, are diversified, rooted in efficiency, use renewable fuels, and are matched in scale and quality to their end-use needs.

Time magazine (1991) recently featured an advertisement that pictured four leaders of Middle East countries who have in some way influenced our access to oil or have otherwise threatened our national security. The focus of the ad was to suggest that nuclear power was the only alternative to these national security problems. Throughout our classroom deliberations, students debated and analyzed the concept of global warming itself as well as energy options, including the most effective opportunities afforded by conservation. The appropriate technology perspective as well as understanding hard and soft technologies gave students several options to consider, but no obvious and clear-cut solutions. Nuclear power is not the only option. Informed decision making was our focus, and there is seldom only one "right" answer.

As students participate in this course and in other CORE courses, they experience an uneasy feeling. This stems from the courses being less content oriented and more directed toward debate, integration of content, critical thinking, problem solving, and the establishing of personal values. The human dimension also places a great deal of validity as well as tension on the decision makers. This posture is unlike most other classes but very much like real-life situations. This structure reflects the quality of education that the faculty at Western State College feels is necessary for graduates of an exemplary institution.

Conclusion

The magnitude and complexity of issues in our contemporary society require an understanding of relationships as well as facts. The interactions of elements within natural as well as social systems demands a comprehensive perspective and a view of disciplines that is interrelated and interdependent. The paradigms of today must change to embrace the complex nature of systems, with the greater human good as the central focus. Values must be an integral part of proposed solutions.

As college graduates prepare to meet the challenges of today and tomorrow, a renewed vision must be evident. The science and technology core course at Western State College works toward establishing this vision.

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Carolyn Carter

Science-Technology-Society and Access to Scientific Knowledge

It is perhaps ironic that two of the most critical issues facing science today—access to scientific knowledge and the "public image" of science—stem in part from a successful attempt to portray science as removed from social concerns. The alienation of much, if not most, of our society from science as a way of knowing may be examined in part as a result of a strenuous attempt in the 17th century to depict the fledgling discipline of professional science as outside the domain of human or secular affairs.

Struggling to secure the survival of science and the young scientific establishment from the turbulence of battles between church and state, the selling of science as acontextual provided a useful strategy in dealing with the political turmoil and intellectual instability of the time (Bordo, 1986). As part of the professionalization of science, the abstraction and decontextualization[1] that ensured the survival of the scientific establishment also served to establish these qualities as basic values of science as depicted in professional discourse and popular mythology.

Political Contexts

Baconian perspectives (Farrington, 1970) on science as an impersonal, objective, rational discipline (wherein domination and control of nature is a goal) continue to influence public perspectives of science and of science education in a society that no longer uniformly buys into the value structures of the 17th century western elite. The current, widely publicized crisis in science education may be one reflection of this clash in values. Studies of scientific literacy in the United States (Miller, 1989) and international comparisons (International Association, 1988) contribute to a political climate where few argue with the "crisis" designation (even though many scientists and science educators would not find compelling the views of scientific literacy reflected in these studies).

Popular opinion maintains that school science does not prepare students for life outside school science, and that even the preparation it provides for school science is not strong. In short, science education is commonly viewed as needing a major "fix" if we desire to continue the technologically based lifestyles and global economic competitiveness that characterize life in the developed world.

Current perspectives on cognition (Lave, 1988; Rogoff & Lave, 1984) describe knowledge development and utilization as a socially situated activity. For example, anthropologists argue that individuals utilizing mathematical knowledge in grocery stores and on paper and pencil tasks often have access to quite different strategies and knowledge bases in the two contexts. From this perspective, a science-technology-society (STS) approach to science education[2] appears to be an appropriate approach for increasing access to scientific knowledge. If STS approach-

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es assist students in developing knowledge grounded in settings of social and personal relevance, STS seems to have the potential to address a major area of weakness in much of current science. Attempts to integrate or to develop new interdisciplinary approaches to learning science and learning about science provide potentially powerful vehicles for dealing with disciplines currently characterized by abstract, decontextualized discourses.

For such reasons, it is tempting to seize upon the calls for an STS approach to teaching science as an panacea or a "technofix"[3] for the problems of access to scientific knowledge. I would argue, however, that to realize the potential of STS instruction to increase access, it is important to critically examine the multiple natures of STS instruction, the variety of meanings and political contexts of access to knowledge, and perspectives on the nature of knowledge in science.

Multiple Meanings of Access

Science education has been forced to examine the value structures under which it operates. It is no longer socially acceptable simply to prepare a small number of individuals (mainly middle and upper class White males) for scientific careers. Preparing all students for participation in a democratic society is now viewed as a vital role for science.

In considering access, it is critical to consider both the questions of access to careers and to knowledge and skills necessary to make informed social decisions—and how these goals influence the structures of science instruction. Thus, questions of access must be addressed in light of social and political contexts in the disciplines involved, and of societal goals, values and beliefs. These questions relate to value decisions as to which knowledge "counts" the most; current metaphors for teaching and learning; political factors such as syllabi, standardized tests, and parental pressures; and social and economic issues of implementing curricular change.

Scientific Careers

Classroom education plays a powerful role in socializing students to a particular set of values, beliefs, world views, and acceptable problems and strategies useful in the practice of science (Kuhn, 1970; Traweek, 1988). This socialization process also includes socialization into accepted views of the nature and boundaries of disciplinary knowledge, the relative valuing of different types of knowledge, and acceptable structures of arguments in particular disciplines (Traweek, 1988). Through this socialization, students also learn to "talk science" or carry out acceptable scientific discourse (Lemke, 1990). They learn, at some level, science "facts," concepts, processes, strategies, and theories that are currently deemed appropriate preprofessional preparation in science.

If this socializing role of science classes is critical to preparing students for careers in science, teachers, parents, and others may find an STS approach to science teaching problematic. This issue becomes particularly critical when female and minority students, traditionally underrepresented in science and science-related disciplines, are preferentially advised into STS courses. This preferential advising occurs frequently in schools because counselors may view STS courses as more accessible or "easier" than traditional science courses. STS courses can become a preferred setting for students who are not considered by their advisers to be potential participants in science-related careers.

If faculty in college science courses value preprofessional training that leads to more rapid "right" answers—using accepted strategies and addressing acceptable problems within the discipline—it is again problematic to expect teachers, counselors, administrators, testing agencies, and others to value STS approaches. If K-12 science education is viewed as a context for students to develop the knowledge necessary to survive in advanced science classes, an STS approach may actually limit student access to further study of science.

If "buying into" values of classroom science at some level is necessary for survival in science courses, STS courses may additionally limit access to careers by posing questions deemed inappropriate for students pursuing science careers. Questioning the assumptions that define the puzzles of normal science (Kuhn, 1970) may be an important part of STS education, but that same questioning may be counterproductive for students in preprofessional science courses (Brush, 1974). An STS approach requires broad changes in our views of what types of knowledge and what abilities to use that knowledge "count" in K-12 science education, or we run the risk of perpetuating the selective access to science-related careers that currently exists.

Solving Problems

If we focus instead on what knowledge students may draw upon in solving problems outside the context of classroom science, questions of access will be framed quite differently. A socially and culturally situated context in which scientific ideas and concepts are addressed may increase not only the "relevance" of knowledge, but also may lead to a very different perspective on the role of science as a human endeavor. If we value access from this perspective, critical issues arise in how the contexts of STS instruction are developed, and the ways in which problems and issues are framed in these contexts.

Framing of issues is always carried out in terms of implicit assumptions and biases (Kuhn, 1970). Thus, to promote access for diverse students in an STS classroom, it is critical to be aware not only of societal issues and related content, but also of values and world views that define how those issues may be examined. An example of issues that must be addressed include:

- What pedagogic approaches to STS instruction hold the most promise for including students of diverse values, goals, and experiences, and particularly for including those who have traditionally been "outsiders" to science?
- If one studies social issues, whose science, technology, culture, and issues are open for study? What assumptions about the values, culture, technological level, and economic and political conditions are being made in framing these issues?
- Who determines what problems are "relevant"?

To examine these questions, it is useful to first explore perspectives on the nature of STS education.

Two Perspectives on STS Education

Rosenthal (1989) describes two perspectives on STS education, a social issues approach and a social studies of science approach. The social issues perspective deals with examinations of science and technology issues in social context. Using a social issues approach, students might examine particular questions or problems in science, technology, and society such as global warming, chemical warfare, or pesticides in food. According to Rosenthal, the social issues approach has been predominant in STS courses and curricular materials in the United States.

The social studies of science approach deals with perspectives on scientific activity and knowledge arising from the social sciences and the humanities. Rosenthal states that this approach figures prominently in discussions of goals and objectives for STS instruction. Such an approach might focus on philosophical, sociological, historical, political, economic, and cultural interactions with science and technology. For example, a social studies of science perspective on STS might focus on an examination of the sociological, political, economic, and values issues involved in the traditional exclusion of women and minorities from medical studies, recent political actions to promote inclusion in these studies, and responses from the research community, funding agencies, and the government.

When one takes a social issues approach to STS instruction—where the examination of the sociology of knowledge stops at the laboratory door—scientific knowledge may be treated as acontextual truth, developed independently of cultural values and assumptions. With this approach, technological and social issues may become vehicles for teaching a "context-free" science, and such instruction need not challenge common stereotypes of science as culture-free.

Because of differing ways in which science may be treated, it is important to define whether we are focusing on an issues based approach, a social studies of science approach, or some combination of the approaches. A social issues approach to STS instruction may be essentially one-sided. From this perspective, students examine the impact of science on technology and society. A social studies of science approach also examines the impact of technology and culture on science. The definition of STS instruction chosen influences the questions we can ask about relevant issues of access, including questions about the power of the approach to include outsiders, those traditionally excluded from science education.

A Social Issues Approach

Studies of scientific literacy, such as those by Miller (1989), provide us at best with information about how people respond to questions concerning "basic scientific facts." However, according to Birke (1990), such studies "tell us little about how people use, and make sense of, the science they encounter in their lives. And the encounter between science and 'the public' is rather one-sided, portraying the public as inevitably deficient." This deficit model of science literacy assumes the structure and outcomes of traditional science courses, which are notoriously inaccessible.

An issues-based STS approach attempts to bridge that gap by connecting learning in and out of school. That is, by situating science learning in the contexts of social and personal issues, students learn science that they will be more likely to encounter outside of school. If they are successful in enlarging the context in which school science knowledge is viewed as legitimate, individuals have a much greater chance of gaining access to science knowledge outside of the science classroom.

In a social issues approach to STS instruction, several questions arise. These include:

- Whose issues are examined and whose science, technology, culture, and knowledge are seen as legitimate?
- What assumptions are utilized and called into question when examining social issues?

Social issues change constantly. The definition and priority of what counts as an important social issue is determined by the culture, values, goals, and experiences of the individuals involved. Issues relevant to persons in the suburbs may differ from those relevant to inner-city dwellers. Male and female students may have different perceptions of the types of knowledge that provide legitimate frameworks for viewing an issue. While a focus on global issues might be useful in particular contexts, students from other communities may consider global issues personally and socially irrelevant to their current lives. However, they may consider local issues compelling contexts for STS instruction.

Global warming is a critical issue for many Americans. Concerns about the long-term fate of the earth have become part of the public consciousness of middle- and upper-class individuals, and many consider it within their power to influence environmental concerns. It is less obvious that global warming is a vital issue for students in those inner city areas where violence and the drug culture have a tremendous impact on the social context. If there is little stability in the lives of students in a community, it may be difficult for them to conceive of their own lives in 20 years, let alone the global environment in 20 years.

This does not mean that global and environmental issues are irrelevant. According to Durning (1990), "In the United States, the poorer the neighborhood, and the darker the skin of its residents, the more likely it is to be near a toxic waste dump" (p. 148). Accessible instruction depends upon appropriate interplay between global and local concerns such that individuals have options to deal with issues that are socially and personally relevant to their lives, and not only with "somebody else's problems."

In an issues-based STS curriculum, multiculturalism does not necessarily imply that material is free from racist (or sexist) biases or that issues are anti-racist or anti-sexist. For example, a multicultural curriculum might look at issues affecting people on other parts of the globe, or people of different cultural or ethnic backgrounds. An anti-racist, anti-sexist curriculum might ask whether race and gender were useful categories in thinking about the issue, and whose perspective was central in defining the issue.

For example, Gill, Europe, and Vance (1987) describe a multicultural unit on famine and starvation that focuses on the symptoms of third-world poverty, such as malnutrition, tuberculosis, rickets, and cholera. Such materials, which are multicultural because they focus on the issues of another culture, may neglect the causes or give a simple textbook explanation of causes of poverty in that culture. Such an approach, without a political, historical, social, or economic analysis of the relationship of poverty to production and distribution of resources at local and global levels, or an examination of the influences of a colonial past, could leave the impression that the problem is the responsibility of the people or the nations involved.

Such an approach would not only neglect to challenge the notion that White western society is somehow superior, but could actually promote racism. It would further decrease access for students whose skin color and economic status is not that of the middle class American model, such as students from ethnic backgrounds similar to that of the third-world nations studied. Similarly, as Commoner (1980) notes, a focus on overpopulation may be misleading because it attributes poverty to large family size rather than large family size to poverty and, thus, obscures the real causes of poverty. Such an analysis could lead poor students, particularly if they come from large families, to come to see themselves as part of the population problem.

STS teachers and curriculum developers must also examine the question of "whose knowledge" is considered legitimate in STS inquiry. The highly publicized cultural literacy debates are a reminder that defining "culture" is fraught with politically-charged value assumptions and that the notion of a core curriculum or a canon of knowledge is problematic at best. Only recently have we come to question the definition of history as *his*tory—a reflection of the activities and spheres of interest commonly viewed as masculine in western society—which often is not inclusive of *her*story. Much of history is told from the perspective of the "victors" and lacks sensitivity to the culture and values of "others." We rarely discuss the assumptions and values implicit in psychological and biological models, which take the development of males as the standard and then describe the deficiencies of females in relation to these standards.

If science instruction presents scientific knowledge as "truth," or as a valid and unbiased reflection of the way the world is, then it is little wonder that women and minorities in our culture differ from White men in the way they relate to that knowledge, for the legitimacy of their experience as a source of knowledge is devalued or denied. If the STS theory/knowledge base is to be examined critically, issues approaches to STS must consider the epistemological stance that informs it.

Social Studies of Science

In discussing alienation from knowledge, Mendelsohn (1988) has noted that many students have rejected science as personal, relevant knowledge for their own lives. He argues that this alienation may not be a matter of unconscious avoidance, but rather of conscious rejection of science as presented in schools. He states:

> It is imperative to recognize that this science is rooted in historical time and place. It has contexts, and it does not exist outside of context. Although we can make some very real claims for universal rules of nature, approaches to it are not necessarily universal. In fact, it turns out that many of our own youngsters have not yet absorbed it as their science. (p. 23)

While a strict social issues approach to STS may assume that science simply *is*, a social studies of science approach to STS asks questions about the assumptions, values, and processes of science as well as the interactions of science with technology and culture. For example, sociologists, anthropologists, and philosophers describe science as a reflection of the society in which it is developed. If that society is racist and sexist, science and science education—as human activities—also contain elements of that racism and sexism. A social studies of science approach seems useful in addressing these assumptions that inform current practice. An approach to teaching science in its historical, philosophical, and sociological context might call into question stereotypic values and views of science (science as objective, elitist, centered on domination and control) and challenge the myth of value neutrality that serves to distance the scientific from the human.

In making cultural assumptions and values explicit, a social studies of science approach may undermine the romantic mythology of science and, thus, have an impact on student access to further study of science. If the mythology of science serves to motivate students to persist in science careers, as Traweek (1988) and Kuhn (1970) describe, questioning this mythology and the status of science in society may have an impact on students' pursuit of science-related careers. As Young (1987) has noted,

> The issues raised by the sociology of knowledge are always in danger of undermining the foundations of the claims of science to value-free objective knowledge, and there is a large and fraught literature concerned with shoring up those foundations. (p. 79)

Initiating a lively, long-term exchange in *Nature* (Theocharis & Psimopoulos, 1987), two British scientists argue that this mythology is critical to the status of science (and scientists) in society. Discussing the impact of nonpositivist philosophies of science on British science, they state:

> Having lost their monopoly in the production of knowledge, scientists have also lost their privileged status in society. Thus the rewards to the creators of science's now ephemeral and disposable theories are currently being reduced to accord with their downgraded and devalued work, and with science's diminished ambitions. (p. 595)

Returning to the question of access to science education, if scientific work is "devalued," in anyone's eyes, by STS approaches, do we run the risk of failing to attract students to pursue and maintain scientific careers? The response must be grounded in the values and perspectives with which we discuss both STS and more traditional science instruction.

Conclusion

As scientists and science educators attempt via STS instruction to "re-situate" science into the social, historical, political, economic, and cultural contexts that have been written out of the discussion, an excellent opportunity exists for examining access issues. This can be done through questioning and testing out alternatives to current structures and metaphors for science and technology instruction. This process in its most powerful form reflects a bringing to bear of knowledge from a multitude of cultures and defining anew a culture in which multiple voices have access to a more accessible science instruction, perhaps similar to what Freire (1989) describes as problem-posing education.

> In problem-posing education, [people] develop their power to perceive critically *the way they exist* in the world *with which* and *in which* they find themselves; they come to see the world not as a static reality, but as a reality in process, in transformation. (pp. 70-71)

Notes

1. From a social constructivist perspective, knowledge cannot be "decontextualized." All knowledge exists in and reflects the values of the contexts in which it is developed, legitimated, and used. I use the term here to reflect the ahistorical, impersonal accounts found in much current science writing, textbooks, and curricular materials.
2. The focus of this article is access to "science" through STS. While such a focus reflects neither the interdisciplinary and integrative nature of many STS programs nor differing questions of access arising from social studies, technology, and science education, access to science is the issue of greatest concern in the current political climate.
3. The notion of a "technofix" reflects a metaphor of technocratic rationality as a way of thinking about social issues. Two recently proposed technofixes for global environmental problems illustrate this notion:

- Mathematician Alexander Abian advocates a "cosmic" solution for dealing with earth's ecological problems (Reese, 1990). Abian suggests improving climate and ecology by utilizing modern technology to (a) reduce the mass of the moon; (b) split the moon into two or more pieces; (c) eliminate the moon in a controlled manner; or (d) change the orbit of the moon.
- A more widely-debated approach to reducing carbon dioxide in the atmosphere is to increase uptake of CO_2 by organisms in the world's oceans. This would be accomplished by dumping vast quantities of iron into the ocean (Kunzig, 1991).

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Arthur G. Wirth

Issues in the Reorganization of Work: Implications for Education

Because the complexities are great, I focus on one theme that I think is basic to both industry and schooling: Which philosophy of work design shall prevail—the technical control model or the democratic socio-technical design of work. The issue reflects a cleavage in the culture between our technocratic and democratic inclinations.

I got involved in all of this in the late 1970s when there were growing concerns about productivity problems in both industry and schools. What grabbed my attention was that while leading-edge thinkers in industry and labor were beginning to see scientific management as the *source* of problems, education policymakers were going all out to make this same model—in the form of technocratic, top-down, test-score accountability—the main instrument of reform. Some of the most creative, committed teachers I knew were becoming demoralized or threatening to quit because of it. That seemed crazy. Since the model was coming from industry I decided to see if anyone in industry thought it was crazy. That led me into a long detour into industrial situations in the United States, England, Norway, and Sweden, where I discovered the people who were pioneering what I am calling democratic socio-technical work theory. I reported on this in *Productive Work in Industry and Schools: Becoming Persons Again* (Wirth, 1983).

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While I have not worked directly in the field of science-technology-society, I believe my general argument has relevance. The thesis is, as we move historically from an industrial to a post-industrial electronic/computer era, industrial-type assumptions about designing work and learning have become handicaps. For example, manipulative behavioral engineering—Taylorism (see Wirth, 1983) in work and programmed linear learning in education—has become dysfunctional for meeting turbulent change. Our preoccupation with the quantitative as the sole measure of progress exacts intolerable costs in terms of the quality of life in our institutions and the world of nature. As I spin out the story, I simply ask STS educators to ask themselves if the issues I point to for American education in general may also apply to their own work.

I look first at some changes in work that led to this development. Then I discuss the philosophical orientation of the socio-technical idea. Finally, I turn to ways in which a strikingly similar debate is shaping up in education as we enter the 1990s.

Changes in Work

We are at the beginning of a third major change in work life in the United States. At our beginning, in the late 1700s (stage 1), we had broken with feudal restrictions and inequalities, and were overwhelmingly self-employed—in farming, the trades, and small commercial en-

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terprises. Eighty percent of non-slave Americans worked on farms. By 1900 (stage 2), the percent of farm workers had been halved to 41 percent; by 1990 it had dropped to 3 percent (Carnoy & Levin, 1985, pp. 53-56).

As we entered the 20th century, the corporate industrial revolution was creating a radically different work world. Pyramidal corporate bureaucracies with top-down managerial directives became the American way of work. Nearly 90 percent of Americans now work for organizations (Carnoy & Levin, 1985, p. 53). Democracy was thought to belong in the political realm with periodic opportunities to vote. In daily worklife, it was argued that democratic processes were irrelevant because competitive reality decreed acceptance of "command and control" managerial authority (p. 54).

The design of industrial-era work remained largely within the parameters established by its founder, Frederick W. Taylor. Thinking, planning, and detailed job design were reserved for the administrator-engineer technical planners at the top. Execution of prescribed, detailed tasks under supervised control was the job for those at lower levels (pp. 55-56).

We are now in the beginning of stage 3, the electronic/computer revolution, which is also marked by the emergence of a global competitive market and dangerous ecological damage due to population and industrial growth. Unprecedented changes are under way. For example, the much heralded shift from smokestack industries to the service sector is far advanced. In 1985 only 19 percent of workers were employed in manufacturing, and "information workers alone—clerks, sales, technical, professional and managerial people—made up 53 percent of the labor force" (*Skills, Schools, and Technology*, 1985, p. 2).

In 1970 all American factories had only about 200 robots. But between 1970 and 1980 General Motors' wage bill soared by 240 percent, while the cost of a robot had stabilized at $5-$6 per hour. The result: 5,000 robots in GM plants by 1985 with an estimated 15,000 for 1990 (Draper, 1985, pp. 46-49).

Even while the labor force is being reduced, there are serious shortages of workers equipped to handle the complexities of computer-aided manufacturing. A recent report stated:

> What manufacturing is increasingly about is working with . . . high tech equipment. . . . At the plants where Stealth planes are produced, they drive "fasteners" with tolerances as close as a thousandth of an inch into contoured surfaces designed to elude radar. Machinists operate computerized tool-making devices. Other workers mold exotic composite material like graphite to make fighter fuselages. ("The Aerospace Labor Crunch," 1988, p. 45)

In California some aerospace firms, concerned about the shortage of skilled, motivated workers, have linked themselves to three community colleges. Degree programs are offered to workers in manufacturing technology, with training in manufacturing, materials, drafting, machinery, and computer-aided design. The goal is to secure multiple-skilled, flexible employees ("The Aerospace Labor Crunch," 1988, p. 45).

About half of Americans now work in offices (*Skills, Schools and Technology*, 1985). A Stanford study stated:

> Office automation wiped out thousands of jobs for low-skilled clerical workers, created new jobs for skilled clerical workers and eliminated many professional jobs that comprised the middle of the career ladder. . . . Both the bottom and the middle of the occupational distribution are shrinking in the insurance industry. (*Skills, Schools and Technology*, 1985, pp. 2-3).

But as Levin and Rumberger (1983) and others have pointed out, the real world of work is much more complex than a solid rush to computer dominated work. The Bureau of Labor Standards did project for the 1978-90 period an increase of more than 100 percent for computer operators, system analysts, and machine mechanics—high tech jobs. But focus on the *rate* of change alone can distort. The number of *actual* job increases is quite different. The five occupations projected to produce the most jobs were all in low-skilled areas: janitors, nurses' aides, sales clerks, cashiers, and food workers (Levin & Rumberger, 1983, pp. 4-6).

Beyond that, of course, is the steady drift toward a dual economy: the new billionaires at the top, many affluent Americans in high tech and professional jobs, and a growing underclass, often people of color, in a quasi-permanent condition of unemployment and poverty. Twenty-three percent of American children are growing up in families below the poverty level (Reed & Sautter, 1990, p. 3).

What are we to make of such dramatic changes? Will our high-tech society raise the skill level of work, or extend the deskilling of work into middle level technical and managerial levels? Will technology create more jobs than are lost? The safest generalization is that we do not really know. The effects will vary. Who could have projected the ramifications for American life when Henry Ford got the gleam in his eye for a mass-produced, horseless carriage?

The one thing we can be sure of is that we are confronted with turbulent change, i.e., change that is rapid and unpredictable. According to Reich (1983), to be competitive in the global market we need a formula to bring together inventive technology with flexible, intelligent response by a committed, engaged work force (p. 19).

Our vulnerability in the world market may be due, in part, to the failure of traditional management to produce such results. This failure has led to the challenges by democratic socio-technical theorists.

Democratic Socio-Technical Design for Work

As evidence of trouble at work accumulated in the 1970s—shabby quality, absenteeism, apathy, drug and alcohol abuse—one response by socio-technical theorists was a critique of the Taylorist tradition of scientific management (see Wirth, 1983, Chap. 3). They saw it as guilty of the "technical fix" error, i.e., the assumption that all problems will yield to expert-designed technical solutions. The reality of human work, they said, is "socio" as well as "technical." "Socio" refers to the communicative, collaborative, idea-generating aspects of human beings (Wirth, 1983).

The mainline efficiency model is out of touch with the "socio" dimension. It falters because it fails to engage the commitment and personal enthusiasm of people and their capacity for learning and problem solving. The new theorists held that the old production model is fundamentally out of touch with "post-industrial" aspects of reality. It worked, Herbst (1974) said, when people's fundamental relation to the world was the physical environment—an environment conceptualized as an aggregate of elements that can be manipulated for human gain. This was the model—atomistic, mechanistic, and deterministic—on which classical science built its theory of universal laws. It was also the orientation that provided the conceptual framework for the creation of bureaucratic organizations based on the principle of replaceable parts. When "fixing" is necessary, one turns to technical manipulation. The pathology emerges when humans begin to treat other humans as parts of the physical environment (Herbst, 1974, p. 203).

In emerging, computer driven post-industrialism, the physicalistic model is called into question. The capacity to deal successfully with the reality of turbulent change depends on building a learning, value-choosing capacity into the system itself. Goulet (1977) made a plea for a concept of *integral efficiency* as an alternative to *mechanical efficiency*. "Managers and designers of technology will need to explore ways of becoming integrally efficient, that is, of producing efficiently while optimizing social and human values. This they must do with as much singlemindedness and practical sense as they now devote to making profits or creating new products" (p. 30).

The shift from the old model of productivity to a new one also requires a shift in our image of humans. It involves, said Becker (1978), a shift from La Mettrie's 18th century rationalist image of humans as *l'homme machine* (man as mechanism) to the image of *homo poeta*—the human as meaning maker. We create "structures of evil," says Becker, whenever we design institutions that prevent people from "staging the world so that they can act in it creatively" (p. 172).

Many hard-headed leaders of management and labor are unlikely to be convinced by such poetic abstractions. The truth is, however, that undeniable movement is taking place in the direction of "horizontal-participative" management by some of the most successful corporations. Plants designed with innovative, socio-technical methods report that these units are 30-50 percent more productive than their counterparts ("Management Discovers," 1986, p. 74). Richard Walton of the Harvard Business School said that advanced computer technology calls for a radical change in traditional work practices (p. 74). The traditional method of dividing work into low-skill discrete tasks becomes obsolete in computer-integrated workplaces where many functions—including materials handling, assembly, inventory control, and testing—are integrated by computer. "The integration no longer makes it possible to define jobs individually or measure an individual's performance. . . . It requires a collection of people to manage a segment of technology and perform as a team" (p. 71).

As Zuboff (1988) points out, workers in hi-tech, computer driven industries such as petrochemicals become interactive with the computer information systems. The effectiveness of the production process no longer depends on physical skills but on the capacity of workers to understand the system, so that good judgment can be brought to bear when problem solving is required, or collaborative efforts can be made to improve the process.

In order for workers to function effectively (i.e., intelligently and collaboratively), they need to have access to the feedback information of the system—which "informates" them (Zuboff, 1988). This empowers them to be decision makers and active agents when action is required.

But this "informating" of the work force, Zuboff says, may be threatening to management. Giving the work force direct access to information is in conflict with the Taylorist "command and control" tradition, which holds that information should reside in the hands of management so that it can control the production process and the work force.

A critical issue thus emerges. To respond effectively to the constant innovations of hi-tech computer technology, the essential requirement is a work force with freedom to learn and freedom to apply their learning to the work process. Management, thus, must choose whether to "automate" computer technology in ways that retain hierarchical control by deskilling workers (at the cost of reducing effectiveness) or to design technology to "informate" workers, which introduces a new and unsettling sense of mutuality and equality into work life.

Zuboff's (1988) studies of hi-tech industries show that both patterns are being followed, with the choice being an uneasy one for American management. Where the second route is followed, new work styles emerge that were inconceivable under Taylorized industrialism. Semi-autonomous work teams in many plants now manage themselves without first-line supervisors, determine their own work space within parameters set by management, have a voice in hiring and firing team members, conduct their own quality control, and schedule their own vacations ("Management Discovers," 1986, p. 71).

American executives on the Committee for Economic Development (1985) declared that a work force educated simply by "old school basics" will not be equipped for meeting the challenges of turbulent change. They presented the case of Proctor and Gamble where employees perform a broad range of tasks, including operating and maintaining equipment and performing their own quality controls. They participate in activities such as goal setting, budgeting, hiring, and firing. Training is effective only if employees have strong literacy and number skills and, above all, the ability to learn and to collaborate in problem solving.

Parallels in Education

What does all of this have to do with education? Having seen the tension between technocratic control and democratic values in the work world, we ought not be surprised if it shows up in education.

In the 1970s, symptoms of institutional malfunctioning were evident in the schools: high dropout rates, truancy, apathy, low test scores. The major response was what Wise (1979) called "the rationalization of instruction" (chap. 2), which assumed that school performance could be improved if learning were treated as a production function: Organize material to be mastered in expert-designed basal materials and introduce performance based instruction and teacher accountability. It led the Texas legislature in the 1980s to enact a law that makes teachers subject to a $50 fine if they are caught teaching reading without an approved basal text (Goodman et al., 1988, pp. 33-34). It was the model favored by then Secretary of Education William Bennett, who said the linchpin of his reform effort was test score results (Roediger, 1988, pp. 17-19). For those with a passion for the "command and control" model of management, it seemed the perfect answer.

As we enter the 1990s, however, there are clear signs of disillusionment. Former Secretary of Education Cavazos declared the reform effort of the '80s a failure. "We tried to improve education by imposing regulations from the top down, while leaving the basic structure of the school untouched. . . . Obviously that hasn't worked" (Cooper, 1989, p. 1).

Issues about the structure of learning can be related more directly to STS by considering the area of science education. In a *New York Times* special section (see Cole, 1990), scientists and science educators offered a critique of the present situation in science teaching. Striking parallels can be seen between their arguments and those made about the need to redesign work and learning in industry.

The depressing picture of the state of science education needs little elaboration: Huge numbers of American students avoid science at both secondary and higher education levels; 40 percent of high school students, who enter college with an intention of pursuing a science career, drop out after the first course; in a recent science test taken by high school students in 14 countries, American students ranked 14th (Cole, 1990, p. 18).

One of the science educators interviewed in the *Times* (Cole, 1990) was Bill Aldridge, executive director of the National Science Teachers Association. Aldridge noted some well-intentioned but counterproductive measures of the '70s and '80s, among these the effort to raise standards by increasing the amount of material to be covered. "What's happening from grade school to graduate school is the suffocation of curiosity under an avalanche of fact" (p. 18).

Much of this pressure derives from the epidemic of testing. Teachers feel forced to cover everything that might be on the test. "Testers break science up into small objects. What you get is an unassembling of the most fantastic features of science—its stories, its patterns. You get denudement of everything that's rich and fun and beautiful" (p. 18). The result is millions of children "wasting their time learning virtually nothing of value" (p. 18).

The most pressing student question is not about science but, Will it be on the test? The approach assumes that *covering* science by the teacher adds up to *learning* science by the students. The pressures support a kind of rapid assembly line coverage of material. It leaves little room for personal engagement, for Socratic dialogue, or for collaborative inquiry and communication. Students who are left in the pipeline are "students who are rewarded for being quiet, for doing what the teacher says" (p. 18).

Teachers who have accepted the system may be frightened by the idea of engaging students in intellectual struggle and give and take, instead of coverage. "If I do that, I'll lose control," is an often-heard comment (Cole, 1990, p. 19), not unlike the comments by beleaguered managers in industry. So, if the problem is seen as fragmentation of instruction and non-involved students, what ideas are offered as alternatives?

Alternative Strategies

The National Academy of Sciences and the National Science Teachers Association are exploring ideas for designing science studies for elementary school children. The agreed-on goal is to develop the ability to think scientifically, develop hypotheses, and test and draw conclusions. They agree that the one sure way to teach this is a "hands-on" approach. They turn to non-school alternatives for approaches that seem promising. A physicist from Princeton's Institute for Advanced Study recommends as an example the San Francisco Exploratorium, which teaches science concepts by using equipment that can be found around the house. The Exploratorium's founder, Frank Oppenheimer, said, "No one flunks a science museum. Nothing may be more important than an environment in which it is safe to be wrong" (Cole, 1990, p. 19).

At the secondary level, the American Association for the Advancement of Science (1989) launched a major effort, Project 2061. Teams of teachers and administrators are devising a K-12 science curriculum with the help of computers. The trend is for students in science, technology, and math classes to work in groups instead of as competitors and to use technology, whether hammers, saws, or computers. The style of instruction is heavily "hands on," with 60 percent of students' time devoted to lab work and the remainder to discussion. "To get students to make their own discoveries and not read about them in a book—that's what science is all about," said one of the commentators (Foderaro, 1990, p. 21).

George Campbell of the National Action Council for Minorities in Engineering found that this type of action-oriented learning helped improve the performance of minorities and women in science. A model minority science program involves students in group projects and study sessions where minority students and their White counterparts have the opportunity to interact. Campbell said, "One of the major reasons that minority students do not succeed in technical fields is that they fail to become involved in group study activities with their peers.

. . . When it comes to science and engineering, which are collaborative efforts, that is crucial" (Sims, 1990, p. 23).

The examples cited all point toward the need to challenge the *structure* of schools, which the top-down "reform efforts" of the '80s failed to do. As we enter the '90s, we are getting powerful models that point to the kind of principles employed in democratic socio-technical work settings. Shanker (1990) notes that successful companies have restructured their management and work arrangements by increasing use of work teams interacting with technology. In Shanker's view, the standard school structure is a major factor that impedes the majority of students from being truly educated. Shanker mentions Charles Handy, a British authority on organizations, who says that the structure of schools discourages active, engaged learning.

Handy (1985) asks us to imagine office work in which a new employee, surrounded by 30 others at similar desks, is told not to communicate with them. Every 45 or 50 minutes, the new employee is told to move to another desk in another room with a different supervisor, new tasks, and 30 different employees. During the week, the employee might be in seven different rooms without any assigned desk or chair, and is discouraged or prohibited from talking to anyone while working (p. 135). Such a model makes sense only if students are perceived as raw material, passed from work station to work station, there to be stamped or worked on by a different specialist, graded at the end, and sorted into appropriate categories for distribution.

What Shanker (1990) says is needed, as an alternative to the industrial factory model, is a moral learning community, where both students and teachers are personally engaged in their own learning. He calls for an "incentive school" competition, open to all the schools of the country, which would create new structures for moral learning communities. Participating schools would be free to develop new ideas and try new practices, with waivers of regulations that might keep schools from considering any promising changes. And they would be given control of all funds while they made their try. He rejects the notion that there is any one right model.

I end with one example, congruent with Shanker's ideas for restructuring: the computer enhanced Cougar Valley Elementary School of Silverdale, Washington (Fiske, 1990). The school combines cooperative team approaches with high technology, and as such provides *one way* for transforming the culture of the school.

Ideas for change at the school came from a brainstorming committee that devised a "Strategy 2020," involving 150 teachers, administrators, and parents, and the goal of designing new ideas and strategies for promoting learning. They developed the following guidelines: (a) Technology should be available to manage learning and to diagnose, present, and evaluate it (A grant of $300,000 provided 221 computers for 518 students.); (b) administrative and educational decisions should be made at the lowest level, preferably by teachers and students; (c) teachers should be managers of instruction, not presenters of information; (d) teachers should function as teams of professionals, sharing ideas and communicating frequently; and (e) students should become more actively involved in their own learning, both individually and in groups (Fiske, 1990).

Teachers team-teach with multiple age groups in large rooms organized around five or six learning centers. Computers help handle the complexity of these open classes in ways that were not available in the 1960s. With the help of computers, teachers are able to gear work to students' individual skill levels and offer more personalized instruction. Teachers become leaders of educational teams that include paraprofessionals, teaching aides, computer lab managers, and volunteers.

A voice mail system is being introduced so that parents can call after hours and get oral reports on their children's progress. This eliminates much of the need for group testing since computer feedback shows where each student stands.

The culture of the school is being changed also by use of a "local area network," which links all the computers in the schools. Teachers use it to record attendance, assemble lunch orders, schedule meetings, and exchange ideas for assignments for particular students (Fiske, 1990).

Parallels can be noted with the socio-technical ideas that Deming took to the Japanese after World War II. He held that

> the quality of a "product" is directly influenced by the frequency of informed interaction between a caring worker and that product. (Rhodes, 1988, p. 29)

Conclusion

I have made an effort to argue that the democratic socio-technical concept that is effective in front-line industries also has relevance for American schools. I commend it to those who are pioneering in the field of science-technology-society, not as "the one right way" but as a framework for generating hypotheses that bring together democratic values with the realities of the electronic era.

The hyphenated concept (socio-technical) indicates the need to take seriously both sides of the hyphen: the technical—yes, more than ever—but, equally important, the "socio," which honors the values of dignity and creativity, and which embodies principles of active learning and collaborative communication necessary to meet the problems of turbulent change. It represents an alternative to technocratic supervision and control over fragmented learning and work that is becoming dysfunctional in both industry and schools.

It also has relevance for another feature of the present stage of work: ecological damage. The socio-technical model has been called the quality of work life movement, because it has held that *quality* of life issues cannot be divorced from quantitative objectives. When we say that to get good work we must honor higher human qualities such as communication, reflective thought, dignity, and caring, we are giving priority to quality of life matters. We reject the reductionistic tendency of the technocrats to treat nature and humans as nothing more than objects for manipulation. We can see then the truth in the observation of Dubos (1972) that alienation and chaos in human affairs and relations have the same origin as chaos between humans and their natural environment.

In short, as Henderson has phrased it, we are confronted with the peculiar situation where *it is becoming pragmatic to be moral* (Vermilye, 1977, p. 235). But never for a moment can we think that it will be easy. A change of this magnitude touches the deep nerve of fear of change, and the even deeper nerve of fear of losing control. As we saw in Zuboff's (1988) account, managers' fear of losing authority in industry may lead them to back away from informed worker participation. Management may break trust by using the call for collaboration to undermine unions. Teachers and workers who have become habituated to working under prescribed controls may fear losing their chains. We are talking about a profound cultural change in a democratic direction that seems to be required by post-industrial reality. There is no guarantee we can make it.

I believe STS educators, in terms of their knowledge, vision, and values, are especially equipped to help us make the change. In my view:

- STS educators are acutely aware of the centrality of science and technology and want students to be effective and at home with scientific and technical reality.
- They seek integrative styles of learning that not only show the interrelatedness of academic disciplines but also alert students to consequences for nature and society.
- They favor constructivist, collaborative styles of learning in which students become personally active in constructing understanding and meaning, and in which they learn the democratic skills of dialogue, conflict, resolution, and trouble shooting. They treat students as *homo poeta*—meaning makers.

The STS rationale, in short, can be a force to resist pressures to solve "productivity problems" in education by nervous acceleration of mechanistic methods and controls. If, as I believe, the STS rationale is congruent with the values of the democratic socio-technical concept, it can help us build a *polis* "in which the processes of technological change will be disciplined by the political wisdom of democracy" (Winner, 1986, p. 132). In such a *polis*, only those technologies and social systems will be designed that match our best sense of who we are and what we want this society to be.

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Merry M. Merryfield

Science-Technology-Society and Global Perspectives

Times have changed. Revolutionary advances in science, technology, communications, and transportation have brought nations and peoples together in ways undreamed of by previous generations. World trade and financial, economic, and political developments have transformed disparate economic systems into a highly interdependent global marketplace. Today, nations inhabiting the planet are often more closely linked by technology than neighboring states or villages were at the turn of this century.

Yet these important changes rarely are reflected in the way most schools in the United States prepare students for the 21st century. American schools largely ignore the viewpoints, languages, cultures, values, traditions, and even the location of other peoples. Not surprisingly, schools and universities reflect the same lack of understanding of global dynamics that characterizes the perspectives of American leaders in government and industry (National Governors' Association, 1989, p. 2).

The science-technology-society (STS) movement recognizes the need for education that prepares young people for the challenges of an ever-changing, interdependent world. If today's students are to become tomorrow's decision makers, they need knowledge of science, technology, and society that is global in scope. Whether students recognize it or not, global connections affect their daily lives. Without knowledge of these connections and the perspectives of other peoples, students cannot make informed decisions. As we face the 21st century, uninformed decisions not only endanger our American way of life but also threaten the survival of our planet.

What are the global perspectives essential to STS? Position statements of the National Council for the Social Studies (1982) and the National Science Teachers Association (in process) recommend that the K-12 curriculum include content that addresses the following generalizations:

1. We are living in an age of increasing globalization in which all people are interacting with transnational, multicultural, and cross-cultural phenomena.
2. The world stage includes a variety of actors beyond nation-states. Individuals, local groups, church groups, scientific and technological organizations, trade unions, multinational corporations, and regional organizations are increasingly interacting and influencing both local and global events.
3. Humans are dependent upon a world environment characterized by finite natural resources; the planet's ecosystem both affects and is affected by humankind.
4. There are relationships between present social, political, technological, and ecological choices and alternative futures for individuals and the planet.

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5. Because of the globalization of the human condition, individuals and communities have increased opportunities and responsibilities to take action in improving their world. The curriculum needs to go beyond knowledge of globalization to develop students who will be active decision makers and participants in their world.

In order to think with a global perspective, students need to understand the historical development and current trends of global systems, to recognize that other peoples may have different viewpoints and that those viewpoints need to be considered, and to appreciate that we all—as individuals, members of organizations, and nations—have an active role in improving our world.

Global issues in an STS curriculum can provide a framework for teaching students to think globally while acting locally. Educators have identified a number of global issues that are central to science education (Barman, Harshman, & Rusch, 1982; Bybee, 1984; Bybee & Bonnstetter, 1986; Bybee & Mau, 1986; Hickman, 1982), social studies (Alger & Harf, 1986; Anderson, 1979; Becker, 1979; Hanvey, 1976; Kniep, 1986, 1989; Muessig & Gilliom, 1981; Woyach & Remy, 1989), and technology education (Waks, 1987). Although some global issues are especially pertinent to different disciplines—such as deforestation in biology, technology transfer in technology education, or international trade in economics—a number of global issues are particularly appropriate to the integration of science, technology, and society.

Global Issues for STS

Only a few centuries ago, people lived in relative isolation from the rest of the world. An outbreak of disease, an ethnic conflict, or a drought might have occurred locally, but may *not* have affected the rest of the world or even been heard of beyond a local community. However, 20th century technologies and economic and political interdependence have transformed the world. An outbreak of a new disease, such as AIDS, is a global concern. Ethnic conflicts often boil over into international disputes as nations around the world align themselves and participate in sending aid or setting up boycotts. A drought in Brazil may send coffee prices spiraling upward in countries far removed from the coffee plantations.

Global issues spring from the concept of interdependence and can be characterized as issues that (a) affect the lives of persons in many parts of the world and (b) cannot be adequately understood or addressed solely in a local or national context.

What global issues are relevant to an STS curriculum? The following sections provide examples of global issues in an STS curriculum and illustrate how global issues can be integrated into a variety of courses. Many of these issues raise ethical questions. Can teachers effectively address such topics as the exportation of toxic wastes, use of fetal tissue in research, or military aid to governments known to use torture without exploring alternative viewpoints and the values upon which they rest? When approached from a global perspective, these STS issues come to mirror the complexities and paradoxes of diverse cultures and interdependent systems.

Environmental Issues

Environmental issues evolve as people interact with and change the physical geography of the planet. Many of the environmental issues facing the planet today are related to the interaction of 20th century technologies and population growth.

Examples

Examples of global environmental issues include the following: soil conservation, land use/degradation, deforestation, pollution (air, water, land), the greenhouse effect, global warming, ozone depletion, acid rain, pesticides, waste disposal, deep well disposal of nuclear wastes, toxic wastes/hazardous substances, relationships between poverty and environmental decay, natural resources as raw materials, displacement of indigenous species, extinction of plants or animals, loss to the gene pool, exportation of toxic wastes.

Classroom Applications

Examples for integrating global environmental issues into coursework include the following:

Science education. Tenth grade chemistry students studying acid-base reactions research the relationships between coal-burning power plants in Ohio and evidence of acid rain in Canadian forests.

Social studies education. Ninth grade geography students examine how communities in Australia, South Africa, Malaysia, Mexico, and their own state regulate the environmental impact of mining operations.

Technology education. Eleventh grade energy and power students design, build, and test alternative fuel vehicles as they explore relationships between the use of coal, acid rain, and deforestation in the United States and Germany.

Health and Population Issues

Two of the most significant trends of the 20th century are the accelerated development of technology and the spiraling expansion of global population. Although both of these trends pose hazards to the planet's ecosystems, improved health care is one of the major technological achievements of our time.

Examples

Examples of global health and population issues include the following: communicable diseases, malnutrition, AIDS, sanitation/sewage, safe drinking water, water fluoridation, toxicity of water, irradiation of foods, food additives, genetic counseling and research, drug abuse, aging, population growth, birth control, abortion, health hazards in building materials such as asbestos and lead, use of fetal tissue, trade-offs between finite resources being used for primary health care versus high-tech health care, resources for prolonging life versus quality of life, governmental policies on family planning.

Classroom Applications

Examples for integrating global health and population issues into coursework include the following:

Science education. Eleventh grade students in advanced biology learn about genetic mutations and examine case studies of development and effects of sickle cell anemia in West Africa and the United States.

Social studies education. Students in a twelfth grade sociology class collect data on beliefs and practices related to family size over three generations in their own community and compare their findings to similar data from Bolivia, India, Japan, Sierra Leone, and Switzerland.

Technology education. Students in a twelfth grade construction class investigate and install sewage disposal units in homes and then look at sewage systems in Beijing, Singapore, Moscow, London, Caracas, and Sidney in order to hypothesize about how sanitation relates to functional communities.

Economic Issues

A fundamental goal of each succeeding generation is to improve the quality of life in terms of such basic human needs as food, shelter, health care, security, education, and leisure. The ability to send one's children to school or build a better house depends upon one's individual, national, and international economic base. Economic issues are central to the universal human concern that we can improve our standards of living.

Examples

Examples of global economic issues include the following: economic development, environmental and resource issues, water rights, poverty and homelessness, urbanization, technology transfer, appropriate technology, the global assembly line, debt, productivity, global distribution of wealth, investment, trade barriers, North-South economic gap, European economic unification, international markets (labor, goods, services), neocolonialism, choices for scientific and technological research, and questionable trade practices (the sale of out-of-date pharmaceuticals to developing nations).

Classroom Applications

Examples for integrating global economic issues into coursework include the following:

Science education. Students in a twelfth grade physics class consider the advisability of Americans working with physicists from Japan, Germany, Poland, and the U.S.S.R. on a series of studies about superconductivity.

Social studies education. Students in a ninth grade economics class interview persons in local multinational industries to learn how global connections relate to a company's decisions to purchase raw materials, construct plants, hire labor, and find markets.

Technology education. Students in a tenth grade manufacturing course compare the way a local food processing plant is run with similar ones in Japan, Taiwan, and Brazil in preparation for operating manufacturing businesses within their community.

Transportation and Communication

Perhaps nowhere are the achievements of technology more dramatic than in transportation and communication. Undreamed of at the turn of the 20th century, technologies in telecommunications and travel have created a new information age. Yet the unequal distribution of these technological advances further stratifies the world's peoples into haves and have nots.

Examples

Examples of global issues in transportation and communication include the following: effects of innovation on people's lives, global distribution of technology, mass public transit versus private transit, effects of a country's relative wealth on its communication and transportation, governmental restraints on technology or information transfer, and access to confidential information on a person's medical, financial, or criminal records.

Classroom Applications

Examples for integrating global transportation and communication issues into coursework include the following:

Science education. A tenth grade chemistry class studies the implications of hydrogen as a fuel through a case study of hydrogen-fueled taxicabs in Japan.

Social studies education. Eleventh grade world history students construct a 20-foot timeline that traces the diffusion of innovations in transportation and communication from 4000 B.C. to the present. They debate which are the 10 most significant innovations affecting their lives and their pen pals in China and Botswana.

Technology education. Tenth grade transportation students look at local issues in mass transit in their community and similar communities in Germany, Japan, and Egypt before designing mass transportation systems for local use and testing models and prototypes of energy efficient vehicles and people movers.

Food and Hunger

Science and technology have greatly impacted global agriculture. However, as the world's farmers increased world output of grain 2.6-fold from 1950 to 1984, the share of hungry and malnourished people grew in Africa, Latin America, and parts of Asia (U.N. World Food Council, 1988). Feeding the world's peoples remains a critical STS issue.

Examples

Examples of global food and hunger issues include the following: the world food supply, surpluses and deficits, effects of natural and human-made disasters, governmental policies, global markets and trade, food aid, cash crops versus food crops, and the practice of stockpiling food in some countries while people in other countries starve.

Classroom Applications

Examples for integrating global food and hunger issues into coursework include the following:

Science education. In eleventh grade advanced biology, students examine case studies of agricultural diffusion in the Philippines, Kenya, the United States, and Argentina, then debate the global effects of new crop strains developed through genetic engineering to increase production.

Social studies education. In eleventh grade U.S. history, students look at the effects of hunger and famine in other countries on immigration to the United States and Canada.

Technology education. In an eighth grade transportation class, students examine the relationship between transportation and availability of different foodstuffs in their community and other communities around the world as part of their preparation for design of vehicles that will transport perishable foodstuffs long distances.

Energy

The technologies of the 20th century demand tremendous outputs of energy. The search continues for dependable, cost-effective sources for energy that do not degrade the environment.

Examples

Examples of global energy issues include the following: sources of energy, short-term and long-term effects of using different sources, the use of wood, coal, hydrogen, natural gas, oil, nuclear energy, solar energy, geo-thermal energy, and hydroelectric plants, research on alternative sources of energy, renewable energy versus non-renewable sources, energy conservation, the relationships between energy and environmental problems or health problems, and issues related to people being harmed by energy plants or the transmission of electricity over power lines.

Classroom Applications

Examples for integrating global energy issues into coursework include the following:

Science education. In eighth grade general science, students examine combustion as a source of energy and the effects of its by-products on global climate.

Social studies education. Social studies majors in teacher education methods create and pilot-test a simulation of a community's hearing over whether or not to build a nuclear power plant.

Technology education. Ninth grade energy and power students collect data and hypothesize how long fossil fuels will last, given trends in worldwide exploration and use, and then conduct energy audits on homes and retrofit them with energy saving devices.

Military Issues

Advances in military technology have led us into an age where weapons of mass destruction are used. The 1991 crisis in the Persian Gulf is a vivid illustration of the interconnections and consequences of global arms trade.

Examples

Examples of global military issues include the following: war technology, weapons sales, chemical and germ warfare, terrorism, human rights, use of space, arms control, international uses of military force, military aid, support for governments known to use torture and repression.

Classroom Applications

Examples for integrating global military issues into coursework include the following:

Science education. In a college chemistry class for elementary and middle school education majors, students look at the chemistry of halogens and binary weapons as a case study of the ethics of using chemical weapons.

Social studies education. In a twelfth grade global studies course, students compare current military and social expenditures with quality of life indicators in a stratified sample of the world's nations.

Technology education. In an eleventh grade communications class, students experiment with lasers in order to transmit signals and then hypothesize what effects such laser technology might have globally.

Global Issues and Global Perspectives

To achieve global perspectives in education, we must go beyond simply including global issues in the curriculum. Rather, the issues need to be seen from a global rather than ethnocentric or nationalistic perspective. A lesson on acid rain, for example, could be taught ethnocentrically from the perspectives of our own local community or globally from the perspectives of mineworkers, environmentalists, or other persons in Canada, Germany, and other parts of the world.

Students also need a historical context for dealing with contemporary global issues. A lesson on global hunger could be taught simply as a current STS issue or could be viewed within the historical context of colonial empires, cultural norms, and the globalization of world markets.

Global perspectives in education recognize the importance of the roles played by many categories of global actors, ranging from individuals in the local community, cities and states, corporations, and religious and service organizations to regional and global organizations of nations. A lesson on technology transfer, for example, could be taught as an arrangement between two nation-states or as a complex interaction among the cultural norms and agendas of individual workers, their unions, aid organizations, local and national political leaders, multinational corporations, and the technicians of donor nations.

Global perspectives also include serious attention to values—both universal human values that our species shares, such as a need for social relationships and a concern for family, and diverse human values, such as differences in cultural norms and beliefs. Global issues are by their very nature value laden, with value conflicts rooted in many global issues.

For example, deforestation could be taught as a physical process, focusing on certain predictable environmental effects, or it could be studied through the eyes of a variety of stakeholders, ranging from timber companies and their workers in the American Northwest, to cattle ranchers, tour operators, and Indians in Brazil, to villagers, scientists, and political leaders in Kenya. Deforestation, as with most global issues, goes beyond science and technology to issues dealing with human values. Without attention given to both universal and diverse human values, the topics will not be fully understood.

Although the choice of which global issues to address depends on the course and the level of the students, it is critical that educators work together to provide students with STS education from a global perspective. In the world of the 1990s, we cannot afford to limit the study of science, technology, and society to a national context. What STS content will best prepare today's 5-year-olds to make decisions as adults in the world of 2006? Will an understanding of American technologies, scientific achievements, energy policy, and environmental choices be sufficient? Or do they need to understand American progress as part of a dynamic, interactive framework of technology issues in South Korea, Germany, India, and Nepal, energy policies of countries such as Japan, Saudi Arabia, and Nigeria, and environmental concerns of local people and scientists from many countries? Which STS curricular choice will lead to better-informed decisions for our youths' personal and professional lives?

Advances in science and technology have led to the globalization of the human condition. Science and technology and their interaction with humans cannot be contained within national borders. STS within a global perspective is essential in the education of youth for the 21st century.

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Rodger W. Bybee

Science-Technology-Society in Science Curriculum: The Policy-Practice Gap

Revolutions in science and technology, public concerns about the environment and resources, and a general reform of curriculum have contributed to a new educational theme, science-technology-society (STS) (Bybee, 1986b; Hurd, 1987; Roy, 1985; Rubba, 1987b). Whether STS remains a fad or develops into an important organizing theme for curriculum depends in some measure on the translation of curriculum policies and classroom practices. This, the major focus of this article, is developed in three sections: the intended curriculum, the actual curriculum, and the learned curriculum (Murnane & Raizen, 1988). This article also has a minor theme focusing on research supporting STS. Articles cited were selected because they form a research base concerning the STS theme and complement another review on current STS research (Rubba, 1987a).

The Intended Curriculum

The intended curriculum is defined as the curriculum represented by those persons and policies describing a particular emphasis (Roberts, 1982). In this case, the intended curriculum is STS and is characterized by the corpus of articles and policy statements recommending STS. Always a critical issue is whether curriculum policies are used to develop curriculum programs. It is in fact much easier to make recommendations for reform than it is to change school programs and practices.

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STS and Contemporary Policies

In the late 1970s, a growing number of educators argued that science courses should include STS (Charles & Samples, 1978; Hurd, 1975; Zoller & Watson, 1974). By the 1980s, the National Science Teachers Association (NSTA, 1982) published *Science-Technology-Society: Science Education for the 1980s.* The NSTA statement directly promoted the STS theme. A brief quotation from the position statement highlights the STS theme:

> to use the skills and knowledge of science and technology as they apply to personal and social decisions; and, to study the interaction among science-technology-society in the context of science-related societal issues. (pp. 1-6)

The NSTA policy statement provided a rationale and general guidelines for incorporating the STS theme into science curriculum and opened the door to implementing STS in school programs and engaging in STS research.

Research-based Policies

In the early-to-middle 1980s, Bybee and colleagues completed several surveys related to the STS theme. The researchers had three objectives: establishing the STS theme in the literature, incorporating a global perspective in science education, and providing information about such practical questions as, What STS topics are important to study? How much time should be devoted to STS topics? What were the trends in teaching STS? and, What were the limitations in teaching about STS? The populations sampled included scientists and engineers (Bybee, 1984a), citizens (Bybee, 1984b), college students (Bybee & Najafi, 1986), science teachers (Bybee & Bonnstetter, 1986), science educators in the United States (Bybee, 1987b), and an international population of science educators (Bybee & Mau, 1986).

The international survey (Bybee & Mau, 1986) was the most extensive in that it included 262 science educators from 41 countries, with a response rate of 80 percent. Some results of that survey are reported here. Table 1 displays a ranking by science educators of science and technology-related problems in terms of importance. The results also indicated that a majority of science educators thought most of the global problems listed in Table 1 would be worse by the year 2000. Particularly important were the following results: The majority of respondents indicated that studying global problems in school was important; a majority recommended an increased emphasis on science and technology-related problems from lower to higher grade levels; and a majority recommended that the science and social studies aspects of STS be incorporated into one course (Bybee & Mau, 1986).

Table 1
Science Educators' Ranking of Science and Technology Related Global Problems

Global Problem	Rank	Mean
World Hunger and Food Resources (food production, agricultural, cropland conservation)	1	3.92
Population Growth (world population, immigration, carrying capacity, foresight capability)	2	4.35
Air Quality and Atmosphere (acid rain, CO_2, depletion of ozone, global warming)	3	5.43
Water Resources (waste disposal, estuaries, supply, distribution, ground water contamination, fertilizer contamination)	4	5.53
War Technology (nerve gas, nuclear developments, nuclear arms threat)	5	5.80
Human Health and Disease (infectious and non-infectious disease, stress, noise, diet and nutrition, exercise, mental health)	6	5.82
Energy Shortages (synthetic fuels, solar power, fossil fuels, conservation, oil production)	7	6.30
Land Use (soil erosion, reclamation, urban development, wildlife habitat loss, deforestation, decertification, salinization)	8	6.52
Hazardous substances (waste dumps, toxic chemicals, lead paints)	9	7.49
Nuclear Reactors (nuclear waste management, breeder reactors, cost of construction, safety, terrorism)	10	8.38
Extinction of Plants and Animals (reducing genetic diversity, wildlife protection)	11	8.37
Mineral Resources (non-fuel minerals, metallic and non-metallic minerals, mining, technology, low-grade deposits, recycling, reuse)	12	9.40

(From: Bybee & Mau, 1986)

Rubba (1989) investigated the semantic meaning assigned to concepts associated with STS by a sample of exemplary secondary-level science teachers. The teachers had positive opinions of science and technology, their understanding of science, and their ability to teach science. Relative to STS, the exemplary teachers also expressed positive opinions about students' understanding of STS concepts, the students' need to understand STS, their own understanding of STS, and their ability to teach STS. However, the teachers did not allot much instructional time to STS. Rubba's (1989) findings generally support other findings. Science teachers are aware of, and support, implementing STS; they do not translate policies to practices. One of the first steps toward the development and implementation of curriculum based on the STS theme is the identification of goals appropriate for STS. Several articles describe goals for the STS theme (Bybee, 1986a, 1987a; Rubba & Wiesenmayer, 1988).

The combination of policies by national organizations and research studies on STS suggests that this theme is important and widely supported. While the review of literature and research supporting an intended STS curriculum is a first step in reform, policy statements and recommendations must not be confused with actual curricular changes. In short, recommendations for change are not synonymous with actual changes in science curricula.

The Actual Curriculum

If STS is more than an accumulation of good ideas or a plethora of well-meaning policies, the theme must be actualized in school programs. That is, there must be real and accurate representation of STS in curriculum materials and instructional strategies that are *used* by science teachers. Simply stated, the actual curriculum is defined as what science teachers use and what they do to portray STS to students.

This section uses textbook reviews and research on classroom practices to assess the degree to which STS has been implemented. That is, what changes have actually occurred in school science programs?

Textbook Reviews

Since the textbook dictates the curriculum in most science classes (Weiss, 1978, 1987), reviews of textbooks serve as indicators of the degree to which the STS theme is part of the actual curriculum. In the late 1970s, two separate studies analyzed biology textbooks for social issues (Boschmann, Hendrix, & Mertens, 1978; Levin & Lindbeck, 1979). The inclusion of STS issues in biology textbooks was neither quantitatively nor qualitatively significant.

A 1984 analysis of the STS content in high school biology textbooks (Rosenthal, 1984) produced no more promising results. In her study, Rosenthal clearly defined social issues, developed 12 categories of social issues based on an extensive review of the literature, and had the classification of social issues reviewed by experts. The study specifically evaluated the emerging STS theme by looking for evidence of STS issues in textbooks. Rosenthal summarizes her finding:

> For 22 textbooks published between 1963 and 1983, the percentage of total textbooks dealing with social issues has declined. There is no evidence from this study that textbook authors and publishers have responded to the statements of numerous scientists' and science educators' call for a greater emphasis on science and society in high school biology textbooks. . . . In general the treatment of science and society in high school biology textbooks minimizes the controversial aspects, avoids questions of ethics and values, lacks a global perspective, and neglects the interdisciplinary nature of problems. (p. 829)

Rosenthal's review of biology textbooks is particularly important for two reasons. First, over 90 percent of high school biology teachers use one of the textbooks reviewed in this study. Second, for the majority of students, high school biology is the last science course they take (Hurd, Bybee, Kahle, & Yager, 1980).

Hamm and Adams (1987) analyzed 4,393 pages in 10 sixth- and seventh-grade science textbooks for the treatment of global problems as identified by Bybee and Mau (1986). Less than 2 percent of the space was devoted to the global problems of population growth, world hunger, air quality and atmosphere, and water resources.

In sum, analysis of sixth- and seventh-grade science textbooks and tenth-grade biology textbooks indicates that they contain little STS content. Given that these levels include the upper elementary, middle level, and lower high school, it is reasonable to conclude that STS is minimally represented in the actual science curriculum for the majority of students.

The foregoing summary clarifies a critical issue, namely that the STS theme has not been embraced by school personnel, textbook authors, and commercial publishers. Yet, a variety of supplemental curriculum materials is available to teachers wishing to include the STS theme in science (Jarcho, 1986; Penick, 1986). And, several textbooks and curriculum materials incorporating the STS theme have been published for use in science courses.

For example, *Global Science* (Christiensen, 1984) and *ChemCom: Chemistry in the Community* (American Chemical Society, 1988) are both textbooks for a full-year science course. *Science for Life and Living: Integrating Science, Technology, and Health* is a K-6 program (Bybee & Landes, 1988). *Design Technology: Children's Engineering* (Dunn & Larson, 1990) is another technology-oriented program for elementary school. Additional programs include *Science-Technology-Society: Preparing for Tomorrow's World* (Iozzi, 1987), *Exploring Technology* (Bame & Cummings, 1980), and *People Create Technology* (Heiner & Hendrix, 1980).

Classroom Practices

Although little information exists about classroom practices and STS, a 1982 survey of science and social studies teachers (Barman, Harshman, & Rusch, 1982) indicated that the majority of teachers supported the integration of science and social studies and 90 percent of those surveyed supported teaching about STS topics. However, 68 percent were undecided about their level of commitment to initiate an STS program.

Probably the most insightful research on classroom practices was reported by Mitman and her colleagues in 1987:

> The instruction of 11 seventh-grade life science teachers was observed to determine the extent to which they made linkages between science content and its societal, reasoning, historical, or attitudinal implications. . . . Results showed that (a) teachers rarely or never addressed the non-content components of science in their presentations and academic work assignments, (b) students perceived content as the prominent focus of their teachers' instruction, and (c) teachers' references to the non-content components were unrelated to growth on all but one student outcome, where the association was negative. Altogether, the results indicate a large gap between scientific literacy as a goal of science instruction and current teaching practice. (Mitman, Mergendoller, Marchman, & Packer, 1987, p. 611)

This study provided a thorough, yet disturbing, picture of what happens, or more appropriately what does not happen, relative to the STS theme in science classrooms.

Implementing STS

Why don't teachers implement programs based on the STS theme? What would contribute to incorporating STS topics in classrooms? In an effort to answer these questions, Bybee and Bonnstetter (1987) surveyed 317 science teachers. Results were similar to those found in earlier studies by Barman et al. (1982), Stubbs (1983), and Barrow and Germann (1987). A majority, 89 percent, of the teachers surveyed had *considered* incorporating STS activities into some aspect of their program. Over 90 percent of the teachers said they *would* incorporate the STS theme *if* materials and instructional strategies were available. Over 70 percent even suggested specific ways in which they would incorporate the STS theme.

When asked about sources of information that might be useful in teaching STS topics, teachers mentioned such sources as journals and other professional publications, college courses, other teachers, and local specialists or coordinators. When the teachers were asked about the limitations on teaching about STS topics, top-ranked reasons were economical, personal, and pedagogical.

Carlson (1986) also conducted a survey focusing on factors that influenced implementation of STS in middle school science programs. Three factors influenced the adoption of STS topics by this sample of teachers: membership in professional organizations, amount of background knowledge, and administrative support. Actual implementation of STS topics was most influenced by time, resources, knowledge, and teaching experience.

Mitchener and Anderson (1989) reported a qualitative investigation of 14 secondary science teachers' perceptions of, and consequent decisions about, the implementation of a model STS program. Analysis of the data sources indicated three groups of teachers: those who accepted the STS program, those who accepted and altered the program, and those who rejected the program. Five themes were common to all three groups. These themes are helpful in locating reasons for accepting, altering, or rejecting the STS program.

The themes with clarifying questions were (a) concerns over content, i.e., Is there enough science? (b) discomfort with student grouping, i.e., How does one group students for STS activities? (c) uncertainties about evaluation, i.e., How does one evaluate STS outcomes? (d) frustrations about the student population, i.e., What about college-bound students? and (e) confusion about the teacher's role, i.e., How does a science teacher teach about social issues? This study reconfirmed the key place of the teacher in the implementation of a new program. Similar results were obtained in an investigation of STS education among secondary teachers in Tennessee (Rhoton, 1990).

Reviews of the actual curriculum reveal that the STS theme is not as significant as recommendations would suggest. The disparity centers on the role of implementation because curriculum materials are available and surveys indicate that most teachers recognize the importance of the STS theme. Science teachers just do not include the theme in their actual curriculum and instruction.

The critical issue of responsibility is raised by those findings. Who is responsible for closing the gap between the intended curriculum and the actual curriculum? Certainly, those who develop science curricula are partially responsible, but they seem to be responding. However, review of major textbook programs and the actual practice of teachers reveal a significant disparity between the intended STS curriculum and the actual STS curriculum.

The Learned Curriculum

Learned curriculum refers to the knowledge, attitudes, and skills that educators intend to influence via the curriculum. For STS, the question is, What are students learning about science and technology-related social issues? National assessments of science learning are reviewed in the first portion of the section and individual research is summarized in the second portion.

National Assessments

The National Assessment of Educational Progress (NAEP) reports on science have been available for 20 years. The 1976-1977 national assessment of science was the first to include items on science and society, and to assess students' awareness of the methods, assumptions, and values of science (NAEP, 1979). In 1976, students at ages 9, 13, and 17 were aware of science-related societal problems and were willing to contribute to the amelioration of the problems, but their reported participation in solving problems was low. Students lacked an overall understanding of scientific research methods and did not understand the difference between basic and applied research. In all, the 1976 results were disappointing and a basis for concern about students' understanding and attitudes toward STS topics (Bybee, Harms, Ward, & Yager, 1980).

In the 1981-1982 national assessment of science, published in *Images of Science* (Hueftle, Rakow, & Welch, 1983), elementary students showed a statistically significant increase in their understanding of STS items. Middle and high school students' understanding generally increased, but the increase was not statistically significant. Hueftle et al. proposed a "media hypothesis" to students' awareness of STS issues. The largest increases on topics were those that had received the greatest attention in the media, such as acid rain and food shortages.

STS topics were not prominent in the 1986 NAEP assessment items (Mullis & Jenkins, 1988), but several questions on the perceived applications of science were included. Students were more likely in 1986 than in 1977 to agree that the applications of science could help to preserve natural resources, reduce air and water pollution, and prevent birth defects. The largest changes across time were the decreases in the percentages of 13- and 17-year-olds who believed that science applications could help to resolve the problems of world starvation (p. 145).

The trend away from STS items in the NAEP assessments is disappointing. The 1990 national assessment (NAEP, 1989) had few STS items.

Research Studies

In 1986-1987, Yager and his colleagues (Yager, 1988a, 1988b; Yager, Blunck, Binadji, McComas, & Penick, 1988) assessed the impact on student learning of science teachers who participated in STS workshops over a 3-year period (1984-1986). In a follow-up study of teachers, Yager et al. (1988) assessed student outcomes in five domains—(a) connections and applications of science concepts, (b) attitudes,

(c) creativity, (d) understanding of scientific process, and (e) STS information. Assessment results were compared for the STS-trained and traditional science teachers at grades 4 through 9. Students in STS programs were better able to apply information to problems, relate new information to other situations, act independently, and make decisions. They also had more favorable attitudes toward science, were more creative, had greater abilities with process skills, and learned at least as much scientific information as students in comparison classes.

Aikenhead, Fleming, and Ryan (1987) assessed Canadian high school graduates' beliefs about STS. Graduates were asked to write an argumentative paragraph on an STS topic. The researchers monitored the reasons students gave to justify their opinions. An analysis of student responses was the basis for an assessment instrument entitled "Views on Science-Technology-Society" (VOSTS). Aikenhead (1988) subsequently validated the VOSTS instrument in a large-scale study and compared VOSTS with other means of assessing students' beliefs about STS topics.

Analysis of the original data from the assessment of Canadian high school students' beliefs about STS was completed by Fleming (1987). He summarizes students' understanding of STS interactions.

> One major interaction between science and society was viewed by students in a rather simplistic fashion: Science (techno-science) should inform society in order to resolve socio-scientific issues, issues which students perceived as technical problems; our society should inform science in terms of science policy as it guides research programs. The formulation of policy for a research program was not perceived as a socio-scientific issue. (p. 185)

The students did not differentiate between science and technology and their view of STS interactions was that science should inform society about solutions to problems but society should set policy for research.

Aikenhead (1987) summarized another portion of the results in this manner:

> In summary, high school graduates harbored diverse and contradictory beliefs about scientific knowledge. Students' paragraphs reflected a belief in certain aspects of authentic science; particularly, the nature of classification schemes, the tentative nature of knowledge, and the social dimensions of knowledge from within the scientific community. On other issues, however, students seemed to be uninformed; for instance, on the nature of scientific models, on the outside influences on scientific knowledge, on the motivations for generating knowledge, and on scientific method. Students generally viewed "the scientific method" as a vague rule of thumb—follow the procedure as given. (p. 485)

Ryan (1987) analyzed data from the Canadian study to determine the students' beliefs about the characteristics of scientists. The majority of students thought that scientists should be concerned with the potential effects of their discoveries, and that scientists are being responsible in their actions.

In all, this line of research has provided insights concerning both methodology and findings. The VOSTS instrument supplied researchers with a valid and reliable means of probing students' understanding of STS issues. The findings suggest a need for education programs that introduce specific aspects of the STS theme.

Zoller and his colleagues (Zoller et al., 1990) used the VOSTS instrument in a study to assess goal attainment in STS education. The research team based their study on the question, "Do STS courses actually work?" The team compared students in an STS course with regular science students. The findings indicated that the STS course was effective in improving high school students' viewpoints concerning STS issues. The answer to the research question, Do STS courses actually work? was yes. Courses that directly focus on STS issues do improve students' knowledge about those issues.

Summary and Conclusion

In the early 1980s, NSTA developed a policy statement supporting the implementation of STS. Findings from several surveys provided supporting policies for including the STS theme in school programs and answered basic questions about the introduction of STS topics into the curriculum.

Based on the foregoing review of research, the actual curriculum does not appear to include as much about STS as the various policy statements might warrant. Textbooks do not typically include STS topics and teaching practices reflect little or no recognition of STS themes. At the same time, curriculum materials and instructional strategies for teaching about STS themes do exist.

Providing information that will help close the immense gap between policy recommendations and classroom practices seems to be the central issue. The efforts of teachers to implement the STS theme have lacked direction and have occurred at a low frequency. The need for greater understanding of systematic implementation—including administrative support, staff development programs, and techniques such as coaching of teachers in new strategies—poses important issues for translating policies to practices.

Evidence at both the national and local levels suggests that students *are* learning about STS issues. Although NAEP results indicate that students understand STS issues and have positive attitudes toward STS study, those findings are offset by other research indicating little is being taught about STS in school programs. What students learn about STS is probably related to factors other than science instruction, namely, the media.

Sustaining the STS innovation requires the translation of policies to practices. Development of curriculum materials and changes in teacher education are essential. If we do not attend to the systematic translation of the STS theme from policies to practices, implementation will be insignificant and STS will be a passing fad. STS makes education meaningful for students, but whether educators take advantage of this opportunity is contingent primarily on the implementation of STS and secondarily on the continued development of research based knowledge.

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Integrating STS Into School Science and Teacher Education: Beyond Awareness

What does it take to integrate science-technology-society (STS) education effectively into school science? As research on this topic continues, we are learning that effective STS integration must go beyond a focus on awareness of STS issues and the use of traditional science instruction methods (Rubba, 1989). Similarly, STS teacher education must go beyond the teaching of STS content and instructional methodologies to helping teachers examine their beliefs and values about STS and science education (Aikenhead, 1984; Mitchener & Anderson, 1989).

This article examines some goals and recent developments in integrating STS education into science education. It then discusses recent research that has provided insights into the integration of STS education in the science classroom and the implications for science teacher education at both the preservice and inservice levels.

STS and Social Responsibility

A myriad of STS-related issues are facing humankind, among them global warming, habitat alteration, high-tech in the workplace, overpopulation, ozone layer depletion, species extinction, waste management and disposal, water quality and quantity, and world hunger. Today's students are the citizens of tomorrow who will face these issues and, knowingly or unknowingly, further aggravate or help resolve them (Ramsey, 1989).

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Hence, our best hope for the resolution of STS-related issues are citizens literate in science and technology, and empowered to make informed decisions and take responsible action. Rubba and Wiesenmayer (1988), among others, have argued that this is the ultimate goal of integrating STS into school science.

The blue-ribbon policy groups that examined the status of school science education in the United States during the early 1980s were critical of students' level of scientific and technological literacy. They recommended that STS be introduced into the K-12 science curriculum in order to prepare students to deal firsthand with STS issues at both the personal and societal levels (Aaronian & Brinckerhoff, 1980; Harms & Yager, 1981; National Science Board, 1983). In 1982 the National Science Teachers Association (NSTA) issued guidelines on school science for the 1980s that emphasized STS. One year later the National Council for the Social Studies (NCSS, 1983) issued guidelines on teaching "science-related societal issues." Both teacher groups renewed their calls for STS education through recent revisions of those guidelines (NCSS, 1990; NSTA, 1990).

As the original recommendations on STS education gained prominence, two researchers independently sought to identify factors that distinguish individuals who take action on societal issues. Sia (Sia, Hungerford, & Tomera, 1986) administered a bank of instruments that measured variables noted in the environmental education literature as possible predictors of action behaviors to two groups of subjects—an environmentally active group and an environmentally non-active group. The resulting data were analyzed using regression analysis. Hines (Hines, Hungerford, & Tomera, 1987) completed a meta-analysis of the extant literature in environmental education on action behaviors. Sia and Hines each concluded that citizens who act on environmental issues (ecologically-based STS issues) possess four characteristics: They (a) are aware of issues, (b) are knowledgeable about actions that might be taken to resolve the issues (c) have the ability to carry out or take informed actions on issues, and (d) possess certain personality and attitude characteristics that dispose them to act.

Studies from that body of environmental education research (Klingler, 1980; Ramsey, Hungerford, & Tomera, 1981) showed that school students take a greater number of actions on environmental issues when the instruction addresses all four of the characteristics identified by Sia and Hines. Studies (Ramsey & Hungerford, 1989; Simpson, 1990; Wiesenmayer & Rubba, 1990) completed since the work of Sia and Hines have added further support. Together these works clearly suggest that when STS education is limited to the delivery of science content and/or only making students aware of prominent issues and knowledge of possible courses of action (the first two components identified by Sia and Hines), it will not lead students to take action nearly as frequently as when the four components identified by Sia and Hines come together in STS instruction. The four components in combination appear to help students develop the knowledge and capabilities to act on STS issues, as well as affective qualities that will dispose them to continue to take action, such as a commitment to an issue and an efficacy perception (the belief one can have an effect on STS issues).

An Instructional Model

One model of STS instruction that includes the four components identified by Sia and Hines, and has been shown to be effective in moving students to take action on STS issues (Ramsey & Hungerford, 1989; Ramsey et al., 1981; Simpson, 1990; Wiesenmayer & Rubba, 1990), is a project approach referred to as STS issue investigation and action instruction (Hungerford, Peyton, & Wilke, 1980; Rubba & Wiesenmayer, 1988). This approach consists of 4-6-week units that can be made part of a science course or science and social studies courses in a coordinated or integrated manner.

An STS issue investigation and action unit may begin with activities in which students examine the nature of science and technology and characteristic interactions among science, technology, and society. Next, critical STS-related issues may be identified and analyzed to determine what makes them issues, to reveal relevant science and social science concepts, and to identify prominent value positions associated with different sides of the issue. Case studies might be used to demonstrate that (a) STS issues can be resolved only through responsible citizenship action and (b) we can have an impact.

An STS issue that is relevant for the community and students may then be selected by the class (or a number of STS issues may be selected by different groups of students within a class) to serve as an STS theme and focus in investigation and action activities. Students learn skills for investigating issues as they apply those skills to the issue. These might include the study of science and/or social science concepts, library research, securing data and information from governmental and private agencies, collecting natural science data on site, and using social science research techniques, such as questionnaires, to collect data within the community.

The students then analyze the information and use their analyses to propose alternative resolutions for the issue. The pros and cons of each resolution are weighed, a resolution(s) selected, and a course(s) of action decided upon. Lastly, students decide which actions they might take as individuals or as members of a group, carry through with their action plans, and evaluate the results.

Making STS issue investigation and action units a part of science courses across a number of grades—for example, starting in middle/junior high school through high school—allows teachers to select community- and student-relevant STS issues involving science concepts that otherwise would be taught in the science courses. Also, it allows teachers to sequence

STS issues so that science and social studies concepts and STS issue investigation and action skills developed in one grade are reinforced in the next while more sophisticated STS concepts and skills are introduced and applied.

Since STS issues involve economics, government, politics, beliefs, attitudes, and values, science and social studies teachers would ideally join together and cooperatively teach an STS issue investigation and action unit. Twenty percent of a sample of middle/junior high school science teachers surveyed by Rubba and Wiesenmayer (1990; Rubba, 1990) indicated that interdisciplinary cooperation had been carried out between teachers of science and teachers of other subjects (e.g., English, math, social studies) in the recent past. An additional 8 percent indicated that their school was moving toward an interdisciplinary curriculum.

The Center for Education in Science, Technology and Society at Pennsylvania State University has been offering summer workshops since 1985 in which science teachers develop STS issue investigation and action units. Each workshop has included at least one team of science and social studies teachers. David Klindienst, the science curriculum coordinator, and Gary Owen, the social studies curriculum coordinator for the State College (Pennsylvania) Area School District, attended the first workshop. The high school STS course they developed and continue to team teach, entitled "Man [sic], Technology and the Environment," meets during two consecutive periods. Students earn both science and social studies credits toward graduation. It is not only desirable, but also feasible, for science and social studies teachers to cooperate on the development and delivery of STS education.

Teacher Capabilities for STS

It has been nearly a decade since the blue-ribbon groups recommended that STS be integrated into the school science curriculum. NSTA and NCSS took the lead by developing guidelines. Florida, Maryland, Michigan, New York, Washington, and Wisconsin were among the first states to take initiatives to provide STS education (Rubba, Brachi, & Wambaugh, 1987). NSTA (1982), in fact, recommended that 5, 15, and 20 percent of science instructional time at the elementary, middle/junior high school, and high school levels, respectively, be dedicated to STS. It appears, however, that most science courses include the equivalent of only a few days of instructional time per academic year on STS, and that the instructional strategies of choice during these STS episodes are the same ones science teachers commonly use to teach science concepts—the lecture and laboratory with supplemental use of discussions and films/videos (Rubba, 1989).

STS vignettes—short illustrative examples, challenging questions, memorable quotations, and paradoxes related to STS issues that are interjected into lessons (Brinckerhoff, 1985)—appear to be a favored discussion method for introducing STS into secondary courses (Bybee & Bonnstetter, 1987). Unfortunately, the reported value of vignettes has not be substantiated. In fact, Rubba, McGuyer, and Wahlund (1991) found interjecting STS vignettes and holding periodic class discussions on the vignettes did not significantly affect student awareness of current STS issues, the importance they assigned to current STS issues, or their achievement with regard to science content. In addition, the frequency with which the vignettes and discussions were used had no effect on these three variables. Similarly, Zielinski and Mechling (1989) found STS vignettes do not affect awareness of current STS issues and attitudes toward STS issues among preservice elementary teachers.

Academic preparation has been the singular goal of science instruction since at least the early 1960s, and today it remains the goal around which preservice and inservice education for science teachers is organized. This continues irrespective of the recommendations in the Project Synthesis Report (Harms & Yager, 1981), which proposed that societal and personal needs are equivalent in status to academic preparation as goals of a school science education, and irrespective of two sets of guidelines from NSTA (1982, 1990) that emphasize STS.

One is tempted to argue that STS has not attained the level of implementation recommended by NSTA simply because the majority of active science teachers are not prepared to teach STS. As a result, the argument goes, most science teachers either avoid STS, dismissing it as just another fad, or they introduce it into science courses to very limited degrees, using their usual instructional methods—the lecture, labs, films/videos, and discussions.

The limited statistics on the number of inservice and preservice science teachers who have received STS education training would appear to support this argument. Over the past 5 years, for example, the Center for Education in Science, Technology and Society at Penn State has been able to accommodate only about 200 teachers in its summer STS teacher education workshops. Another 200 preservice secondary science teachers received STS teacher education at Penn State over the same period. Similar statistics have been posted by the Center for Science and Environmental Education at Southern Illinois University, the Science Education Center at Clarion University, and the half-dozen other university/college groups working in the area of STS education.

The argument above appears valid until one looks deeper and considers the influence of teachers' values and beliefs on the success or failure of the new curricula. Mitchener and Anderson (1989) used qualitative research methodologies to explore the perceptions of and the consequent decisions made by 14 junior high school teachers from a single department about the development and implementation of an STS course. The course, entitled "Topics in Applied Science," had been developed during the late 1970s by a writing team of 12 teachers from the district, and was cited in 1982 as an exemplary science program by NSTA.

The science teachers fell into three groups—four teachers who strongly accepted the STS course, five who accepted it but significantly altered the course, and a group of four teachers who rejected the STS course. No relationship was found between membership in these three groups and variables such as years of teaching experience, content area expertise, and gender. However, five areas of concern were found to be common across the three groups and significant in determining group membership, influencing the teachers' decisions to accept, alter, or reject the STS course. These areas included (a) course content, (b) student grouping, (c) evaluation of students, (d) the targeted student population, and (e) the role of the teacher.

Although most of the teachers expressed strong support for the applications-oriented goals of the STS course, most of them still saw the purpose of school science to be the preparation of students for future science classes. In addition, the teachers wanted the course's content to be easily identified as "science" by students and parents. Use of cooperative grouping and the change in teacher role from expert-lecturer to facilitator were difficult for the teachers to accept and carry out. Consequently, it often did not occur, even though the teachers had been trained and said they valued the intent behind the strategies. Use of open-ended evaluation activities provided another source of discomfort. And the presence of "low-ability" students in the course created dissonance for teachers who had an elitist view of their role in the school.

Mitchener and Anderson (1989) found that the science teachers' STS education practices, or lack of them, were deeply rooted in their beliefs and values, to the point that, "although the teachers attempted to adjust, their old beliefs and practices lingered in varying degrees" (pp. 367). Aikenhead (1984) suggests that a change in STS practices will require that science teachers restructure their beliefs and values concerning the goals of a school science education.

Recommendations

STS education directed at the goal of socially responsible action on STS issues is distinctly different from the type of curriculum, instruction, and evaluation we have traditionally found and continue to find in the science classroom. It is distinct from that which inservice science teachers were prepared to deliver and that which most preservice science teachers presently are being prepared to deliver. It is different from the science education that inservice and preservice science teachers experienced at the pre-college, undergraduate, and graduate levels.

Borrowing a perspective from constructivist epistemology (Gates, 1991), one might argue that the beliefs and values that direct the science teaching practices of a science teacher have been constructed out of a complex of science education, science teacher education, and science teaching experiences. This may include: (a) a period in the elementary grades when science instruction was limited or not provided; (b) middle/junior high school science that emphasized preparation for high school; (c) high school science that was taught mainly for and to an elite group of students who intended to go on to college; (d) undergraduate school science courses that were designed for science majors and taught by faculty who perceived it to be their duty to separate out the group of students who would be successful in science graduate studies; (e) preservice teacher education coursework that emphasized teaching for academic preparation; (f) a student teaching experience with a science teacher whose teaching practices also were directed at the goal of academic preparation; (g) teaching experience in a school district in which teachers were rewarded based upon factors such as high standardized test results and the number of students who went on to college; (h) graduate school science courses for pre-professional or professional scientists; and (i) inservice teacher education that continued to emphasize the goal of academic preparation.

Before appropriate STS teaching practices can be fully developed and put into practice, science teachers' beliefs and values must be compatible with the notion of responsible citizen action on STS issues as a goal of a school science education. Preservice and inservice science teachers must have opportunities to (a) examine their beliefs and values about responsible citizen action on STS issues and the place of STS in school science education, (b) confront inconsistencies in their beliefs and values about STS action as a science education goal, and (c) construct more appropriate beliefs, values, and corresponding science teaching practices, all under the careful guidance of a knowledgeable science educator or model science teacher.

Unfortunately, many of us involved in the education of science teachers have not yet recognized the full importance of addressing science teachers' beliefs and value systems. The failure of large numbers of science teachers to use inquiry in their science teaching is a case in point (Mitchener & Anderson, 1989).

In both the preservice and inservice education of science teachers, we have tended to disregard teachers' extant beliefs and values, assuming or at least acting as though once the mechanics of new teaching practices are "learned," the inherent benefits of the new practices will convert teachers. We have tended not to provide sufficient or appropriate opportunities for science teachers to examine and reconstruct the beliefs and values that affect the adoption and full implementation of science teaching practices.

The integration of STS into school science education, to prepare students to take responsible action toward the resolution of STS issues, mandates that extensive efforts be undertaken in STS teacher education. However, STS teacher education will only be successful if we employ strategies that help science teachers construct appropriate beliefs and values as they learn to implement STS. Robust strategies must be developed and implemented that are substantial enough to counter the influences of science teachers' school and college science, science teacher education, and prior science teaching experiences. To do otherwise, to continue to ignore science teachers' beliefs and values about the place of STS in a school science education, is to be preordained to the status quo.

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