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ABSTRACT

Recognizing the potential pitfalls resulting from a lack of human foresight lies at the heart of the science-technology-society (STS) movement. This issue of "Theory Into Practice" is the second part of a two-part series that examines the educational opportunities arising as educators attempt to develop student understanding of STS. In the first article of this issue, Donald H. Bragsaw examines the opportunities to work across traditional boundaries to integrate knowledge to an extent greater than our histories have yet seen. Leonard J. Waks describes a responsibility spiral, an organizing framework to help educators identify, select, organize, and sequence learning experiences designed to promote the understanding necessary for responsible citizenship. The integrative theme is explicated further by Gerald W. Marker and Glen Aikenhead in articles on social studies and science instruction, respectively. Patrick Fullick describes a project in the United Kingdom that is intended to teach students about the social, economic, and technological aspects of science, the SATIS (Science and Technology in Society) project. Direct, hands-on experiences are advocated in separate articles by Sharon A. Brusic and Phillip A. Heath as opportunities to provide an experiential arena for issues-oriented instruction. Paul W. De Vore discusses the new order of knowledge and understanding required for a quality human future. Dennis W. Cheek examines new approaches to the evaluation of student learning and understanding. Wanda T. May returns to the integrative nature of STS and notes that the complex issues and events cannot be located, studied, or resolved in single "academic disciplines." (PR)

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

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This Issue

In a recent issue of *The New York Times,* Edward Tenner (1991) raises these tantalizing questions: "Why do the seats get smaller as the airplanes get larger? Why does voice mail seem to double the time to complete a telephone call? Why do filter-tip cigarettes often fail to reduce nicotine intake?" Tenner then points out that all too often our well-intended efforts to improve the human condition through innovations in technology are accompanied by unintended, unforeseen, and often unsavory consequences—a phenomenon Tenner refers to as "revenge effects."

For example, touch-tone telephones have increased the dialing speed, but the time saved by punching numbers is now consumed by systems designed to take advantage of it. Combining the telephone number, the carrier access code, and credit card number, a call may require punching as many as 30 digits. As Tenner points out, "The world seems to be getting even . . . twisting our cleverness against us. . . . This is not a new phenomenon, but technology has magnified it."

The Tenner article raises perplexing questions about the interaction of science and technology with society and the complex web of linkages among the three. What roles should science and technology play in responding to human wants and needs? How shall we define progress? What trade-offs are we as a society willing to accept in applying the fruits of science and technology to human and environmental concerns. What is the proper role of society in nurturing and monitoring scientific and technological exploration and innovation? As Tenner points out, "Innovation involves both imperfect machines and unpredictable people. Revenge effects don't mean that progress is impossible, only that in planning for it we must look more to Rube Goldberg than to Isaac Newton."

In an important sense, comprehending the revenge effect phenomenon—recognizing the potential of pitfalls resulting from a lack of human foresight—lies at the heart of the science-technology-society (STS) movement. The challenge to the schools seems clear. Not only should students study the countless ways scientific and technological developments have enhanced our lives, but they should learn as well about the tangle of interconnected consequences that spin off such developments. Only then will they truly comprehend the symbiotic and dynamic relationship among science, technology, and society.

This two-issue series of *Theory Into Practice* examines the educational challenges and opportunities arising as educators attempt to develop in students an understanding of both the Isaac Newton and the Rube Goldberg aspects of STS. The first issue, dated Autumn 1991, focused on such challenges as determining the structure of this emerging STS initiative, its theoretical underpinnings, and its future. Authors in the first issue examined the history of science, technology, and social studies education, considered the contributions of various disciplines to the study of this field, and discussed factors influencing the teaching of STS.

In this issue, the authors examine the opportunities accompanying this emerging area of study. The opportunities to work across traditional boundaries, to integrate knowledge to an extent greater than our histories have yet seen, are explored by Bragaw. Waks pursues a somewhat different theme in presenting a responsibility spiral; an organizing framework to help educators identify, select, organize, and sequence learning experiences designed to promote the understanding necessary for responsible citizenship. The integrative theme is explicated further by Marker and Aikenhead in social studies and science instruction, respectively. In a related vein, Fullick describes a project in the United Kingdom that is intended to teach students about the social, economic, and technological aspects of science.

Direct, hands-on experiences are advocated by Brusic and Heath as opportunities to provide an experiential arena for issues-oriented instruction. They perceive the doing of STS as an avenue to developing a knowledge and skill base for ultimately improving the world and human condition. The need for and opportunity to develop a new literacy is addressed by De Vore, who discusses the new order of knowledge and understanding required for a quality human future.

Cheek examines new approaches to the evaluation of student learning and understanding. Not only does STS present us with new opportunities for curriculum development and instruction but with prospects for modifying our evaluation efforts to produce assessment that is more consistent with the intent of STS. Finally, May returns to the integrative nature of STS and notes that the complex issues and events cannot be located, studied, or resolved in single "academic disciplines." The primary goals and interests of STS, then, are moral and political in nature.

The authors clearly do not all view STS from the same perspective. Many differences remain to be reconciled or, alternatively, adjusted to. Nonetheless, areas of agreement exist: the integrative aspects of STS, new perceptions of the nature of literacy, and new bases of knowledge and skills required in today's world.

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

Guest Editors

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Tenner, E. (1991, July 26). Voice mail and fire ants. *The New York Times*, p. A11.

Donald H. Bragaw

Society, Technology, and Science: Is There Room for Another Imperative?

An assistant superintendent in a Boston suburb reported recently on a science-technology-society (STS) interdisciplinary course "struggling to be born" (Jacobs, 1989). The analysis of this "struggle" can inform us of the context of implementation of any program.

What were the identifiable obstacles? First, STS was a course in search of a "respectable home," a school subject. Was it a science course? a social studies course? or did it fit into the new technology (a.k.a. industrial arts) program? If it was not any of these, what was it and how would the students get credit? Who would be its advocate or defender?

Secondly, the people who planned the STS program decided to focus the course on STS issues of public debate, such as acid rain and other environmental concerns, for the substance of the course. Such a focus did not have the same immediate appeal to students (in suburban Boston) as a regular discipline elective or a traditional advanced placement course.

If one did adopt an STS course program, would the science, or history, or technology component be discipline valid? Would it be possible to teach "true" science, or history? The solution the course proposers agreed to was that the program would focus on reviewing or strengthening already learned concepts but not introducing new ones. Despite this modification, content validity became a major stumbling block for the discipline "purists," and a lack of enthusiasm among the more "traditional" types took its toll when the time came for student preregistration. The course failed to attain sufficient enrollment.

Related to the lack of interest in the course was the fact that the STS notion seemed to be promoting a "different attitude toward knowledge." Was this an intellectually sound program? To ask some teachers to approach their subject from a new integrated or interdisciplinary perspective would be not only alien but unacceptable to a majority of their colleagues. It was not the way they had been taught, or the way they, themselves, taught. They could not reconcile, for example, the lack of an adequate textbook to accommodate the new design.

Lastly, administrative, logistical, personnel, and budgetary support for an "orphan" program was hard to justify unless enrollment was adequate. Because students did not respond, the course was not offered.

The experience described above, and freely interpreted by this author, was in reference to an elective course at the secondary level of instruction. The obstacles cited, however, are real ones for any "new" program (course, unit, lesson, or topic) in a school district, whatever the level. It is especially true of a program that has an aura of change, or innovation. How does a new program, a new emphasis, receive the imprimatur of school personnel concerned? That

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key question is determined in large measure by a "climate" of change that appears to be necessary before a new program of any type can see the light of day.

Can STS become a new program, or thrust, within the present educational structures? Recent reform efforts have not proven significantly effective in allowing new topics to enter into the late 19th and early 20th century mainstream of established school subjects (Popkewitz, 1988). This article addresses that question and makes several suggestions for how STS might succeed in breaching the relatively stringent school programs in place today and in the forseeable future.

Climate for Change

Effective schools research has indicated that establishing the climate for change is crucial to success (Goodlad, 1987; Lieberman, 1988; Lieberman & Rosenholtz, 1987). Success in implementing a new program depends on whether (a) it is considered to be of an imperative nature, (b) the proponents have a sense of mission, (c) the development of the program has been an intellectually stimulating and inspiring process, and (d) the program has arisen in a socio-democratic fashion keyed to participation and democratic decisioning—in what might be described as a populist tradition. Inhered in each of those conditions is the quality of leadership—be it principal, lead teacher, or assistant superintendent—quality as defined by intellectual depth, active commitment, and a touch of charisma. Without these factors, a new program design, a new course, or even a new unit has little chance of success.

The literature on renewal, reform, restructuring, or implementation in education is filled with promising practices, a great deal of conjecture (and sometimes contradiction), and inconclusive results. The fact that so much is going on is at once encouraging and a cause of cynicism. Administrator bulletins, teacher magazines, and other professional journals thrive on the latest field test of the most recent idea of the current curriculum research and development people. However, the absence of any real change in the schools would suggest that little notice is paid to this constant flow of articles. Principals are too concerned with maintaining present programs in the face of state mandates and budget cuts. Admonitions to institute outcome based curriculum, for example, take precedence over establishing a professional culture in the schools.

The same is true of the introduction of new ideas in subject matter areas. So-called reform reports in all of the academic areas of the curriculum have emerged (and continue to do so) with suggestions that range from "let us return to the golden age of education" (a time that strangely resembles the time when they were in school) to "tear the house down" and let us begin again. The fields of social studies and science, the most likely initial homes of STS programs, are two areas where this construct of change has been most prominent.

Science is battered for not making the United States number one in theoretical and practical science. Results of both national and international tests of scientific knowledge place the United States at or near the bottom (Berger, 1988; "U.S. Students," 1989). At the present time, science rides another "sputnik" and the government and many foundations, who look to the traditional security of scientific investigation, are willing to finance another trip to the "moon of multiple science proposals and grants" in order to regain the world lead in science (Alper, 1989).

Many leaders in science education agree that a hands-on approach to science education is necessary to teach the scientific method effectively, and they welcome the attention they are receiving. Only time will tell whether this new push will result in the overhaul of science programs and greater student achievement. Interestingly, all of the present or proposed science education improvement projects have a social and behavioral component to them, and some profess a science-technology-society orientation for at least part of the design (e.g., *Science for All Americans*, 1989). Recognition of the moral and ethical implications of scientific research and discoveries has finally become critical to proposal submissions. That, by itself, is a major accomplishment.

Social studies suffers from a spate of nostalgia. It is far easier to look back to the days when there was presumably more certainty of who we, as a nation, were, and where we were going. The study of history has a way of seducing us into believing that is true. If we accept the judgment of many of the neo-conservative reformers, the schools should now adopt the report of the American Historical Association's Committee on the Study of History of 1899 as the guide to what should be in social studies . . . or, as they prefer to call it, history programs (Bennett, 1987; Ravitch, 1987).

Thus, STS comes along at a time when the forces promoting the incorporation of new, or different, knowledge configurations are barely able to find berths in even the most innovative professional journals. A case study of the implementation of an STS based course in two junior high schools reflects the general research on reception of change in any school at the present time (Mitchener & Anderson, 1989). Teachers are fearful of administrators and school boards who hold them accountable for "basics" and are, therefore, reluctant either to modify or enter into new course arrangements. The slow pace of change in content, teacher behavior, and school reform has been cause for much concern by university and other reformers (Deal, 1990).

Establishing a National Imperative

During and after the Watergate crisis in the mid-1970s, the law profession suddenly discovered law-related education as a way to repair the damage that had been done to law and lawyers by the Nixon administration. This newfound curriculum emphasis, starting in the offices of the American Bar Association, took off in a well-financed and well-promoted effort that continues to this day. The tarnished image and the flowing dollars assured that an already comfortable curriculum fit between law and education would be enhanced and highlighted in our schools through workshops, conferences, and interesting learning materials.

Is there a natural fit for such an imperative that would sustain STS in the same manner? The demands for improved school science programs continue to be based almost solely on the classical academic tradition that stresses fact-oriented, pure science but not a strong societal or moral imperative that would impel an STS consciousness. In a recent back-page commentary in *Education Week*, Atkins (1990) asserts that science must not be weakened by an added emphasis on technology. He states that the realm that is uniquely science must be preserved so as to promote uncluttered scientists whose attention is not diverted by technology applications and the money that may attend to it. One might assume that Atkins would also be opposed to any extensive examination of the social implications of science principles studied.

Similar kinds of pleas can be heard when applied to other "academic" curriculum areas. Social studies, for example, suffers the same fate, mired as it is in the "acad-anemic" argument over whether discipline-focused history and geography are the core of social studies instruction, as opposed to those who would argue for an idea-focused, issues orientation that would draw upon the entire scope of the physical and social sciences as well as the humanities. Unfortunately integrative, or interdisciplinary, programs such as STS hang on by their fingertips in times of economic difficulty, and are but tolerated in flush times.

The only imperative—and it is a potentially dynamic one—that seems to exist for STS in the schools (outside the ranks of the already committed cadre) lies in problems of the environment—the dire condition of the planet earth and its increasingly fragile ecology. Even then, the association of science and technology and societal factors are not always seen as significantly connected. Efforts such as that of Lester Brown and the Worldwatch Institute staff, reported in their annual report on the state of the world (Starke, 1990), should be sufficient to motivate such an imperative. However, despite its wide distribution among influential thousands, it, or the environmental crisis, has not provided the same impetus as that provided in the field of law by the Watergate crisis. Corporate America, dependent on scientific and technological breakthroughs, has been slow to respond to environmental degradation. I would hazard a guess that few school administrators or classroom teachers read such reports. Membership in the Sierra Club, Greenpeace, and other environmentally conscious groups remains small. School based recycling efforts are in infant stages, as are school environmental awareness programs in most areas in the country.

The technology of war may come close to an imperative, but it takes an international conflict to reveal to the general public how science has impacted technology (and reverse) and how each of those forces affect society. By the time the weapons reach the target, the moral aspects of the events are outshadowed by the impact of fighting for a "just cause." The effect of technology becomes the primary concern, not its derivation in science or its interaction with society. An imperative of, and for, the science for peace has never been attractive or compelling except to a small minority.

If STS is to become a force in education, it must break out of its confinement and create a critical demand for its presence: a moral and ethical imperative. Beyond what is already being done by the STS professionals in a limited number of projects, a public campaign must be mounted. STS reformers must do a heavy job of selling STS to the press and the public.

Recently in Pittsfield, Massachusetts, General Electric unveiled a new house that had been developed and built through the magic of science and technology (Gilmore, 1990). The house, it is claimed, is a triumph of science—an innovative mixture of chemicals and wonder metals that has produced a "dwelling . . . covered with superstrong, superdurable plastic panels . . . and metal with 'a memory.' " Bend and twist the metal and it will return to its original shape! Such materials are not only for houses but for toys, automobiles, and a myriad of other uses.

The troubling aspect of this sensational news is that no mention is made of whether the material can be disposed of safely once it has lost its appeal. Both the press and the public have a need to ask the right question of this amazing scientific and technological phenomenon. Like truth squads during political campaigns, consciousness of the consequences of presumed technological progress is a mission of great importance for the STS committed cadre.

Part of the problem of non-acceptance of innovative (or different) school programs is that parents and the general public are not educated to new ideas early enough and frequently enough to make them not only conscious of them but advocates of them. Reliance on peripheral environmental organizations to carry out the public awareness is not enough. The popular press, especially those newspapers and periodicals that reach into the kitchen, dining room, and den, is a significant avenue for such STS advocacy.

School people welcome change when they can accommodate it to the familiar (White, 1985). The public campaign may be a precondition to creating a receptive school climate, providing a connective to the community that will assure a support mechanism. Beyond that, the school leadership must create a situation that allows the "imperative" to soak into the school's normal culture. The way that has been successful in the past has been to unite the school behind a sense of mission.

The Civic Mission of Schools

Butts (1989) has enjoined the educational community to return the schools to a renewal of its civic mission. The true meaning and function of schooling has been lost in the deluge of information. The basic question is: What is the central function of schools? Is it only to educate, or train, individuals for assuming an economically productive role in society? Or, as Butts would have it, do schools have a larger purpose—making better the society in which we will all live.

Goodlad (1987) reiterates this notion in indicating that school districts should commit themselves to comprehensive social and civic goals. The civic mission is the public's interest—a theme that pervades American philosophical thought from Jefferson and Dewey to Barber (1986). In view of the increasingly severe population, power, and environmental problems confronting our global society, if ever schools had need of a civic mission, the time is now.

Present reform, much of it at the state level, looks to accountability and the rigid interpretation of prescribed syllabuses so as to conform to state achievement testing. None of that testing includes items related to student ability to deal with problem solving or issue analysis and resolution. Indeed, the restrictive nature of the content elements forces school districts to emphasize repetitive and "short order" learning of specific information. The discussion of the human condition, that with which the student will need to understand and deal, is not a prime focus of school systems. The "dialectic of freedom," of which Greene (1988) speaks, does not appear on the school's agenda.

The mission of democracy, learning the tools of free discussion leading to consideration of possible alternatives to survival issues that confront our society, can be achieved only through schools setting goals that are imperative of student attention and study. As early as 1975, Shen called attention to the civic scientific literacy that he believed was essential to the solution of social problems. For him the promise and dangers of scientific and technological advances and their influence on the social life of the nation should be tied to education and the democratic process.

When the focus of STS topics, for example, is on investigating local environmental issues, students are usually involved in their own learning through intellectual engagement and skills development. That experience also accomplishes a worthwhile community—local to global—service. These are two major goals for positive democratic education: intellectual development and civic responsibility.

Recent units prepared and taught by my elementary education graduate students would suggest that such a mission can be achieved. Each of the inservice teachers—sometimes working with preservice teachers—prepared a teachable unit built around a public policy issue that was interdisciplinary in nature and yet consistent with state guidelines. Inevitably the majority of the topics chosen were of an STS nature. The units dealt, for example, with contamination of the local water supply and the threat of the extinction of the sea turtle population by commercial shrimp fishing. Both of these topics were of local and immediate student (and public) interest. Most of the units involved field investigation and research, and most contained a civic action component. The "turtle" preservationists testified at an open public hearing, advocating shrimp nets that exclude turtles. Student interest and academic achievement exceeded expectations. Many of the teachers have become converts to making such STS policy issues a regular part of their curricular and instructional baggage. Given this STS change catalyst as a school mission, an entire faculty could make a significant difference for school reform and restructuring.

Developing a social/civic interdisciplinary issues base for STS at the secondary level has been both encouraged and downplayed by writers in the field. Patrick and Remy (1985) expressed a strong desire that an interdisciplinary issues approach be used when dealing with STS. But they and others were quick to cite studies that throw the "disciplines blanket" over the use of such issues as a central school focus. That argument maintains that the students' lack of discipline based information would limit their ability to deal intelligently with the issues (Hertzberg, 1980). This discipline argument has so pervaded schooling that it automatically becomes the crutch people use to discourage innovation in curriculum, and this is especially true in social studies. Students at the elementary and secondary level need the ability to explore ideas. Freeing students from discipline walls, and allowing them to investigate ideas, problems, and issues, should be a major purpose of schooling—involving as it must the study of the "formal" math, history, and grammar necessary to make sense of their investigations.

Because schools tend to be static places, creating a civic commitment is not always an easy task. The STS environmental focus is a less threatening topic, and one that has a potential community-school cooperative component that would serve to unite the two educational entities together in what could be a highly rewarding civic mission. The challenge is to create a learning climate that allows students to develop the intellectual and commitment capacities to become informed, thoughtful, critically aware, and active citizens. STS can do that (Bragaw & Hartoonian, 1988).

The Role of Leadership

Much of the research concerning the creation of effective schools focuses on the crucial role of the principal or lead teacher. From the early work of Stake and Easley (1978) to current studies citing the significance of the role (Barth, 1988), the overwhelming sense is that without the principal or significant other playing an active part, change will not have a good chance of success. But the general appraisal of the principal has not always been encouraging. Noting that principals, like teachers, "learn their job by doing it," Lieberman and Rosenholtz (1987) have portrayed these leaders as people who are not concerned with innovation or change strategies. Most principals appear to act as "gate-keepers," interested primarily in maintaining the school, keeping the "lid" on, and doing routine administrative and evaluative tasks with as little instructional, curriculum development, or implementation involvement as possible. Increasingly, however, the newly emerging direction is that this key role, or its appropriate surrogate, must also be an intellectual force in any renewal or restructuring of the school's direction. The evidence is equally apparent that administrator training programs remain tied to a non-intellectual frame (Popkewitz, Tabachnick, & Wehlage, 1982).

Effective instructional leadership has two important aspects: (a) the leader as inspirational and intellectual force and (b) the leader as team organizer and supporter. Giroux has long asserted the need to recognize the intellectual capacities and performance of teachers and administrators (Giroux, 1988). For too long we have assigned administrators and teachers the role of unthinking cultural transmitters rather than expecting them to be intelligent human beings able to take charge of their professional lives, their subjects, and their educational destinies. No one can implement that which they do not intellectually (and emotionally) own. What further proof of that is there than the projects of the '60s whose developers herded teachers into demonstration rooms, plied them with tables of sample goodies, and asked them to leave their brains in the checkroom. Those efforts failed to take hold, although both the goals and the materials were worthy. Teachers possessed the materials, not the ideas that governed them (Haas, 1980).

When Eisner (1979) talks of curriculum as the "transformation of ideas by acts of educational imagination" (pp. 46-47), he makes the assumption that the people involved in the transformation process have the opportunity to explore the ideas that will transform them. He also suggests that the people closest to the "transformation" will be involved in the act. Transformation must come from within, and the intellectualization of the district's educational community must be stimulated, permitted, and encouraged to flourish.

The other role for the instructional leader is the team organizer and supporter. As Wirth (1991) points out, innovative leaders who operate in a socio-democratic process mode, and who have the stamina and the know-how to sustain a long-term commitment, can succeed if they involve the people who are most intimately connected. Those leaders must also have, and be able to inspire others to have, an enthusiasm for the change process (Wirth, 1991).

A School Based Strategy

Providing a school climate/culture for change must be the first task of any school leader who desires to make a difference. If that change is in an STS direction, then the STS mentality must be ignited in the staff. But allowing STS to happen through conferences and teacher workshops will not bring it into being. Given the present circumstances of school change or reform and the reality of schools, the focus of STS missionaries must be on administrators—giving them not only the base information but some cues to a strategy of change. The leader imbued with the STS imperative can then plant the necessary seeds. This consciousness-raising or awareness phase—developing an intellectual curiosity and enthusiasm among administrators—is an essential first step. How that administrator obtains conversion may occur in a variety of ways: direct intervention by STS projects or being spurred on by an inspired teacher, student, or parent. But that conversion must take place.

Beginning with the most innovative science and social studies teachers, instructional leaders can create expectations for, gain the support of, and provide resources for releasing their creativity to work on STS instructional materials—the place where teachers are most involved and directly affected by change. With the success of one combination working independently, a larger collegial team could be encouraged to gather necessary resources and then develop compatible STS lesson materials and, possibly, units to integrate into regular courses. Eventually this larger group would be encouraged to serve as an autonomous coordinating group to mobilize resources and ideas for involving the entire school in STS programs. Shifting the curriculum and instructional power base—with full responsibility for budget, scheduling, and evaluation—is a key leadership decision. That leader should remain intellectually and physically involved in this process but administratively distant.

One of the important roles of the coordinating group would be to identify exemplary programs within convenient distances, to facilitate the process and prevent the reinvention syndrome. The hesitancy of some faculties to enter into new programs often hinges on whether they can "see" a similar program in operation. The present STS community should be able to supply a compendium of schools with STS programs that would be willing to cooperate, communicate, and, perhaps, be visited. Irma Jarcho's herculean efforts at networking through the *Teachers Clearinghouse for Science and Society Education Newsletter*[1] is a significant place to start. In a wide-ranging article on effective schools and change, Levine (1991) states that school projects should "seek out and consider using materials, methods, and approaches that have been successful in schools and projects elsewhere" (p. 392).

Encouraging cooperating faculty and students to establish an active program of school-community involvement in STS issues, such as recycling, air or water pollution projects, and endangered species protection, would serve to generate student support. Such involvement is a critical component to the success of any program, for teachers are most enthusiastic when they feel and see success with students. Further, such student interest and outreach would tend to develop community and parental support and involvement. This latter condition will go far to encourage faculty to feel more secure in any change efforts on their part.

The principal or any leaders of STS efforts must also practice the skills of an STS public relations cheerleader. It is not sufficient to promote STS staff involvement; others must know about it. Colleagues within the school need to know in order to encourage them to cooperate and become involved; administrators at all levels need to know so that the good work is not sabotaged along the way; and parents need to know how this will improve their children's growth, potential test scores, and entry into college or life. The public relations effort should also be a reward to those who have been diligent and committed and their successes heralded in as wide a forum as possible. The nature of this process is to create a receptivity mood for all concerned: a school-wide atmosphere of intellectual ferment and productive activity, especially among those most intimately involved with the learning process.

No one system of innovative change works for all. The search is perpetual, and it must be tailored to the school and community. Whatever the change strategy adopted, the key is to promote, develop, and maintain the leadership capacities of those willing to advance a new view of knowledge that has implications for the survival of the planet.[2]

Conclusion

The first draft of this article was written during a period of our history when we narrowly escaped the unleashing of biological and chemical warfare. The horror of multiple warhead missiles carrying technically perfected science to pinpointed targets has become a reality. The social impact of science and technology has become terrifyingly real, and yet our school programs continue on their traditional path. Our lifetime faces the challenge of a totally new configuration of reality that requires far greater integration of knowledge than our histories have yet seen.

It may well be that we have entered a post-historical era when the pace and kinds of change are so rapid and so profound that the old alignments of knowledge will not serve human needs. While the reconceptualization of knowledge is being hesitantly explored and researched in isolated efforts at the university level, few elementary or secondary schools are making efforts at integrative approaches to learning, of which STS provides an excellent example. The task for STS proponents is monumental; but the task is worth doing. STS must find room at the schoolhouse inn.

Notes

1. Available from Irma Jarcho, 1 W. 88th Street, New York, NY 10024.
2. The discussion in this section owes a great deal to the work of Cooper (1988).

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Leonard J. Waks

The Responsibility Spiral: A Curriculum Framework for STS Education

The science-technology-society (STS) movement is an educational innovation designed to promote responsible citizenship in our technologically dominated era. Today's citizens are faced with personal and social choices that are beyond the scope of traditional values: life-extension, genetic screening, strategic defense in space, release of genetically engineered organisms into the environment. Today's responsible citizens must understand these innovations and their impacts on society. At present this understanding is not widely distributed among citizens, and this threatens the quality of our lives, our institutions, and our natural environment (Prewitt, 1983).

In this article, the "responsibility spiral" is presented as an organizing framework to help educators identify, select, organize, and sequence learning experiences to promote this form of understanding. By moving through the phases of the spiral, learners of all ages can be guided in forming their convictions and commitments, their life-style choices and values, as these bear upon the technology dominated issues facing our society. As they move through these phases, on issue after issue, confronting and thinking through science and technology dominated issues of increasing complexity, learners can make progress toward mature social responsibility.

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The spiral (Figure 1) consists of a series of "cycle-units" devoted to specific STS issues such as nuclear reactors or genetic engineering. Each unit is composed of five "phases," labeled (a) self-understanding, (b) study and reflection, (c) decision making, (d) responsible action, and (e) integration. The spiral, a sequence of such cycle-units, is a useful organizing tool for STS units at all educational levels from childhood to adult and continuing education.

The responsibility spiral and its application will be discussed in later sections. First, the concept of responsibility itself must be considered.

Responsibility

STS educators speak of the need for education to promote an ethic of social responsibility in our technological era. Just what is social responsibility, and what does it demand of today's citizens?

From the beginning of the STS movement, ethical and values concerns, and particularly the notion of responsibility, have played an important role. As the philosopher Hans Jonas (1984) has noted, contemporary technology has irreversibly altered the nature of human action with the magnitude and novelty of its works and their impact on humanity's global future. In the new situation, our inherited ethical and value ideas, geared to the direct, face-to-face dealings of one person and another within narrow limits of space, time, and power, are no longer adequate.

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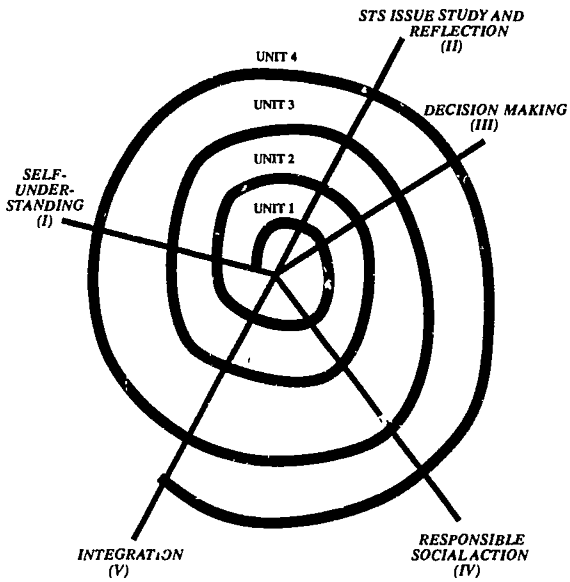

Figure 1. Phases of the responsibility spiral.

This leaves us unprepared to think through our contemporary problems and options, and form convictions and make commitments appropriate for our time. Jonas asserts that "the lengthened reach of our deeds moves *responsibility,* with nothing less than [humanity's] fate for its object, into the center of the ethical stage" (p. x).

Our first associations with the elusive idea of responsibility may be with *obligation* and accountability, with making demands and expecting compliance—"students are responsible for silence in the halls!" Even hide-bound conservatives will grant that there is more to responsibility than this. A second set of associations is related to *awareness.* Responsible drivers do not merely follow the rules of the road but sharpen their senses and stay alert for unexpected dangers.

However, a person becomes responsible not merely by complying with rules, or even by expanding awareness, but also by consciously *accepting* responsibility, growing into it, shouldering it. Responsibility, in its most important sense, consists as much in choosing and shaping rules of conduct as in following them.

The elements of choice, acceptance, and commitment implicit in responsibility connect it to two of the most fundamental aspects of our humanness: caring and personal creativity. As Fingarette (1967) notes, persons take on responsibility, become responsible agents, when they accept as a matter of personal concern, something that matters to them, something society has offered—and the consummation of responsibility may include the creative transformation, in large ways or small, of what is offered, for example, when "We are the World" is offered in response to the problem of hunger.

This makes responsibility central to being a person. The growth of responsibility is a crucial, and perfectly natural, though by no means inevitable, feature of growing into personhood. It is a central goal of education, the fourth "R." How do adults assist in this process? As we begin to judge the child ripe for accepting responsibility, we begin to hold her or him accountable, and "it is in the nature of the human being that, if we have chosen our moment well, [the child] usually responds to this treatment by actually accepting responsibility (Fingarette, 1967, p. 33)." But when this fails, we recognize that the child has not yet accepted responsibility, so we back off from holding the child accountable.

> The child eventually becomes a responsible person by being treated more and more like one. But when he [sic] fails, we excuse him by saying "he is only a child." [But] the more the child demonstrates a persistent, intelligent, and reasonably wide-ranging effectiveness and purposefulness in some area of his conduct, the more we are inclined to minimize the qualification of our treatment of him as a responsible person. When at last he comes to act consistently like a responsible person, then he *is* one, and only then. (Fingarette, p. 33)

This implies that only when responsibility is freely accepted can the connection to obligation be made to stick. We can make demands of, and express our moral indignation about, those who refuse to accept responsibility. But our demands are futile if addressed to those who have not already invested themselves, for otherwise there are no pegs within them upon which to hang these demands.

Fingarette's insight is that responsibility is not a mere burden, but a natural, potentially joyful, and even essential feature of the active adult life. Responsibility is not merely one of the costs of adult life but also one of its chief benefits, even if it is something of an acquired taste.

Education for responsibility requires that, as young people mature, they must be confronted with significant challenges. As learners "ripen," the demands must be stepped up, and nurturing support in the form of instruction, coaching, and encouraging praise is provided. However, if the young start off alienated, or are confronted with meaningless demands or demeaning tasks instead of real challenges, or are denied necessary support and encouragement, responsibility is not likely to blossom, and both the young people and the society at large are certain to be losers.

STS education situates the learner as a responsible agent, a young citizen, in a society increasingly dominated by the impacts of science and technology. Responsible citizens take responsibility for the impacts of science and technology on society. They (a) seek to *understand* how changing science and technology are affecting people in our society for good or ill, (b) actively think about and *decide* what is right and best for society, and (c) make a commitment to *participate actively,* both as individuals making personal decisions and as members of society bringing their values to bear on collective decision making, to make a positive difference. The responsibility spiral is a framework to organize education to promote responsibility.

Phases of the Responsibility Spiral

In 1985 a national task force, composed of K-12 teacher leaders in science, technology, social studies, and English education, and college teachers representing several disciplines, met at Pennsylvania State University under the auspices of the Science through Science, Technology and Society (S-STS) Project to set forth a clear definition of science-technology-society education (S-STS Project, 1985). The task force established seven criteria[1] as essential to STS lessons, units, and curriculum materials:

1. *Responsibility.* The material develops learners' understanding of themselves as interdependent members of society and of society as a responsible agent within the ecosystem of nature.
2. *Mutual influences of science, technology, and society.* The mutual influences of technology, science, and society on each other are clearly presented.
3. *Relation to social issues.* The relations of technological or scientific developments to societally relevant issues are made clearly, early, and in compelling ways to capture attention.
4. *Balance of viewpoints.* The material presents a balance of differing viewpoints about the issues and options without necessarily striving to hide the teacher's or author's perspective.
5. *Decision making and problem solving.* The material engages students in developing problem-solving and decision-making skills.
6. *Responsible action.* The material encourages learners to become involved in a societal or personal course of action after weighing the tradeoffs among values and effects drawn from various scenarios and alternative options.
7. *Integration of a point of view.* The material helps learners to venture beyond the specific subject matter to broader considerations of science, technology, and society, which include a treatment of personal and societal values/ethics.

The phases of the cycles that form the responsibility spiral derive directly from these criteria.

Phase I: Self-Understanding

Criterion 1 of the S-STS Project states that STS develops the learners' understanding of themselves as interdependent members of society and of society as a responsible agent of the ecosystem of nature. Breaking this into its component parts, the starting point is the learners' understanding of themselves as individuals and interdependent members of society. In our society, each learner is to be valued as a unique individual, with values, talents, goals, and plans of his or her own. As a citizen each is guaranteed basic liberties to live as he or she decides, and is responsible for his or her own life. This is fundamental to our way of life.

But learners are not islands unto themselves. Because we share the planet earth as our home, the well-being of one cannot be isolated from that of the others. We are interdependent. The learner is a responsible agent in the capacity of citizen. The way we live as a society affects the ecosystem, which sustains the basic needs of life, and we are to be held responsible for making these collective decisions well, through the various decision-making and problem-solving processes of our democracy.

Activities of self-understanding. In the first phase, the learners' work consists of identifying their own images of the good life for self, society, and the world community. What are their ideals, what do they think it would take to move these toward realization? What role do they wish to play themselves?

Learners also explore what they have learned about the technology-related issues of the time, or that are forecast for the future. What are their feelings? Are they frightened about the bomb, pollution, running out of resources, prospects of dehumanized employment? Learners explore the sources of their convictions.

Responsibility sets the context for the work at this and every other phase of the cycle; the work is never merely academic. Learners are never mere spectators; they are encouraged to enter the world with a responsibility-oriented perspective. From that standpoint people, events, and things enter the learners' field of perception, thought, and concern.

In facilitating the work at this phase, teachers may encourage personal sharing, probe for deeper meanings, conduct discussions of experiences or readings, and suggest journal keeping. Values clarification techniques may be utilized. Regardless of tactics, learning is focused on the learner, and a context for STS conceptual knowledge and issues awareness is laid within the learner's own field of awareness and concerns.

Phase II: Study and Reflection

S-STS Criterion 2 states that the mutual relations of science, technology, and society on each other are clearly presented. As Figure 2 indicates, this consists of six different relationships. Two of these six relationships are singled out in S-STS Criterion 3 as needing especially early, clear, and compelling presentations, in order to capture the learner's attention. These two relationships are (a) the impacts of science on society and (b) the impacts of technology on society (signified by the heavy black arrows). The STS learner, in the course of deepening self-understanding and developing attitudes of responsibility, is to attend to these relations in issue after issue, forming a clear conceptual pattern through repetition.

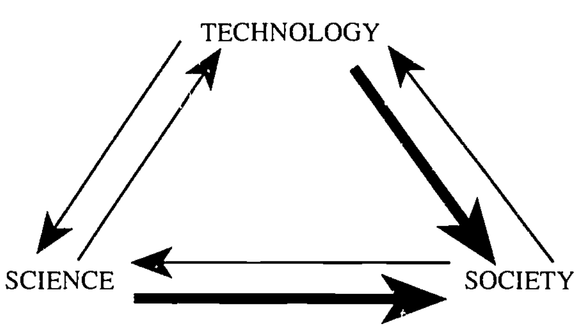

Figure 2. Relations among science, technology, and society.

Scientific and technological institutions, and the new discoveries and innovations emanating from them, have complex effects. They secure the needs of some while harming others. They bring about changes that some view as positive and others as negative. They create new opportunities for some but destroy opportunities for others. Investigations are intended to clarify these impacts and, if possible, to lead to a decision about what is right. But there is frequently considerable obscurity regarding what the impacts are, and whether they are good or bad.

Different individuals and groups rely upon different methods to gain some understanding of these impacts—everything from cost-benefit analysis to biblical exegesis. Not surprisingly, investigations and results are often incommensurate. This is both inevitable in pluralist society and one of its great evolutionary advantages; cultural diversity, like biological diversity, strengthens the community.

We may talk about a "technology-dominated issue" when different groups in society have basic differences as to how to address technology-related problems; the issue cannot significantly be settled to everyone's satisfaction using available interpretive or analytical tools. Then the problem becomes a social issue and political factors are added to the technical ones (Peña and Waks, 1989). Recognizing the essentially contested nature of technology-dominated, societally relevant issues, Criterion 4 states that in STS study and reflection, the materials present a balance of differing viewpoints about the issues and options, without striving to hide the viewpoint of the author, and the lessons strive for balance without necessarily hiding the view of the teacher.

Activities of study and reflection. The work at the second phase consists in gaining awareness and understanding about particular scientific and technological developments and their impacts—how they promote and maintain the good of some, how they prevent and constrain the good of others. It consists in learning about people, things, events, ideas, and issues in the learner's world, and reflecting on them to deepen understanding and draw implications for decision making and social action. It involves understanding the nature of science, technology, and society, and their mutual interactions. It involves illustrative case studies, explored for sociological and axiological implications. Ethical and value theories and applied ethics are potential resources for structuring these explorations.

Work at this phase provides one set of connection points with the discipline based elements of the curriculum—for the science, mathematics, engineering technology, and social science learning that may be used to elucidate the STS issues. Work at this phase includes what Hungerford (Hungerford, Peyton, & Wilke, 1980) and Rubba (1986) call "issue awareness" and "issue investigation." It includes much of the didactic teaching and seminar discussions for understanding values in the STS curriculum framework developed by the Social Science Education Consortium (Hickman, Patrick, & Bybee, 1987).

Phase III: Decision Making

Criterion 5 states that STS material must engage the student in problem solving and decision making. This is particularly important in light of the indeterminate nature of the issues. It would be all too easy for escapist, anti-responsibility attitudes to hide behind this indeterminacy and say, in effect, "There is no way of making rational headway on these issues. One group sees it one way, another sees it differently. That's all there is to it."

This criterion states that impersonal subject matter learning, and indeterminate thinking in which the learners fail to resolve the issue for themselves, is insufficient. It is not enough to learn "about" energy or whales. The student must confront the information and alternatives and then go beyond them, make a decision, take a stand, judge one path as the right or best one.

Activities of decision making. Work at this phase consists in learning about the decision-making and negotiation processes, making decisions, and defending them by providing reasons and evidence. Various analytical and pedagogical tools, such as ethical dilemmas, classroom debates, technology assessment exercises, and mock parliaments and courts can enliven this work.

This phase also provides connecting points for the basic liberal arts elements in the curriculum. Students learn to think by writing, express their opinions in persuasive speaking, and learn to focus reasons and evidence logically upon a conclusion.

Phase IV: Responsible Action

Criterion 6 states that the material encourages learners to become involved in a societal or personal course of action after weighing the trade-offs among values drawn from various scenarios or options. This criterion indicates that STS education must go beyond academic rationality (see also Waks & Prakash, 1985). Words are not sufficient, even when they express value judgments and decisions. The materials must be presented in such a way as to encourage the student to become involved in action, either alone or in concert with others and either through an informal alliance or an established political or public interest group.

Brooke (1900/1955) expressed this well:

> Whatever feelings and hopes we have, we are bound to shape them into form in life, not only at home, but in the work we do in the world. Whatever we feel justly we ought to shape; whatever we think, to give it clear form; whatever we have inside us, our duty is to mold it outside of us into clear speech or act. The secret of education and self-education is to learn to embody our thoughts into words . . . to realize our knowledge in experiment, to shape our feelings into action; to represent without us all we are within; and to do so steadily all our life long. (p. 259)

Activities of responsible action. Work at this phase represents the flowering of responsibility education on the issue at hand. It consists in charting and undertaking individual or social courses of action. These may include organizing a community meeting, joining a public interest group, working in an environmental cleanup project, traveling to the state legislature to lobby for pending legislation, joining in a consumer boycott of an environmentally unsafe product, organizing a performance to get money for family farmers or hungry children. This work may be sponsored by community organizations, such as an urban gardening project sponsored by the horticulture society, a household chemical removal project sponsored by the environmental health council, or a river basin clean-up project.

Phase V: Integration

Criterion 7 states that the teaching-learning endeavor must aim at a generalization from the specific issue addressed. The learner is to venture beyond specific subject matter to broader considerations of science, technology and society including a treatment of personal and societal values/ethics. The learner is to be not merely a responsible actor in this case, but a person growing in responsibility.

This criterion indicates that a study of any specific technology-dominated issue is not enough. It is insufficient for students to be led through a "decision" or even an "action" on issues identified in curriculum units. The units provide "illustrative cases" and the learners must be assisted in venturing out from these cases, seeking patterns, hazarding generalizations, considering principles, forming a personal *standpoint* from which new technology-dominated issues can be identified, investigated, assessed, and addressed through various available social and political processes.

Guidelines for Implementation

The four guidelines that follow are intended to assist teachers and curriculum developers in implementing the spiral model. They focus on the goal of STS teaching, the components of the STS curriculum, the STS curriculum as a whole, and the linkages of STS with other curriculum dimensions.

1. The STS curriculum is focused on responsibility: It begins and ends with the learner as a responsible individual and as a responsible member of society.

Learners are active, need-motivated, goal-directed people. The time and energy they allocate to learning and the learning activities they engage in (or fail to engage in) stem from their short- and long-term goals, whether conscious or unconscious, wise or reckless.

This is especially true when we turn to learning related to the formation of values and especially those that comprise responsibility. Each cycle-unit starts with a dialogue with the learner, exploring growing concerns, a maturing willingness to try on new responsibilities. It ends with further dialogue, to discover areas where acknowledgement is needed, concerns have matured, principles have taken shape, and demands may be stepped up.

2. The five phases are distinguished to assure proper attention to each.

In day-to-day living, the separate "phases" are integrated. All people from time to time stop to consider their needs, values, plans, and responsibilities (phase one), study, trace patterns, reflect (phase two), make judgments and come to decisions (phase three), act upon their convictions (phase four), and reevaluate their values, plans, and responsibilities, integrating experiences undergone and actions taken and forming some general ideas and principles (phase five). The responsibility spiral distinguishes these five phases in order to focus needed attention on each in curriculum planning.

3. The STS curriculum as a whole is analyzed and, when necessary, reorganized to assure proper balance for and sequencing of the five phases of the responsibility cycle.

There are better and worse contexts for the work at each phase of the cycle. Self-understanding work requires different conditions than systematic reflection or action. At each level of education, the spiral framework brings into focus how each phase is addressed. It does not assert that every STS unit, regardless of topic or length, must provide an equal share of work at each phase. But it does assert that there must be balanced and appropriate attention to each over the course of the STS units across the curriculum and at each educational level.

4. The responsibility spiral is the "inner core" of STS education. It is surrounded by the rest of the curriculum, which may be linked to the core in creative ways.

STS will be implemented in both free-standing STS courses and as components in (discipline based) science and social studies education. The articulation between STS and the rest of the curriculum may be strong or weak; the curriculum components may be mutually reinforcing or at odds with each other. Opportunities always exist for strengthening connections, making STS and discipline based learning mutually reinforcing. The STS cycle-units provide both the core of STS learning and the connecting points for academic curriculum conte...

Conclusion

The ultimate challenge of responsibility education is not merely to change curriculum content. Rather, it is to transform all existing educational structures to promote global responsibility as a core organizing value.

Mass education as we know it is a new cultural form, providing for the socialization of competence, attitudes, and values for life in industrial society. The goals of mass education during the last 100 years have been shaped by the industrial division of labor and the material values of the industrial era. Children and youth have learned in schools to adjust their perceptions, thinking processes, emotions, aspirations, and behavior patterns to the demands of individual production and modern urban life.

But the culture of industrialism now finds itself challenged. Nuclear weapons and environmental pollution from the global industrial enterprise threaten the very structure of life on earth.

In democratic societies an effective response to such problems requires a critical mass of citizens from all classes and groups to become aware, attentive, informed, and politically involved. There must be an effective challenge to contemporary, culturally-determined values and life-style choices, and an awareness of the new ethical dilemmas facing humankind, followed by individual and political action to address those problems the elites have thus far been unable to confront.

To accomplish this goal will require a thorough transformation of the social instrumentalities of the industrial era, including the system of schools and the communications media, to serve the new needs of humanity. Courses in ethics and values in science, engineering, and business are frankly "drops in the bucket" in curricula geared as a whole for industrial output and undertaken by individual students to maximize their income opportunities (Mayer, 1988, provides an insightful study of the impact of these courses). Regardless of their content, current educational means remain forms of socialization for industrial society (Waks, 1991).

In both theory and practice, STS implies a shift in educational focus, to amplify connections between cognitive learning and practical (action-directed) aims in order to promote a new, sustainable society. This will entail a thorough reevaluation of all standard routines of instruction and evaluation. The responsibility spiral provides a framework for STS learning during this period of reevaluation.

Note

1. The seven unordered criteria of the S-STS Project have been renumbered here to clarify their connections to the responsibility spiral.

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Gerald W. Marker

Integrating Science-Technology-Society Into Social Studies Education

Those advocating that science, technology, and society (STS) be included in the social studies curriculum join a sizable group of people promoting special topics or approaches. All claim to advance citizenship in one form or another. An illustrative list of such special interests includes: women's studies, law-related education, peace studies, multicultural education, global education, Black studies, studies on the evils of communism, free enterprise education, environmental education, AIDS education, and energy education.

Some of these movements, such as studying the evils of communism, receive little notice today. Others, such as law-related education and global education, continue to get considerable attention. In light of this competition for space in the social studies curriculum, what is the future of STS? Does STS merit inclusion in the social studies curriculum and, if so, where and in what form? This article addresses these questions and illustrates how STS can be integrated into the social studies curriculum.

Does STS Belong in the Social Studies?

At first glance many current STS topics appear to belong in the science curriculum. Genetic engineering, acid rain, nuclear waste disposal, artificial intelligence, artificial human organs, global warming, and ground water pollution all have scientific components. Such issues are, by their very nature, often highly technical. If technology is the application of scientific knowledge to create systems to solve the problems of human adaptation, then the understanding of those systems will likely require some scientific knowledge (Bybee & Landes, 1988).

The development of such scientific understanding is clearly the task of science education. However, STS has a third component, society, and this facet of STS is typically even more problematic than the scientific understanding of technology. This component of STS is also what makes it fit logically into the social studies curriculum and has prompted its inclusion in social studies frameworks (Hickman, Patrick, & Bybee, 1987; Science and Society Committee, 1990) and reviews of social studies research (Giese, Parisi, & Bybee, 1991).

What are the social aspects of technology? One could begin, for example, with the fact that major inventions in the technology arena often result in a host of related and often unforeseen social changes, which Hanvey (1975) has referred to as "surprise effects." Thus while television entertains us, it has also changed how families spend time together, altered reading habits, changed the major source of news for most Americans, created the 30-second political film clip, revolutionized merchandising, made possible TV evangelists, and created a powerful educational alternative to schools, to mention only a few.

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Birth control devices, in addition to controlling conception, have challenged long-standing religious values, changed the age at which young people marry, and facilitated the development of families where both parents work outside the home. The point is that technology has social consequences, some foreseen and others unintended. This relationship is not new. The invention of gunpowder or the process for making steel changed the lives of earlier generations as surely as space travel and the microchip are changing ours.

The constant introduction of complex new technology can also cause cognitive dissonance and anxiety for both adults and children (Baron, 1988). Technology can seem out of control; people feel victimized when the technology on which they have come to depend suddenly fails them, whether it is a computer, refrigerator, or an automobile. Matters are further complicated when even the experts, those in the "priesthood" of a particular technology, fail to agree regarding the consequences of employing that technology.

For example, can nuclear power plants be made safe? Has television reduced political campaigns to superficial, carefully staged events? Is our technology-rich lifestyle gradually making the earth uninhabitable? Such concerns about the impact of technology led to the establishment of the U.S. Office of Technology Assessment in 1972. OTA's mission was to look at the long-term effects of technology on society (Garcia, 1988).

While technology is a powerful force in modern society, it and the science that supports it are also influenced by the society in which they exist. This is especially true in democratic societies where the general population participates in decisions regarding the allocation of resources and the formulation of laws and policies. A public decision to spend more on the development of a space station or to limit the funds for AIDS research or new types of nuclear power plants influences the invention and design of new technologies.

Some groups already call for limits on technological development and for a return to a time when life was simpler and technology less dominant. Others would have us believe that new technology is inherently good, that new is better, that "progress" is necessary whatever the costs. If people feel that technology is out of control, then laws limiting scientific inquiry and the development of technology will reflect that. Referenda on STS issues (nuclear power, reduction of auto emissions, transport and disposal of hazardous waste) now appear regularly on local and state ballots. Unless the public, including students, can be made to understand the relationship between science, technology, and society, we face the prospect of public decisions that are increasingly uninformed and irrational.

Citizenship education is the one goal most social studies educators seem willing to support; beyond that, the profession fragments (Marker & Mehlinger, 1991). Each of the social science disciplines that form the basis for the social studies curriculum has something to contribute to understanding the relationship between science, technology, and society. If the public is to continue to participate in decisions involving technology and the nature of our society, we seem to have little choice but to make the study of STS a part of the social studies curriculum.

Strategies for Integration

If STS merits a place in the social studies, the strategy issue must be confronted. How can STS content best be fitted into an already overcrowded curriculum? Remy (1990) outlines three alternatives: infusion into existing courses, extension of existing units, and the creation of separate courses. In a 1987 study, Disinger concluded that infusion was the most common method of including environmental topics in both the elementary and secondary curricula. The situation is probably no different in social studies. Furthermore, the development and adoption of new courses, especially interdisciplinary courses, is extremely difficult. The odds against that approach are high. Infusion and extension appear to be the most realistic alternatives. Certainly the success of Project Learning Tree, which produced curriculum materials designed to be infused into existing courses, demonstrates that such an approach can be effective (Charles, 1987).

The "Big Ideas" of STS

There are certain generalizations, "big ideas," that deserve attention wherever and whenever STS content is dealt with in the curriculum. Some state curriculum frameworks and some local curriculum guides contain lists of specific social studies competencies, but such an approach seems unrealistic for STS because what is often needed is a new perspective rather than new content. It also seems more reasonable to ask teachers to concentrate on a few important "big ideas" than to expect them to cope with a lengthy checklist of things to be learned. Therefore the following generalizations are suggested as the core of STS instruction, regardless of grade level or subject.

1. Modern life as we know it is highly dependent on technology, and is becoming more so each year.
2. Technological innovations bring about both anticipated and unanticipated (surprise) effects. The latter is especially likely when a "foreign" technology is introduced into a culture unlike the one in which it was developed.
3. Technological innovations seldom have equal impact on all groups in a society.
4. Technological innovations reflect the values of the culture in which they are developed, i.e., necessity is the mother of invention but culture is the mother of necessity.
5. The technology of a culture often changes more rapidly than the social institutions it affects.
6. Technological innovations often involve trade-offs in the allocation of resources, power, and authority.
7. A global technology that spans many different cultures and nations is developing.
8. Technological innovations are closely linked to the scientific knowledge that makes them possible.
9. The development of technological innovations is enhanced by social pluralism and diversity and by freedom of inqu. y.
10. In democratic societies, citizens have a right and a responsibility to participate in the development of laws and policies that control the use and development of technology.

If students had a working knowledge of these big ideas, STS literacy in social studies would have made a major advance.

Analytic Exercises

In addition to focusing on "big ideas," analytic exercises can introduce a new perspective when looking at familiar social studies content. As with the big ideas just noted, such exercises, adapted to grade level, can be used throughout the curriculum to study innovations. The following is an example of such an exercise adapted from the work of Anderson (1984).

1. List all the effects you can think of for one technological innovation introduced into your culture during the past century.
2. Categorize the effects on your list according to whether they were planned and/or unforeseen by those who introduced or eagerly adopted the innovation.
3. Indicate which effects were felt only in a local area and which were felt regionally, nationally and globally.
4. Divide the effects on your list into those you consider "positive," that is, benefiting people in general, and "negative," that is, harmful.
5. List four factors you consider essential to a good quality environment for human beings, and which influenced your choices in item No. 4.
6. Which subgroups in society benefited most from the innovation you are assessing? Which subgroups of society bear (or did bear) the majority of the burdens of the negative effects? List two reasons for the inequitable distribution of benefit and burden.
7. What was the time lapse between (a) the scientific or technological discovery that made the innovation possible and its widespread introduction or adoption? and (b) between the planned benefits and the appearance and/or awareness of the burdens?
8. In terms of the burdens associated with an innovation, (a) What actions have been/are being taken to alleviate the burdens? (b) Who (government, industry, consumers) are taking these actions? (c) Who is paying the cost of alleviating these burdens in money? (d) Who is paying the cost of alleviating these burdens in quality of life?
9. What areas of *choice* did the innovation open up for individuals?
10. What choices did the innovation open up for society in general (seen most likely in legislative and judicial decisions)?

An analytic approach to STS topics can also help students see that such issues involve conflicting assumptions, interpretations and options; that there is no "right answer" to such dilemmas. Historical examples can show students that people can help shape their own destiny and that they can control technology and the science that supports it. The study of the relationship between science, technology, and society can develop in students a sense of commitment to the rational, democratic control of the relationship between technology and society.

Even though some democratic systems may be threatened by technology (Tanner, 1990), modern life as we know it is highly dependent upon it. It is unrealistic to believe that we can somehow stop the invention of new technology or give up what we have and return to a world uncomplicated by technological change. Technology will be with us and the social studies curriculum must help students cope with that reality. Through the use of organizing generalizations and analytic exercises, the introduction of large amounts of new content can be avoided, thus facilitating the infusion of STS into the social studies curriculum.

STS in Elementary Social Studies

Social studies in the elementary grades is still dominated by the study of families and life in local communities (Marker & Mehlinger, 1991). Within that curriculum context, however, students can study how a technology like the telephone changed business and family life. They can study how the technology of the assembly line has changed work roles in their community.

Students can discover how the automobile changed the shape of cities and made suburbs possible and how VCRs and computers are changing what goes on in schools. They can study the various technologies that make a modern supermarket possible and how computers and radar have changed the lives of local law enforcement officers. Simplified versions of Anderson's analytic exercise can bring new life to the primary grades, where the study of the family, school, neighborhood, and local community still dominate the curriculum (Joyce, Little, & Wronski, 1991).

In the intermediate grades, considerable attention is given to the study of other cultures (Joyce et al., 1991). Often the focus is on the diversity of how humans relate to their physical environment, e.g., housing, clothing, work, play, food, families, and beliefs. Without major adjustments, the focus of such units could shift to how these other cultures use technology to cope with their physical environments and how those cultures in turn have been changed by these technologies.

For example, how have the refrigerator and freezer changed peoples' diets? What has been the impact of the technology of irrigation or plant genetics on land use and settlement patterns? What happens when a "foreign" technology such as the snowmobile is introduced into the Lapp culture? (Anderson, 1984). Were these consequences anticipated?

The point is that much of what is studied in elementary social studies already has potential as a vehicle to explore the relationship between science, technology, and society. A unique focus, a different set of questions, may be all that is needed.

STS in the Secondary Social Studies Curriculum

Because space is limited and because secondary teachers are more concerned about content (Leming, 1989), this section focuses on the content opportunities that would facilitate infusing STS into secondary social studies courses. American history and government dominate the social studies in the secondary grades (Joyce et al., 1991). Fortunately, both courses already contain topics, or what Disinger (1987) would call "benign niches," that lend themselves to study from an STS perspective.

American History

American history provides dramatic illustrations of the relationship between technology and society. Americans have contributed significantly to the development of 19th and 20th century technology. The cotton gin, thrashing machine, and moldboard plough dramatically changed agriculture in the young nation (LaRue, 1988). In the 20th century, rural electrification and, later, chemical fertilizers and pesticides again revolutionized agriculture and, with it, small-town America.

The opening of the American West provides another example of the technology-society connection. Students can easily see the social impact of the telegraph, steam locomotives, and ships. These revolutions in communication and transportation made it easier to bind the huge new territory to a nation governed from a capital thousands of miles away.

The industrialization of the 19th and 20th centuries would not have been possible without the technologies of mass production, the assembly line, and interchangeable parts. These technologies changed lifestyles and migration patterns and provide excellent examples of both the positive and negative effects of technology on social institutions such as the family, the church, social clubs, and education (LaRue, 1988).

History teachers are sometimes criticized for their preoccupation with military history, and yet both world wars can be studied as events that stimulated the development of technologies that later revolutionized American life (e.g., radar, the jet engine, rockets, and the development of lightweight metals).

Government and Civics

Government and civics courses offer endless opportunities to study how technology both shapes and is shaped by society. Electronic networks and huge private and government data banks are possible because of modern computers. These networks and data banks make possible the convenience of things such as bank cards and high speed criminal identification, but they can also conflict with the privacy rights protected by Article IV of the U.S. Constitution (Marker, 1987).

Government agencies can be studied in terms of their role in relation to technology. The U.S. Environmental Protection Agency both regulates technology (through such things as environmental impact statements) and addresses the negative effects of technology (e.g., hazardous waste dumps). The Patent and Trademark Office now licenses new life forms created by genetic engineers. The U.S. Food and Drug Administration must consider a host of new food additives and medical drugs, which calls for new policies.

The lawmaking process can be studied from the vantage point of legislation to clean up the air or control the mining of the world's seabeds or to require seat belts or air bags in automobiles. Students can begin to understand both the complexity and technical nature of modern technology while at the same time studying examples of how technology can be controlled. Such cases can also teach students to distinguish between individual decisions (Will I use fertility drugs or a birth control device?) and collective decisions (Will I vote for a candidate who supports government research in the area of family planning?) involving technology.

Study of the judicial branch of government offers other STS opportunities. The courts are now confronted with many cases illustrative of the way technology increases social choices. Who finally decides where hazardous waste can be stored or over which routes it can be transported? When is it no longer permissible to forcibly employ medical technology to keep a person alive? Are electronic records subject to the privacy protection of the Fourth Amendment? In short, the judicial branch is often the arena where society tries to resolve the frequent poor fit between technology and society. It is an accommodation process that never ends.

World History

Like American history, world history provides many opportunities for helping students gain an STS perspective. For example, the National Commission on Social Studies in the Schools (1989) suggests as one of three themes for a world and American history and geography course on the period 1750-1900, "the industrial-technological transformation which has also altered conditions of life and landscape everywhere, even where modern industry has not established itself" (pp. 17-18). World history teachers have always faced the problem of deciding what to include from the mass of possible content. To have the industrial-technological transformation suggested as one of only three themes for such a course suggests the importance of technology in human history.

Examples need not be limited to the social impact of new technology. LaRue (1988) suggests that a study of Japan's decision to eliminate guns from its arsenal in the 17th century provides an example of how values can influence choices in science and technology, choices that in turn can have direct social consequences.

Economics

The high school economics course is an ideal place to study the trade-offs involved in the science-technology-society relationship. Petroleum now supplies the power for modern industry and transportation. The global economy literally runs on oil but one of the costs of such an arrangement is to make the nations of the world highly dependent upon the politically unstable Middle East. Three times during the past two decades developments in that part of the world have sent oil shocks through the economies of developed and developing nations alike. The technologies that depend on oil now dictate foreign policy decisions and nations now have little choice but to fight to maintain their access to oil.

A study of the economics of alternative energy sources provides an excellent example of the relationship between supply, demand, price, and public policy. Students easily identify with anything that affects their cars. Would they be willing, for example, to pay a $1.50 tax per gallon of gasoline if the proceeds were used to develop alternative sources of power and eventually free us from dependence on Middle East oil? Would a more effective approach be for the government to mandate higher fuel efficiency standards for vehicles? What would be the economic impact of a government decision to mandate the replacing of gasoline and diesel powered vehicles with those powered by electricity or by raising the legal driving age to 18?

The situation presents students with the classic choice of whether to use incentives or regulations to achieve a social goal (National Issues Forums, 1989). A study of our energy options would involve most of the concepts seen as central to economic understanding and it would support many of the generalizations proposed earlier.

Sociology

High school sociology courses make it possible to view technology and science from the perspective of their social impacts. Countless examples can illustrate to students that there is no such thing as a socially neutral technology. Students of the TV generation can study the impact of that technology on the American family. Satellites and jet airplanes have made possible the creation of global fashions. The automobile fostered the suburban lifestyle. Businesses and factories that never close create shift work, which in turn serves as another force for change in the American family.

Sociology teachers can hardly avoid dealing with the relationship between society and technology. It is only a matter of deciding which examples to study.

Conclusion

Technology affects society in pervasive and often unexpected ways. In democratic societies, citizens play a direct role in controlling and regulating technology, so it is important that they understand the reciprocal relationship between technology and society.

The social studies curriculum already contains topics and units that, if studied from an STS perspective, can help students grasp important concepts and generalizations about STS. Infusing an STS perspective into the social studies curriculum is both realistic and desirable. In fact, given our overwhelming dependence upon technology, social studies educators have little choice if society is to continue to control technology, rather than vice versa.

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Glen Aikenhead

The Integration of STS into Science Education

> 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, 1991, p. 303)

While classroom teachers will always be the key to achieving the educational goal expressed by Rubba above, teachers will be helped significantly by the availability of supportive classroom materials. The current paucity of STS science textbooks is, however, a serious hindrance to the successful integration of STS into science education (Bybee, 1991). Few science teachers have the time, energy, and resources to develop their own STS materials.

As Bybee (1991) suggests, science teachers need an STS science textbook that translates STS theory into practical classroom practice. Most needed is an STS science textbook general enough to be relevant to all communities, but flexible enough to encourage teachers to integrate supplementary STS materials that deal with local or global issues of interest to their students.

This article has two purposes: (a) to describe the major features and characteristics that a new generation of science textbooks require, and (b) to illustrate these features and characteristics concretely by referring to an STS science textbook currently being implemented in the tenth grade.

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Organizing STS Instruction

STS science materials are best organized in a manner depicted by the arrow in Figure 1. The arrow maps out a preferred sequence of teaching events (Eijkelhof & Kortland, 1987), which are summarized in this section. STS instruction begins in the realm of society, represented by the box that forms the outer boundary of Figure 1. A key question or problem is posed; for instance, Should we be concerned about high voltage power lines in our community? or, How can we explain the conflicting scientific testimony in a newspaper article?

Next, there is usually some technology with which students need to become familiar, even at a superficial level, in order to understand the society based question or problem. Because technology is all about developing knowledge and designing processes to respond to human needs, and because students live far more in a technological world than in a scientific world, social issues are first and foremost related to technology. The domain of technology is represented by the black doughnut in Figure 1.

A social question or problem (the beginning of the arrow in Figure 1) creates the need to know certain technological knowledge (the doughtnut area in Figure 1), but both create the need to know some science content (the central circle in Figure 1); for example, What is a magnetic flux of electromagnetic radiation from power lines? or, What is the effect of magnetic flux on human tissue? This science content helps

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students understand the technology well enough to make thoughtful decisions on a related social issue (the arrowhead in Figure 1).

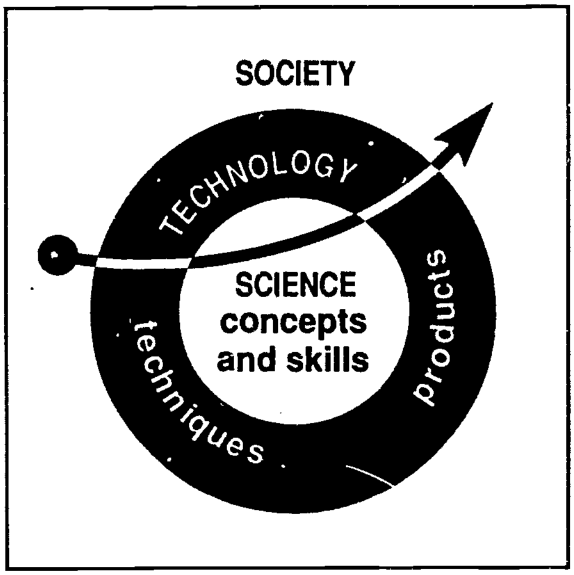

Figure 1. A schematic illustrating a possible sequence for organizing STS material (modified from Eijkelhof & Kortland, 1987).

In STS science, traditional science content is not watered down (Ziman, 1980) but is embedded in a social-technological context (depicted by Figure 1). As described later in the article, the choice of context is made on the basis of (a) the meaningfulness to students and (b) the science content logically generated by the context—on a need-to-know basis—required by a particular science curriculum. From the students' point of view, however, their science content arises from, and is logically sequenced by, a real-life situation. In this sense, STS science is student oriented, rather than scientist oriented.

In a traditional scientist oriented curriculum, science content and the sequence of its presentation are determined by how academic scientists view science, not how students view their everyday world. The dichotomy between a scientist's view of scientific content and a student's view of the everyday world defines a fundamental difference between traditional science teaching and STS science teaching. In STS science teaching, traditional science content is certainly taught, but students learn this content while constantly linking it with their everyday world.

The sequence of events suggested by the arrow in Figure 1 moves from the original domain of society, through the domains of technology and traditional science, and then out again into technology and society. By revisiting the technology of which students had only a superficial awareness, students apply the science they have learned in order to thoroughly grasp the significance of the technology. More complex technologies can be introduced at this time. Finally, the arrow in Figure 1 ends in the domain of society. Here students often address the original key question or social problem by making a decision. Students make thoughtful decisions informed by (a) an in-depth understanding of the underlying science, and (b) a grasp of the relevant technology.

Figure 1 suggests a sequence that is useful for a lesson, a unit, or for a textbook in STS science. Variations in lessons or units can be achieved by starting a class in the technology domain (the black doughnut in Figure 1) with an instance of an interesting technology (for example, television satellite dishes). Alternatively, teachers can begin with an intriguing bit of science content, and move along the arrow from there. Figure 1 does not indicate the time spent in each domain. A teacher makes that decision. Perhaps 60 to 80 percent of the instruction time will be dedicated to the central circle in Figure 1.

For the purpose of translating the theory of Figure 1 into practice, a recently published STS science textbook will be considered. A short description of the textbook will clarify this new classroom resource.

An STS Science Textbook

Logical Reasoning in Science & Technology (LoRST) (Aikenhead, 1991) teaches scientific facts and principles along with critical reasoning skills to a target audience of tenth grade students of average (or above average) academic ability. Students learn scientific facts and principles from physics, chemistry, and biology in a way that connects those facts and principles with the students' everyday world. The interdisciplinary nature of *LoRST* corresponds to (a) a need to know about an everyday event, and (b) the National Science Teachers Association's (1990) "scope, sequence, and coordination" conception of a tenth grade science curriculum.

LoRST is organized by and large according to the sequence described in Figure 1. The textbook begins with the societal problem of drinking and driving and presents court cases in which contradictory testimony arises concerning the technology of the Borkenstein breathalyzer (Unit 1). The social issue of drinking and driving creates the need to know (a) the rules used when arguing over scientific evidence; (b) how science and technology interact with each other and how they both interact with various aspects of society: the law, moral reasoning, and public policy; (c) the technology of the breathalyzer; and (d) scientific content such as mixtures, concentration, chemical reactions, photometry, electrical circuits, and the biology of body cells and systems.

Each of these four needs is addressed by *LoRST*. The first need to know (rules of arguing) leads to a hands-on investigation into scientific decision making (Unit 2) and a systematic study of critical thinking (Unit 3). The second need to know (the interaction between science and technology) is the subject of Unit 4, while the third need to know (breathalyzer technology) is taken up in Unit 6. The fourth need (science content) comprises the majority of time spent in *LoRST* (Units 5 to 8). The sequence of science topics is determined by following a blood sample from the body through the Borkenstein breathalyzer.

While the science content of *LoRST* is "driven by" a social-technological issue, the content is by no means watered down. When teaching the section on concentration or balancing chemical equations, for instance, teachers involved in the development of *LoRST* reported that their students achieved greater depth in solving quantitative problems than normally expected. Students tend to view the science content as helpful in making sense out of both (a) the social-technological context provided in the introduction, and (b) the social context of their everyday world.

The textbook ends with a unit on decision making that includes a decision-making guide (Unit 9). Students question various technologies developed to prevent drinking and driving. As students practice using the decision-making guide (on a local or global issue of the teacher's choosing—the domain of society), they synthesize the book's scientific content with its critical reasoning skills.

The Social Context of Science

Kranzberg (1991) points out that the kernal of STS studies is a problem that arises at the interface of science, technology, and society. This social context renders the study of science relevant to most students. It gives students the chance to apply science content to their own everyday world. Moreover, the social context transforms an outdated image of school science into an up-to-date version in keeping with the 1990s.

Professional science of the 1990s (authentic science) is inextricably intertwined with society (Aikenhead, 1985). This modern view of science is in stark contrast with the purely academic view that defines science as isolated from its social milieu (Kowal, 1991). The social isolation of traditional science teaching has discouraged bright, creative high school science students from pursuing science careers (Bondi, 1985; Oxford University, 1989) Therefore, STS science teaching, with its social context character, addresses the nation's need for more scientists and engineers as much as it addresses the need for a science literate citizenry to be capable of responsible, informed action.

The social issue of drinking and driving was chosen as an organizing STS theme in *LoRST* for three reasons. The issue is, unfortunately, of critical importance to every community. Alcohol is the most fatal toxic chemical in the environment when it pollutes a driver's body. Secondly, the issue of drinking and driving requires (demands) particularly realistic decisions by students, rather than the more idealistic, hypothetical decisions sometimes associated with global issues (Carter, 1991). Students in the tenth grade know they will soon take personal action based on their own decisions. Thus, the action orientation stressed by Rubba (1991) is particularly realistic in *LoRST*. And thirdly, the issue creates the need to know much of the science content defined by the local curriculum.

Although the scientific content in *LoRST* is organized around the theme of drinking and driving, the content is applied to a number of other issues of current interest. For instance, students solve mathematical problems that apply the scientific concept of concentration to the world of recipes, false advertising, toxic chemicals, and farm fertilizers, as well as in court cases on impaired driving. Because the science content is embedded in a social-technological context, and thus becomes "contextualized science" (Carter, 1991), the study of science becomes more interesting and more meaningful than the traditional decontextualized science (Kowal, 1991). Tenth graders are generally eager to apply their scientific knowledge to real-life situations.

In summary, the STS issue of drinking and driving gives students practice at (a) developing critical-thinking skills, (b) making thoughtful decisions, and (c) synthesizing scientific knowledge with a social issue. The skill at making decisions (scientific, legal, moral, logical, and public policy) gradually develops with study and practice throughout *LoRST*. Learning tends to be spiral in that regard.

The Social Studies of Science

Carter (1991) outlines two perspectives that exist in STS science: (a) the "social problem" perspective described in the previous section, and (b) the "social studies of science" perspective, which "asks questions about the assumptions, values, and processes of science as well as the interactions of science with technology and culture" (p. 277). This social studies of science perspective—the nature of science—deals essentially with the question: How do scientists know what they know?

This question is given high priority in *LoRST*. In a unit on scientific decision making, for instance, students engage in their own scientific open-ended inquiries, and then, through guided discussion, reflect upon how they generated their scientific knowledge during those activities. Students become keenly aware of the subjective and social aspects of the consensus-making process used in science to establish scientific facts. Indeed, consensus making in science is defined in terms of "thoughtful decision making"—decisions guided by explicated values and accurate knowledge (Aikenhead, 1985).

Students' personal experiences with generating scientific knowledge are expanded in another activity in which students explore a history of science case study of heat. Students discover that professional scientists are not so different from themselves in that they are also prone to subjectivity and social influence. These ideas about the nature of science are reinforced throughout the book during many science topics.

The case study of heat found in *LoRST* clarifies for students the mix of fact and values that exists in science (Kowal, 1991) and what it means to say that scientific observations are theory-laden and culturally biased (Ziman, 1984). By looking for hidden assumptions, a skill introduced in *LoRST* prior to the case study, students discover how values play a role in the generation of scientific knowledge.

For example, Count Rumford's allegiance to the vibration theory of heat dictated what observations his experiments were designed to detect. (He concentrated on the heat transfer in his metal shavings and ignored the work done by his horse.) *LoRST* helps students to extrapolate their new understanding of the nature of science to similar 20th century issues such as our allegiance to the mass-energy conservation law. In a section about scientific values (Unit 9), students examine the contradictory values that guide decision making in public science and in private science.

Goals

The ultimate goal of teaching science through STS is to improve significantly the science literacy of all students, including those going on to careers in science and technology. Because literacy is the empowerment to interact meaningfully and reasonably with one's environment (Fleming, 1989; Hurd, 1988), STS science textbooks need to lead students to construct their own meaning of their world related to science and technology. Teaching for scientific literacy comprises a *balanced* approach among several dimensions (Hart, 1987):

- the key facts, principles, and concepts of science
- the intellectual processes used when doing science
- the manipulative skills required for doing science
- the interactions among science, technology, and society
- the nature of science itself
- the values that underlie science
- personal interests and attitudes toward scientific and technological matters

Closely aligned with the goal of literacy are the goals of achieving critical thinking and intellectual independence (National Science Foundation, 1990; Scheffler, 1965). STS science textbooks must encourage critical thinking and intellectual independence by training students to construct their own logical reasons for events and to critically analyze the reasons of others. Conflicts between scientific experts can be studied for four reasons: (a) as a method of honing critical reasoning skills; (b) as a way of understanding the nature of science; (c) as an experience in which to learn or apply science content; and (d) as a forum for recognizing the interactions among science, technology, and society.

In *LoRST*, for example, a question is posed concerning two conflicting epidemiological studies. The students sort out the contradictory positions of the experts on both sides of the issue (whether or not "the pill" has dangerous side effects). In sorting out these conflicting positions, students must answer the questions: How did the scientific community gain the knowledge about which the experts disagree? and, What is the status of that knowledge? Students must not only recognize logical and illogical reasoning but they must know conceptual details from science and technology. For example, in the activities, "Your Turn to Be Lawyer," "You Be the Breathalyzer," and "The Latest Scientific Research," students rigorously apply details about concentration, measurement uncertainty, and sampling, respectively.

After students have had first-hand experience with the process of scientific consensus making (Unit 2) and have practiced the skill of finding unstated assumptions (Unit 3), students tend to be more critical of expert testimony. Students remember the subjectivity involved in their own scientific consensus making and the consensus making described in the case study of heat. By knowing the provisional nature of experts' knowledge as well as its inherent uncertainties, students evaluate the positions espoused by the experts more critically and more independently (Geddis, 1988; McPeck, 1981).

LoRST's emphasis on logical reasoning translates into practice the NSF mandate to improve all students' critical thinking (NSF, 1990). Specific critical reasoning skills are taught in a unit on "Science & Critical Thinking: The Logic Game" (Unit 3). These skills are then applied throughout the book. More important than the individual reasoning skills themselves is the increase in students' *predisposition* to analyze, to question, and to articulate a reasoned argument—"habits of mind" (NSF, 1990, cited in Hurd, 1991, p. 258).

Science Versus Technology

Kranzberg (1991, p. 235) distinguishes between "knowing why" (science) and "knowing how" (technology). He contradicts most science textbooks by claiming, very correctly, that technology is *not* applied science. The misconception that technology is applied science pervades the ideology of North American science (Collingridge, 1989; Snow, 1987; Ziman, 1984). Zuga (1991) and Kowal (1991) point out the fuzzy thinking that accrues from failing to distinguish between science and technology. An informed decision on an STS issue is not likely possible without an appreciation of technology and an understanding of how it differs from science.

In a *LoRST* unit entitled "Science, Technology and R & D," students study the differences between science and technology and examine how the two interact. Decisions over the breathalyzer and over funding medical research show students how technology has its own domain of knowledge and technique, quite apart from science's domain. The definitions of "science" and "technology" in *LoRST* emphasize their human nature:

> Science is people satisfying their curiosity about the world around them . . . . Technology is people responding to human needs by discovering, designing, and producing things or ideas for society. (Aikenhead, 1991, pp. 96-97)

The everyday world of students is more complex than the simple science/technology dichotomy suggested by the definitions above. The real world of science and technology is invariably a world of research and development (R & D) (Ziman, 1984). Thus, *LoRST* introduces students to R & D, defining it as a coordinated combination of science and technology. Students are asked to (a) classify a list of projects as being science, technology, or R & D in nature; (b) find the technology-is-applied-science misconception in a newspaper article; and (c) write a paragraph about the varied resources that one considers in making a technological decision.

Women in Science and Technology

The nation's critical shortage of creative scientists and engineers is exacerbated by the dramatic underrepresentation of women in science and technology. A major goal for school science in the 1990s is to encourage young women to become involved in science and technology (Kahle, 1988). While the humanistic character of STS science tends to appeal to young women (as well as reflect an authentic image of science), more must be done by textbook writers than include pictures of women doing science (Bleier, 1988). As Jones and Wheatley (1988) point out, new science texts must offer students a balance of socially traditional male and female contexts in which to learn and apply the book's content.

For instance, by focusing on technology traditionally familiar to young women (for example, recipes, cooking, and hair dryers), *LoRST* encourages them to pose in-depth questions about that technology, thereby leading them to find scientific explanations for why the familiar technology behaves as it does. Success tends to build confidence, and confidence encourages young women to study traditionally masculine topics, such as catalysts, electric circuits, and systems. *LoRST* has "job" columns that describe career opportunities in science and technology in a way that encourages both young women and young men.

If school science continues to socialize students into a purely masculine ideology of science (Carter, 1991), the impact on the nation's R & D capabilities will become even more critically negative than it is now (Hurd, 1988). Academic science programs are out of harmony "with the ethos of modern science and technology" (Hurd, 1991, p. 258). Women have special "feminine" contributions to make to science and technology (Bleier, 1988; Keller, 1983). Both the ethos of modern science and a feminine perspective on science must appear obvious in textbooks seeking to encourage young women into science and technology.

Constructivism

Hurd (1991) concludes that the new courses of the future must be developed "with a full recognition of recent developments in the cognitive sciences, putting students more in control of their own learning" (p. 258). One major development over the past decade is the principle of constructivism (Cheek, 1989; West & Pines, 1985). Constructivism assumes that meaningful learning takes place when students construct their own meaning of an event. This can occur in a number of ways: by active participation, by reflection, and by practice at transferring a scientific idea to an everyday context. Through participation, reflection, and practice, students can incorporate new ideas into their previous knowledge, or perhaps even replace their previously held, common-sense conceptions with more precise scientific conceptions.

For example, the *LoRST* activity "The Law of Heating (and Cooling) Bodies" was designed to connect students' everyday world (such as heating syrup, oil, and water on a stove) with the realm of scientific thinking (specific heat capacity). The activity reveals how someone's assumptions about heat affect the person's interpretation of experimental data. The classic case of Joseph Black and Count Rumford is introduced. Students are assigned to research teams to explore and become familiar with the variables that seem to affect heat transfer. The instructional approach is to have different research teams work on different variables, and then participate in an "international conference" where the class reaches a consensus on what to believe. (This instruction method had been introduced to students and practiced in previous activities.) To prepare for the conference, students analyze and interpret their heat data. The data equally support Black's caloric theory of heat and Rumford's vibration theory. Both theories correspond to students' preconceptions of heat, and both theories are misconceptions in terms of current scientific thinking. The students are required to communicate their results and argue over which hypothesis is better supported by the evidence.

A subsequent heat activity, a history of science case study, recognizes that students have great difficulty conceptualizing the difference between temperature and heat. The activity legitimizes students' preconceptions by identifying those preconceptions with scientific theories of the past. Falsifying evidence is presented to students. Its inability to convince the clever scientists of the day to change their minds supports students who intuitively see nothing wrong with their own preconceptions. Finally, the issue is resolved in the case study by showing why both Black and Rumford had it wrong, and by introducing a new paradigm (Joule's energy concept) that changed scientists' thinking. Students answer questions that specifically address the paradigm shift of the scientists. Teachers who wish to teach in a constructivist manner will turn the class's attention to the paradigm shifts that occurred with students as they worked through the heat activities in *LoRST*.

Rather than covering an encyclopedia of correct answers for tests and course credits, the constructivist approach in STS science guides students to construct their knowledge for personal use in their everyday lives. In *LoRST* students are asked: How do you know? What does it mean? How does it help you make sense out of . . . ? Time is taken to ensure that students (a) apply ideas to their complex everyday world (for example, analyzing newspaper articles), and (b) achieve a firmer grasp of the topics (that is, engage in higher order thinking).

Language and Reading

An STS science textbook can be student centered in a number of ways. For instance, a text can include issues that relate to student interests, it can take a constructivist approach that revolves around students' conceptualizations, and it can suggest specific teaching strategies (such as simulations, student-centered discussions, and group work) that are organized around student participation. Equally important, however, is the textbook's writing style.

Young, Ruck, and Crocker (1991) claim, "Science texts violate students' expectations because the language is unlike anything they have previously encountered. The way science books present ideas is a discrepant event in the students' experience" (p. 46). The traditional formal, succinctly dense, science language makes textbooks scientist centered, not student centered.

Rather than requiring students to completely change their reading style in order to understand the science text language, one can modify the text language to conform more with student expectations. In order to achieve this goal, *LoRST* was written in a style that is unusually narrative, sometimes even chatty, and was structured from a student's perspective.

For instance, vocabulary is often introduced by discussing the common, everyday use of the terms. Next, a situation is presented that reveals a need to be more precise, and then the scientific meaning or terminology is introduced, but always in qualitative, not quantitative, terms. When the text moves to the quantitative realm, the transition is very explicit to students; for example, "Let's translate Henry's Law into math." Feedback from students who participated in the development of *LoRST* indicates that most students appreciate its narrative writing style.

Other Features of an STS Textbook

The student-centered approach to STS science instruction means that students have ample opportunity to engage in "hands-on" and "minds-on" labs. *LoRST*, for instance, contains 32 activities, ranging from traditional science labs to simulations in which students analyze the media in order to make decisions on public policy related to science and technology. Many of the activities are structured so teachers can easily make choices, modifications, or substitutions to fit their class situation. The community and mass media, rather than the textbook alone, are sources of information for students and teachers.

The process of designing experiments, or critiquing the experimental designs of others, pervades *LoRST* activities. Students are introduced to the vocabulary of manipulated, controlled, and responding variables in an activity investigating the period of a pendulum. These concepts are reinforced in many other activities. For example, students design their own experiment on digestion and then describe their design in terms of the manipulated, controlled, and responding variables.

Because STS content should be relevant to every classroom, STS science textbooks must encourage flexibility on the part of the teacher. Although the teacher's guide to *LoRST* specifies how a teacher can cover the text in about 80 to 110 hours of instruction, a great deal of flexibility is designed into the instruction. A teacher can easily omit sections of the book, leaving time to introduce other STS modules required by the curriculum, or modules of interest to students. *LoRST* can serve as a framework for many STS topics. In a sense, *LoRST* is a nature-of-science framework into which the social issue of drinking and driving has been integrated. Teachers can integrate other science-related social issues into that framework. *LoRST* shows how this integration is achieved.

The development of *LoRST* was unique. It followed a three-stage sequence that took advantage of classroom realism well known to teachers and students. First, the author wrote and taught draft No. 1 in a local high school. Based on this classroom collaboration with students, the text was modified to yield a second draft. By initiating the project in a classroom setting: (a) the classroom materials evolved "in situ" (on-the-spot instruction) with average tenth grade students, (b) the appropriate teaching strategies for a real classroom situation were identified (Aikenhead, 1988), and (c) the rough draft of the teacher guide was written.

This second draft of *LoRST* was taught by three volunteer teachers. Their classes were observed daily and the text was modified according to students' expressed needs. This collaboration with students and teachers led to another revision of student materials, as well as to testing appropriate teaching strategies. As a result of this collaborative R & D project, *LoRST* was polished into a third draft. Next, this third draft was field tested across Saskatchewan and evaluated by teachers both sympathetic with and critical of an STS approach to teaching science. Teacher feedback resulted in further revisions to *LoRST*. The resulting material (student text and teacher's guide) was adopted by the province of Saskatchewan as a principal textbook for grade 10.

Conclusion

STS science requires a fundamentally different approach to teaching science. STS science shifts the focus from (a) knowledge transmittal of an academic scientist to (b) knowledge construction of a student. This student-oriented approach continues to emphasize the basic facts, skills, and concepts of traditional science, but does so by embedding that science content in social-technological contexts meaningful to students.

STS science is a challenge to textbook writers. This article outlined some features and characteristics of STS science textbooks that are needed for implementing an STS curriculum. Textbooks must explicitly integrate (a) societal issues that interact with science, (b) a modern view of the nature of science, (c) the literacy requirements of those who live in a society increasingly dominated by science and technology, (d) the technological world that interacts with science, (e) a feminine contribution to science (in terms of numbers of participants and new types of ideas), (f) a student-centered approach to learning (from the topics chosen to the language used), and (g) a constructivist approach to learning that exemplifies, where appropriate, the social construction of scientific knowledge itself. These features and characteristics of an STS textbook were illustrated by reference to *Logical Reasoning in Science & Technology (LoRST)* (Aikenhead, 1991). The integration of STS into science education is crucial. Not only is the quality of a future citizenry at stake, but the quality and quantity of our future scientists and engineers hang in the balance.

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Patrick Fullick

Addressing Science and Technology Issues in the United Kingdom: The SATIS Project

Science and technology occupy a major area of interest and concern for a large number of people in the United Kingdom. Popular books and magazine articles, television and radio programs, and science fiction novels all go toward satisfying a seemingly unquenchable thirst for scientific knowledge. As an example of this, the book, *A Brief History of Time* (Hawking, 1988) has sold over 500,000 copies in the United Kingdom, and has been on the bestseller lists for over 3 years. Indeed, a local bookseller remarked to me recently that it was difficult to devote enough space in his shop to books on science and technology, so great is this thirst. As a science educator, my first response to this was to be quite excited that such an interest exists; reflection at leisure makes me wonder whether it should not also make me a little wary.

Why are people so interested in matters relating to science and technology? I think there are probably two quite different and separate reasons. One relates to a feeling that we are no longer in control of our own destiny; that science and technology have in some way "taken over." The greenhouse effect, ozone depletion, acid rain, Chernobyl—all these have obtained extensive media coverage, with the result that many people feel we are living in a world that is doomed to be destroyed by forces of our own making. The solution to these excesses may also be seen as lying in the domain of science, and so whether you are an optimist or a pessimist, you cannot help but have your attention focused in this direction.

The other reason is a simple fascination many have for science and technology itself, whether in the power to put people on the moon or in the power to explain the origins of life itself. These two fascinations are very different in their origins, but are examples of what one might call the "halo effect" that surrounds science and technology and have important roots in their power to shape our lives.

Technology and science have, of course, often been seen as intimately linked. The old idea, rooted in our 19th century forebears, that the scientist makes the discovery, which the technologist then exploits and refines, is still with us (Rogers, 1983). It is surprising that this fallacy should have grown such firm roots in a century that saw the flowering of thermodynamics, the science that grew out of the need to understand the steam engine, and even more surprising that it should continue to flourish with the development of solid state physics, which was in response to the need for ever faster and smaller electronic processors. That such a fundamental misconception of the relationship between technology and science is still part of society's approach to these disciplines is profoundly disturbing. One is not greatly reassured when one probes further beneath the surface, as we shall see.

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So what good has this keen interest and fascination been to society as a whole? Are we living in a society where science and technology are increasingly being harnessed for the good of humankind? Are all our citizens equipped to play a part in decision making of the type that will decide on the siting of a new nuclear power station? Do decision makers in government and industry unerringly understand the matters of scientific and technological relevance that affect their policies?

Bodmer (1989) has used the term "sciency" as a term analogous to literacy. By extension of the analogy, a population we may call "scient" should exhibit an understanding of science that would make informed and reasoned contributions to public debate about science. Despite the apparent keen interest in science noted above, I do not detect widespread sciency in the United Kingdom.

I suggest that there are many reasons for this. Although many people are interested in science and technology, large sections of the population remain uninterested or unaware. Coverage of science and technology is patchy. In particular, the expertise of those writing or broadcasting may often be overtaken by their enthusiasm for the story.

Eijkelhof and Millar (1988) have shown that much writing about radiation and radioactivity in the media contains factual errors based on a conceptual misunderstanding of the nature of the phenomenon of nuclear radiation. At best this serves to advance the reader's understanding of the subject no further, while at worst it must cause irrevocable damage to whatever cognitive model of the phenomenon exists within his or her mind. Just what *is* one to make of this statement (from the *Sun* newspaper [London] of May 3, 1986, quoted in Eijkelhof and Millar, 1988, p. 39) about the hazards of the radioactive material from the Chernobyl accident:

> A spokesman . . . said the radiation was "pretty harmless" in the air. But it can find its way into milk through contaminated grass eaten by cows.

Our population needs to have some degree of scientific and technological awareness in order to be full participants in a technologically oriented society. This concern formed the common element that brought a group of U.K. science educators together in the mid-1980s, with the added challenge of providing new and stimulating materials for the use of teachers in schools.

Pressure for Change

During the late 1970s and early 1980s, a great discussion took place in the United Kingdom about the most appropriate way to increase young people's awareness of science and technology. The need to do this was founded on the general concerns outlined above, but was rooted firmly in social issues (Firman, 1984). First, an adequate supply of scientists and engineers would need to be produced from a population of young people that would decline throughout the 1990s (a demographic trend common in many European countries), while secondly it was felt desirable that future generations should be acquainted with science and technology in order to live and work in an increasingly complex society.

In 1985, the U.K. Department of Education and Science published a statement of government policy on science education, called "Science 5-16" (DES/WO, 1985c). This document had the general agreement of science educators throughout the United Kingdom, and had within it 10 principles for good practice in science education, as well as endorsement of the philosophy of "science for all." The 10 principles included:

> Relevance: Science education should draw extensively on the everyday experience of pupils, and should be aimed at preparing pupils . . . for adult and working life.
>
> Teaching methods: Science is a practical subject, and should be taught at all stages in a way which emphasises practical, investigative and problem solving activity. (pp. 4-5)

Concerns about the examination system were also being debated (e.g., Powell, 1979), leading to a recognition that a system of assessment had to be devised that would test the abilities and achievements of young people rather than list their failures. In addition, the courses followed would need to promote flexibility and skills acquisition if they were to succeed in educating a work force that would adapt to society's future requirements.

As a result of these debates and discussions, in September 1986, 14-year-old students in England and Wales began courses with a new assessment system called the GCSE (General Certificate of Secondary Education). The GCSE replaced the previous two-tier examination system with a single examination for all students. It introduced coursework assessment for a significant proportion of the marks awarded in assessing students' final grades, the balance of the marks being derived from a terminal examination (SEAC, 1990a). In GCSE science syllabuses, 20 to 30 percent of a student's marks are derived from coursework, the exact figure varying among different syllabuses.

The content of GCSE syllabuses offered by examining bodies is governed by a set of regulations called the National Criteria, first introduced in 1985 (DES/WO, 1985a) and subsequently revised in 1990 (SEAC, 1990b). The National Criteria are laid down by the School Examinations and Assessment Council (SEAC) and each subject has its own National Criteria, derived from a broader set of National Criteria, which cover all subjects.

Before schools may teach any new syllabus to students intending to enter for a GCSE in that subject, the syllabus must be approved by SEAC to ensure that the National Criteria for that subject are met. This is now set within the context of a National Curriculum, introduced as part of the Education Reform Act 1988 (DES/WO, 1988), which set out the Programmes of Study that all students between the ages of 5 and 16 must follow.

In promoting a scientifically and technologically aware population, several statements in the National Criteria for Science relate to specific aims. These are as follows:

> To provide through the exploration and study of science a coherent educational experience which enables [pupils] to acquire sufficient understanding and knowledge to:
>
> > become confident citizens in a technological world, able to take or develop an informed interest in matters of scientific import;
> >
> > recognise the usefulness, and limitations, of scientific methods and appreciate their applicability in other disciplines and in everyday life. (SEAC, 1990c, p. 2).

These aims are reinforced by a clear condition with respect to the award of marks in the assessment of pupils:

> At least 15 percent of the total available credit is to be allocated to assessment(s) relating to technological applications and social, economic and environmental implications. (SEAC, 1990c, p. 4)

It is interesting to compare this last statement with that from the earlier criteria, issued in 1985:

> At least 15 percent of the total available marks are to be allocated to assessment(s) relating to technological applications and social, economic and environmental issues . . . the greatest emphasis being given to technological applications. (DES/WO, 1985b, p. 4)

The significant differences in these statements is the removal of the stress laid on technological applications. This is significant because it seems to be tacit recognition that, although an understanding of the practical applications of science is important, it can no longer be regarded as taking precedence over an ability to participate in debate about the issues that arise from science, either in its application (e.g., in the context of nuclear power) or in its exploration (e.g., in the context of human genome research).

Also in these statements is an implied linear connection between science and technology of the sort referred to in the opening section above. I would argue that, while sciency is a necessary condition for informed debate on matters relating to technology, it is not a sufficient condition, and that a similar sort of condition for "technological literacy" must be set if we are to ensure a population that is both scientifically and technologically literate. While developments in the National Curriculum mean that the subject of technology is one that will be studied by all pupils between the ages of 5 and 16, it is not yet clear what contribution, if any, this will make to technological literacy.

Effect on Science Courses

The introduction of the GCSE examination and the National Curriculum have been effective agents for change in the way in which science is taught to young people, especially with regard to the exploration of social issues through such techniques as discussion (DES, 1990, p. 9). As the preceding section shows, much of the pressure for change came from within the teaching profession itself, but it is important to stress also the key role played by learned bodies such as the Royal Society (1985) and by industry through patronage and the support of curriculum development (e.g., Marshall, 1987).

Since these changes in the statutory framework of the science curriculum have been in place for over 5 years, there has been ample opportunity to develop curriculum materials that enable teachers to begin to address the social issues of science in earnest. This is borne out by examining course material for newly developed courses and by the plethora of resources produced by educational publishers to support those courses already established. Thus, schools now have a choice of a wide range of courses that cover the statutory science curriculum and approach the discussion of social issues in different ways.

These approaches to social issues may be broadly classified into two groups. Most courses are based on a model that has been represented by Holman (1987) as "science first" (see Figure 1). One example of such an approach and the work arising from it may be drawn from the Nuffield Co-ordinated Sciences (1988) scheme. Pupils study the way glass is made from sand and other raw materials, and make glass for themselves in the laboratory. Later on they discuss the economics of recycling glass, and examine the cost of schemes that make use of returnable bottles (the way in which milk is delivered to the doorstep in the United Kingdom).

The *Salters' Science* course (1990) adopts an alternative approach, which Holman (1987) characterizes as "applications first" (see Figure 2). In this course, students start from everyday situations and issues that are familiar to them, and then discover how science applies and relates to these. Thus, in a unit starting from the situation of a physician examining a patient, ideas relating to x-rays, ultrasound, energy, and other physical phenomena are developed.

The latter approach is much less common in United Kingdom curriculum development for reasons that are not clear, but which probably relate to the difficulty in constructing a course with such an approach to cover a strictly defined body of material. The applications-first model has been adopted in the United States by the Chemical Education for Public Understanding Program (CEPUP) (1991), which is aimed at promoting the public understanding of chemicals and their interaction with people.

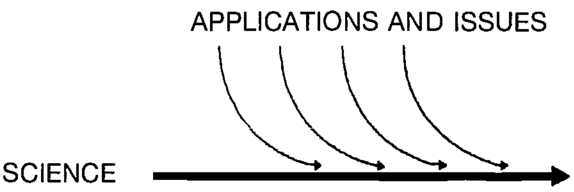

Figure 1. The science-first model.

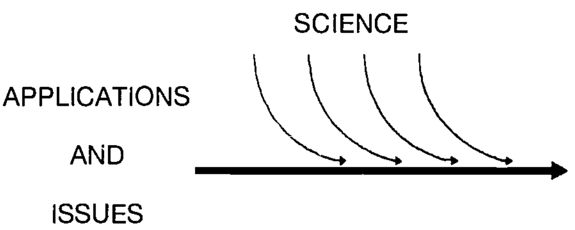

Figure 2. The applications-first model.

The SATIS Project

The Science and Technology in Society (SATIS) project was set up by the Association for Science Education (ASE), the professional organization of U.K. science teachers, to produce materials that would show young people in the 14-16 age group how science and society are interdependent. This was in response to the pressures for change outlined above, particularly the introduction of the GCSE, where resources were needed to supplement curriculum materials already available in order to support teachers as they attempted to follow the aims of the National Criteria relating to science, technology, and society. Thus, the project was not intended to produce a new course but to produce a bank of resource units that would enrich and enhance existing curriculum materials (Holman, 1985b).

Project funds came from an educational charity and a number of leading United Kingdom companies. A central team consisting of science educators from schools, colleges, and university departments and advisers from Local Education Authorities was set up, working with the project director, John Holman. The central team helped to determine policy and coordinate the inservice training of teachers, as well as being involved directly in the production of material (see Holman, 1985a).

In addition to providing teachers with the materials to help them tackle the social aspects of science, the central team felt it was desirable to produce materials in a way that would require students to take an active part in the learning process. Thus, it would not be enough to produce a passage on the debate about nuclear power with a set of questions for students to answer; instead, the exercise should involve students in some activity that made them think for themselves about the issues to be discussed.

In producing resources, the team wanted to keep within the guidelines set by "Science 5-16," and thus contribute to the promotion of good practice in school science teaching. The eventual aim was to create a scientifically literate population and convince young people that science is a worthwhile and stimulating activity.

SATIS Materials

In preparing SATIS materials, it was necessary to keep in mind the demanding criteria that such materials must satisfy if they are to be widely used. These criteria include:

- Cheapness—Teachers will not consider material if it is expensive to acquire and/or use. This ruled out the production of a textbook as a resource.
- Ease of use—If it is to be widely used, the material must not need large amounts of teacher preparation time.
- Relevance—Not only does material need to be relevant to young people's lives, it needs to be relevant to the syllabus their teacher is following.

The last reason determined an important point of philosophy for the project, namely the model that was to be used—"science first" or "applications first." After much discussion, it was decided to use the "science first" model for practical reasons. Although the "applications first" approach immediately makes material relevant to the experience of young people, it is hard for the teacher to identify the relevance of the material to the syllabus topic under study. The team felt this would be a major disincentive to teachers to make use of the resources, and so SATIS units were developed using the science-first model.

The final format of resources was agreed to be as follows:

- A bank of resource units (not a new course)
- Produced as reproducible masters to be copied by schools
- Units to be active and varied in approach, including discussions, home surveys, data analysis, case studies, simulations and role plays, decision-making exercises, and experimental work

Writing of units was carried out by volunteer teachers and other science educators, with advice on specific aspects of units being given by experts in the particular field concerned. All units were extensively tested in a range of schools, the feedback from these being incorporated into the final version of the units.

A typical SATIS unit contains some reading (to convey new ideas and reinforce previous work), questions, and an activity of some sort. An example of such an activity is problem 2 in a unit on the economics of the chlor-alkali industry (ASE, 1988a, p 6). In this problem, students are asked to role play the parts of members of the board of directors of SALCHEM, a fictitious chlor-alkali company. The problem is illustrated with a map and facts about a fictitious town, "Anytown," (see Figure 3), and states that SALCHEM is considering building a new factory near Anytown. The problem continues as follows:

> You prefer to build your new factory at the site shown on the map. However the local council is against this site. This is because it lies inside the Green Belt land, which they want to protect from building. They have offered to pay you to reclaim a piece of marshland in order to build your plant at the site shown on the map.
>
> Write your reply to the council, explaining why you believe your preferred site is more suitable than their suggested one. Explain what benefit you can bring to the town.

Besides linking with work done in the students' "conventional" studies, this activity extends the work to consider the siting of a factory producing chlorine and the economics of producing it and its co-products.

Marketing of the units has been carried out by the ASE, the units being sold as packs of 10 (a decaunit). One hundred units have been produced, and copies have been sold to nearly every school in England and Wales. Topics covered in SATIS units include homeopathic medicine, safety in road transport, invitro fertilization, the development of nuclear fusion as a power source, and many others (for a full list of units, see SATIS decaunit 10, ASE, 1988b).

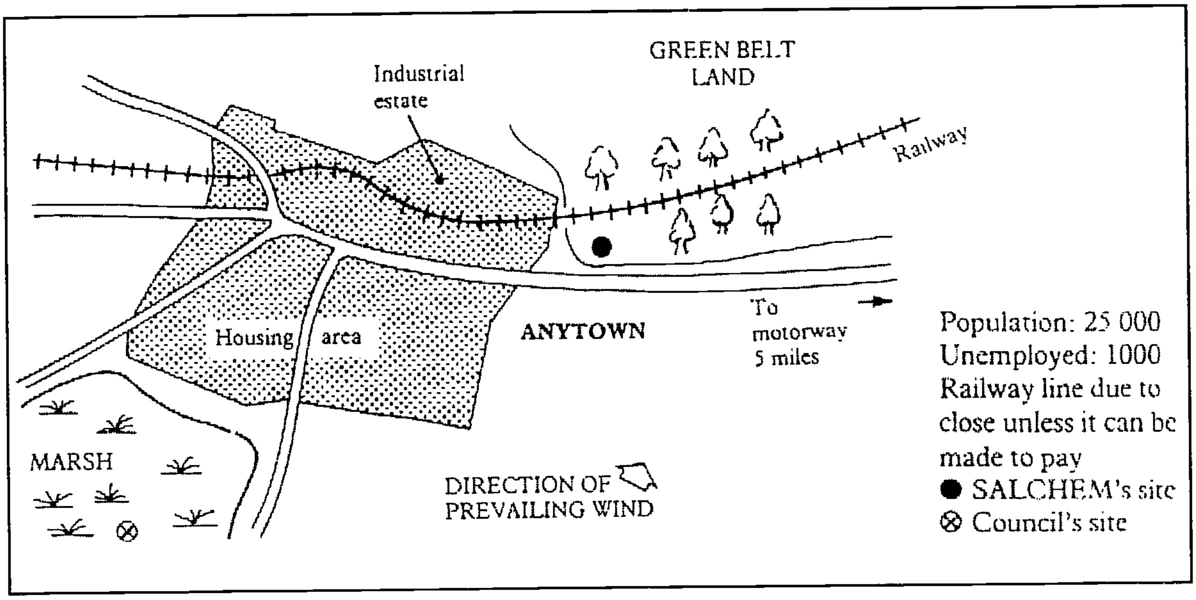

Figure 3. The map of Anytown, from the SATIS unit on the economics of the chlor-alkali industry (ASE, 1988a, p.6).

Evaluating SATIS

Having produced resources that found their way into nearly every school in the country, it was necessary to get a clear picture of how effective the material had been in satisfying the needs of teachers and in promoting the active learning of science. Accordingly, an evaluation officer was appointed who carried out an evaluation project over a period of 1 year. The evaluation exercise was a valuable experience for all the members of the project team, and confirmed our initial ideas that material must be relevant in two ways if it is to be well-used by teachers and liked by students. These two forms of relevance are:

- relevance to the syllabus
- relevance to students' lives, either as a starting point or as something that will clearly be of use in the future.

It was particularly encouraging to see that many schools use SATIS as a starting point for developing their own, locally relevant, materials on related themes (Walker, 1990). Such developments are always pleasing, since the end result is the production of far more material than a small team could ever hope to create.

The Future Development of SATIS

Since the resources produced by the project were launched in June 1986, there have been many developments in science education, including the introduction of the National Curriculum. The last 3 years have seen the production of a number of tape-slide sequences supporting some of the units, with the recent publication of further resource packs updating and extending the existing materials. User groups of teachers have been active in modifying existing SATIS units and writing new material for use in local contexts. Collaboration with BBC Schools Radio has been undertaken, and a series of programs has been produced to act as "triggers" for class discussion sessions relating to certain units (Curry, 1989).

An extension of the project to the 16-19-year-old age range was launched at the ASE conference in January 1991 (the SATIS 16-19 project), with 100 units for use with young people taking courses in the sciences and in general studies in this age group. The Science Across Europe project will be publishing materials in 10 languages between late 1991 and late 1993, seeking to encourage young people to think about and exchange their perceptions of the science-society interface in a European context. The Early SATIS project will begin publishing materials for pupils in the 8-14-year-old age range this year. These will include audio and video resources to be broadcast over national radio and television networks.

More Distant Aims

To what extent do the developments outlined above lead us to hope that our young people may form a population that is scientifically and technologically aware? I think three issues are tied up within this question, and all must be explored before we can answer the target question in any definitive way.

First, to what extent do new science courses devised in the light of the discussion and debates of the early and mid 1980s help young people to make sense of science itself—that is, do our new methods of teaching science lead young people to be competent scientists and to pursue science as a career they perceive to be worthwhile? Chapman (1991) has argued that science education to this end is of decreasing importance, taking the view that present developments in technology reduce the need for education in science, and that we should instead educate our young people for life in a post-industrial society. I would dispute this view on three counts:

1. An understanding of science itself and the ability to function as a scientist are essential contributors to sciency.
2. To neglect the education of young people in a major area of intellectual endeavor is to impoverish future generations.
3. The development of technology is unlikely without the concomitant development of science.

The second issue for exploration is the way in which new science courses encourage and promote a scient population, with a view to the creation of a generation able to play a full role in the discussion of public issues, virtually all of which involve scientific questions (Bodmer, 1989). The SATIS evaluation has provided us with a partial picture of young people's perception of science learned about in these new ways, but the picture is far from complete. We know from the evaluation that young people enjoy learning about science when they can relate it to social issues and applications, and that they are enthusiastic about learning in this way (as are their teachers!), but much more work is still to be done before we can predict with any confidence that our population of the future is overwhelmingly scient.

Thirdly, what needs to be done to ensure a population that is technologically literate? Much debate has gone on in the United Kingdom about the nature of technology and how technological competence may be achieved by young people, with Black and Harrison's (1985) paper providing the idea of "Task-Action-Capability" (TAC) as the main target of technology education. A broader understanding of technology, set in the context of society as a whole and alongside science, is necessary if education in technology is to lead to technological literacy.

At present, we do not have sufficient information to address my earlier question regarding the development of a population that is scientifically and technologically aware. New courses take time to have effect; resources take time to be adopted by schools; those educated under the "new regime" of science education have only just reached voting age (18 in the United Kingdom). Without doubt it is important to address the question, and to do so quickly. The next century will bring with it increasing demands for our young people to engage in debates that relate to the place of technology and science in the world community—and the time to begin educating them to do so is now.

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Sharon A. Brusic

Achieving STS Goals Through Experiential Learning

Educators from a number of disciplines are currently giving attention to the inclusion of technology in the curriculum. However, many of them seem to be juggling technology in order to determine where and how it fits into the curriculum. Should it be incorporated with science? social studies? Is it a separate discipline? Is it interdisciplinary?

Part of the confusion results from the fact that technology is described in multitudinous ways; hence, approaches to studying it are abundant. Some people equate technology with things, especially computers and automated machines. Others associate technology with words or ideas, such as progress, change, advancements, or dilemmas. Still others connect technology with a special form of knowledge or know-how (De Vore, 1980; Savage & Sterry, 1990). Each of these perspectives leads educators to develop different approaches to studying this multifaceted phenomenon.

Many educators involved in the science-technology-society (STS) movement seem to support the study of technology as an integral part of other elementary and secondary subject areas, such as science and social studies. At higher educational levels, they condone the study of technology in a liberal arts context. These interdisciplinary or multidisciplinary approaches are often focused on the products of technology (the artifacts or "things"), their development within a certain historical and/or social backdrop, or their impact on society and the environment (Cutcliffe, 1989). Studies may center around general themes, such as technological change, or they may focus on the development of specific artifacts or techniques, such as telephones, interchangeable parts, and steam engines. For the most part, these studies may be classified as *"outside,"* or externalist, approaches because students study *about* technology, not *in* technology.

In contrast, technology educators have an *"insider,"* or internalist, approach. They primarily focus on the human process of creating technology; students study *in* technology more than they study *about* it. The technology educator's approach is more process oriented and people centered. This approach to studying technology is further delineated in this article with the goal of explaining and demonstrating technology educators' two major contributions to STS education: (a) presenting a different view of technology and (b) providing an experiential arena in which to achieve the STS goals.

Technology Educators' Perspective

Technology educators portray technology as an active process that requires human thought and action for the main purpose of satisfying

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people's wants and needs (Savage & Sterry, 1990). When people engage in purposeful activity in order to use or change their natural environment to satisfy their wants and needs, they are engaging in technological activities.

A Different View of Technology

A number of educational activities, courses, or programs implemented since the 1970s include the term technology in their name. The focus of many of these, however, is on technological artifacts—products of technology—and their impact on society and the environment. If technology was synonymous with hardware or machines, such as computers or military weaponry, then perhaps these approaches to studying technology would be sufficient.

However, technology is not simply the equivalent of artifacts. Educators often assume that they are providing a complete picture of technology in their curriculum by merely adding more technological tools or machines to their repertoire of instructional media or including more discussions and readings about them. Albeit necessary or useful to do this, this "outside" approach to examining technology does not supplant the need for exploring technology as something greater than the sum of its products and their influence on society and the environment.

Further, the "outside" approach minimizes the human role in designing or creating the technology. While technological artifacts and processes affect society and the environment, they are also products of human ingenuity and imagination that were influenced by social or environmental wants or needs. These facets of technology—purposeful human endeavor and the special knowledge or skills required to make it possible—are often overlooked by other methods of inquiry (i.e., sociological, philosophical, historical, scientific). They are, however, the core of the technology education curriculum.

People have engaged in technological activities since prehistoric times. The stone ax, pencil, and electric generator are as much products of our technological heritage as are the robotic welder, computer, and breeder reactor. People used special knowledge, skills, and processes in order to create these inventions and innovations. Today, people continue to solve problems or provide for human sustenance and comfort by engaging in technological activity. This systematic process and know-how forms the content base for technology education and provides students with a different, yet important, view of technology.

An Experiential Approach

The hallmark of the technology educators' approach is the value they place on experiential learning. Technology education and its precursors (i.e., industrial arts, practical arts, manual arts, manual training) have consistently exemplified the importance of practice and experience in education (Zuga, 1991). In the words of educational philosopher, Alfred North Whitehead (1929):

> First-hand knowledge is the ultimate basis of intellectual life. To a large extent book-learning conveys second-hand information, and as such can never rise to the importance of immediate practice. (p. 79)

Modern technology education programs continue to highlight this first-hand knowledge approach by actively engaging students in solving technological problems and using technological products. This methodology is founded on the belief that technology is experience based and people centered. Human activity is key to technology; hence, human activity continues to be the most efficient and effective method of teaching technology in the technology education setting.

In technology education, students are thrust into technologists' roles through a variety of activities that require them to analyze human wants and needs, create technological solutions, and use technological products. Students see and experience another side of technology—the technologists' perspectives—the points of view of people who conceive of the ideas and make them work. This experience helps them to develop a more complete and realistic view of technology.

Making STS Goals Achievable

The technology educators' approach differs from that of other educators (e.g., science and social studies educators). However, the combination of all these approaches and perspectives is what makes STS studies so appealing and essential. It is through this concerted effort that students have the greatest opportunity to achieve the primary goal of STS studies—to become scientifically and technologically literate (NSTA, 1985).

According to a position statement made by the board of directors of the National Science Teachers Association (NSTA, 1985), a scientifically and technologically literate (S&TL) person exhibits 13 characteristics. Several of these traits bear close resemblance to the characteristics of technological literacy for high school graduates identified in a study by Croft (1989). Although the phrasing of characteristics differs in each report, the similarity lends support to the idea that particular characteristics may be more representative of technological literacy (TL) than scientific literacy (SL). The primary goal of technology education is to advance TL.

Figure 1 presents five characteristics of the S&TL person (NSTA, 1985) adjacent to technology education program objectives that address similar concepts (Snyder & Hales, 1981, p. 42). This figure describes those areas in which technologyeducation has the potential to make the greatest contribution to students' scientific and technological literacy.

For decades, technology educators and their predecessors have demonstrated expertise and success in promoting students' attainment of the types of skills and understandings currently associated with SL or TL. This has been, and continues to be, accomplished through an action-oriented curriculum that engrosses students in creating and using technology.

In the sections that follow, numerous technology educators' approaches are described. The sections correspond to the five characteristics of the S&TL person shown in Figure 1. They are a representative sample of technology education activities under way across the United States that were specifically designed to help students attain SL or TL, as described by NSTA (1985) and Croft (1989).

Understanding The STS Relationship

Many young people have only a vague understanding of the relationship between science, technology, and society. This is partly due to the fact that the fragmented school curriculum does

Scientifically and technologically literate persons[1]:	Technology education students will[2]:
Understand how society influences science and technology as well as how science and technology influence society	Understand and appreciate the evolution and relationships of society and technical means
Recognize the limitations as well as the usefulness of science and technology in advancing human welfare	Develop attitudes and abilities in the proper use of tools, techniques, and resources of technical and industrial systems
Appreciate science and technology for the intellectual stimulus they provide	Explore and develop human potentials related to responsible work, leisure, and citizenship roles in a technological society
Understand the applications of technology and the decisions entailed in the use of technology	Establish beliefs and values based upon the impact of technology and how it alters environments
Have sufficient knowledge and experience to appreciate the worthiness of research and technological development	Develop creative solutions to present and future societal problems using technical means

1. These characteristics are taken from a position statement made by NSTA's board of directors (1985, unnumbered).
2. These technology education program objectives are taken from Snyder and Hales (1981, p. 42).

Figure 1. Characteristics of a scientifically and technologically literate person compared with technology education program objectives.

not easily accommodate subject matter that crosses subject lines. It is often presumed that students will make the connections themselves by piecing together things they learn in each subject.

Technology educators do not presume that students can grasp the complex relationship between science, technology, and society on their own. They have designed and implemented numerous activities over the years that give students concrete opportunities to explore this relationship (e.g., ITEA, 1985; Maley, 1973, 1985, 1989; New York State, 1987).

For example, a popular activity in many technology education classrooms involves student-generated prototypes of technological products, such as the waterwheel, elevator, camera, and hydroelectric power plant. Typically, students choose a significant technological invention or innovation based on their review of various printed materials, including social studies textbooks and library books. Students create a scale model of the device based on the information they uncover during their research. They use the materials, tools, and machines available to them in the technology education facility to create a model that is as authentic as possible. Wherever possible, the scale models are working models that can be used and tested.

During this process, students have the opportunity to see and experience the science-technology-society relationship. They draw their idea from a social or historical context; they create the device based on the scientific and technical information available; and, whenever possible, they test or use their device for the purpose of developing a better comprehension of the scientific, technological, or social significance of this innovation.

Throughout this process, the teacher serves as a resource by directing students to new sources of information, asking probing questions, demonstrating necessary production techniques, and encouraging students to recognize and appreciate the intricacies of science, technology, and society with respect to this specific device. It is through this complete educational process that students can truly assimilate the integrated nature of STS.

Recognizing Limitations and Usefulness

Technology educators have done a superb job of addressing the limitations and usefulness of science and technology in advancing human welfare. In fact, this may well be their greatest strength in terms of strengthening students' achievement of STS goals.

Many technology education facilities are well equipped to engage students in practical activities aimed at demonstrating the limitations and usefulness of science and technology. The activity based, application-oriented curriculum is designed to turn abstract concepts into concrete experience, thereby making technical and seemingly complicated ideas understandable to students. One way this is accomplished is through activities aimed at showing students how things work or how things are done.

For example, a high school industrial arts teacher, Robert Gauger, described a situation he once encountered that instigated a welcomed change in his school curriculum (Gauger, 1989). A chemistry teacher at Gauger's school asked him to give a demonstration for the science students on how an air conditioning system works. The chemistry teacher wanted the science students to see a practical application of phase change. Students and teachers called the demonstration a great success. In fact, the experience led Gauger to introduce into his technology education curriculum two new courses that specifically focused on science-technology linkages. Gauger called the idea "unified science-tech" and named his courses "technology of chemistry" and "technology of physics."

For generations, the industrial arts and technology education curriculum has provided students with unified science-tech (Gauger, 1989) experiences—they just have not had that name. Students have ample opportunities to see and experience the limitations and usefulness of science and technology through a variety of technology laboratory experiences (ITEA, 1985). In the example described (Gauger, 1989), students saw the usefulness of knowing about phase change. Likewise, they learned how the laws of science and nature impose restrictions (limitations) on the design of the air conditioner.

As another example, high school technology students learn about molecular chemistry when they shape or form plastics and metals for various production projects (Wright, 1987). Other students enrolled in construction courses put physics concepts to work when they build structures that must meet specific criteria (Huth, 1989). Middle school students learn about aerodynamics and Newton's laws of motion when they participate in a technology module on flight (Iley, 1987; Smith, 1987). Elementary school students who participate in the Mission 21 Technology Education Program (Brusic & Barnes, 1992; Dunlap, Croft, & Brusic, in press) do technological activities that apply concepts from earth and physical science units. The technology education curriculum is overflowing with concrete examples on how students can explore ways that science and technology advance human welfare (i.e., give people things they want and need) within certain limitations (i.e., laws of science and nature).

Appreciating the Intellectual Stimulus

By their very nature, science and technology can arouse curiosity and interest. Unfortunately, though, many students do not appreciate these qualities. Various educational reports released during the 1980s (see AAAS, 1989; Mullis & Jenkins, 1988; National Science Board Commission, 1983) suggest that large numbers of students are disinterested in science and technology and that they will be ill prepared for their future roles as consumers, citizens, and workers in a technological society. This STS objective addresses this concern by emphasizing the critical importance of developing students' appreciation for the intellectual stimulus that science and technology provide.

In The Woodlands, Texas, technology educators found a way to achieve this objective by involving students in learning about science, technology, and other school subjects in an exciting, new way. They use a central project approach made up of many smaller, component projects (McHaney & Bernhardt, 1988, 1989).

The focus of the central project during the first year was "to research, design and build a habitat which would sustain four people in an outer space simulation for 72 hours and . . . carry out the 3-day mission" (McHaney & Bernhardt, 1989, p. 2). The activity, then dubbed "Project Space Station" (McHaney & Bernhardt, 1988) involved more than 400 students at their school. The space theme was relevant and meaningful to students in their community, which is just north of Johnson Space Center in Houston, Texas. McHaney and Bernhardt stress the importance of choosing central project ideas that are relevant to a school's community.

The success of the project during the 1987-88 school year led them to expand it during the next school year. In an effort to parallel the National Aeronautics and Space Administration's (NASA) plans, they expanded the project to include the development of a staffed-lunar outpost and invited students in Canada and Japan to participate in the activity. The expanded central project activity was now designated as the "International Student Space Simulation (ISSS)" (McHaney & Bernhardt, 1989).

Today, the ISSS is being conducted simultaneously in a number of schools (Bernhardt & McHaney, 1990). Students at each site design and build a mock space station suitable for human habitation for 72 hours. They also envision and solve numerous engineering and technological problems prior to the culminating event—the mock launch of the space station and its 72-hour mission. Bernhardt & McHaney (1990) describe the educational experience taking place in these schools:

> [The students were] separated by thousands of miles, skin colors, cultural and religious differences, and varying governmental philosophies . . . yet everyone was united in the quest of the unknown and the dedication to explore the heavens together. . . . This mission demonstrated the potential and the desire that exist to work together to solve problems and to explore space. (p. 44)

McHaney's and Bernhardt's (1988, 1989) central project approach is just one example of how technology educators can make science and technology education exciting and, hence, intellectually stimulating. Other technology educators have devised and implemented other approaches that have been equally innovative and successful at the elementary level (Brusic, Dunlap, Dugger, & LaPorte, 1988) and the middle school level (Iley, 1987; New York State, 1987; Smith, 1987; Welty, 1989).

Understanding Applications and Decisions

Technology educators specialize in helping students to understand and appreciate the *human-made* world. This differs from science educators' focus on the *natural* world and social studies educators' focus on the *interactions* of societies and cultures within these worlds. One way technology educators help students to understand and appreciate the human-made world is through an experiential curriculum that engages students in applying technology and making decisions about its use. Nowhere is this more apparent than in technology education classrooms and laboratories where students engage in realistic manufacturing or construction simulations such as those first introduced through the Industrial Arts Curriculum Project (Lux & Ray, 1970, 1971).

The primary educational purpose of these activities or courses is to help students comprehend the systems by which products are manufactured and structures are constructed. These simulations involve students in the complete manufacturing or construction process, from planning through product design, management, production, and marketing. Students often form mock companies, sell stock, and organize themselves into working teams, which have specific responsibilities within the company.

In manufacturing classes, the end goal is to mass produce quality, marketable products in the technology facility. In construction classes, the goal is to erect, on-site, a structure that meets the customer's expectations or is marketable. Moreover, students strive to do this work within reasonable time frames, by industry's standards, and to realize a profit for the shareholders in their mock company.

Students experience the complete process, including the creative-thinking, decision-making, and problem-solving responsibilities that are inherent in the operation. Likewise, they experience the excitement of successes and the agony that arises from inadequate planning or bad decisions.

Manufacturing and construction simulations have been remarkably successful in technology education. However, other types of simulation experiences can be equally effective when organized by technology education teachers with expertise in other areas, such as communication technology (Sanders, 1991) and energy technology.

Gaining Knowledge, Experience

The experiential curriculum of technology education centers around the idea that appreciation comes from knowledge and experience. Every technology education activity described thus far likewise supports the STS objective of developing this appreciation.

However, technological development is the central focus of some technology education activities, which makes them especially useful for helping students to achieve this objective. These activities explicitly involve students in the process of technological development, often referred to by technology educators as technological problem solving (Waetjen, 1989).

Technological problem solving is realized in numerous ways in technology classrooms. Most often, students are presented with problems (human wants or needs). Students analyze the problem, develop alternate solutions, choose the optimal solution that fits within the constraints, and then create and test their solution.

Problems are highly varied. Elementary school students might create a battery-powered question and answer game that informs players when their answers are right or wrong (Brusic & Barnes, 1992). In a middle school class, students might solve a transportation problem by building rubberband-powered vehicles (New York State, 1987). High school students in Bellevue, Washington, design and make appropriate packaging for materials or goods produced in foreign countries (Rye & Watson, 1987). College students enrolled in a communication technology course may plan and create various components for a product's promotional campaign, including a television commercial with computer-generated graphics, radio announcement, photographic display, and printed brochures (Sanders, 1991).

Technological development or problem solving is a doing process, and it is a significant part of technology education curriculum today. If educators truly want students to appreciate the worthiness of research and technological development, they need to grant students more opportunities to experience its excitement firsthand.

Conclusion

Technology educators have a wealth of knowledge and experience to contribute to STS education. Their experiential approach to studying technology makes their perspective on technology different from, yet equally important as, that of other educators who strive to help students attain scientific and technological literacy. The challenge lies in finding the best way to meld their expertise with that of educators from other disciplines in order to establish a holistic STS curriculum for students of all ages. In the words of Alfred North Whitehead (1929):

> Education should turn out pupil[s] with something [they know] well and something [they] can do well. This intimate union of practice and theory aids both. The intellect does not work best in a vacuum. The stimulation of creative impulse requires . . . the quick transition to practice. (p. 74)

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Phillip A. Heath

Organizing for STS Teaching and Learning: The Doing of STS

A dramatic change in public perceptions of science, technology, and the social studies has taken place during the past 4 decades (Hickman, Patrick, & Bybee, 1987; NCSS, 1990; NSTA, 1990). Whereas science was once equated primarily with laboratory investigations, technology with the application of science to encourage progress, and social studies with history, geography, and government, these disciplines are increasingly being seen as more complex and sophisticated and as key components in developing a knowledge and skill base for assisting citizens to improve the human condition. Sparked by such issues as acid rain, biomedical ethics, and depletion of natural resources, educators and the public are becoming aware of the need for citizens who not only understand the scientific and technological bases of these issues but are willing and able to participate in formulating public policies regarding them.

At the same time, however, a clear view of the responsibilities of elementary and secondary schools for the implementation of science-technology-society (STS) curriculum has come about more slowly. Many educators are concerned that the existing curriculum in most schools is too narrowly focused, too historically bound, and too compartmentalized to deal adequately with these new challenges (Brandt, 1988). What is advocated is a curriculum that promotes learning of content and processes, enables students to deal with problems and issues in an increasingly technological environment, and provides the basis for career choices (NSTA, 1990; Yager, 1990). Central to the arguments of STS proponents is that STS approaches to teaching and learning have the potential for meeting some of these needs.

In focusing on the "doing" of STS, this article discusses the various considerations and decisions related to facilitating the infusion of STS content and skills into a school curriculum and the factors that might help sustain instruction once it has begun. Among the components of this framework are (a) definition and goals, (b) location within the curriculum, (c) instructional approaches, and (d) a support system.

Definition and Goals

A first step in developing STS curriculum, whether a unit or a whole course, is defining STS and identifying anticipated student learning outcomes. STS can generally be referred to as an instructional approach that incorporates appropriate STS knowledge, skills, attitudes, and values. Operationally STS instruction is unique in that (a) it begins by focusing on issues that are current and relevant to student interests and content areas, (b) it engages students in the development of decision-making skills and attitudes and encourages them to make informed judgments about science and technology issues, (c) it integrates

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instruction and learning from many curricular areas, and (d) it promotes science, technology, and social literacy.

Guidelines developed by the National Council for the Social Studies (NCSS) may help schools build an operational definition of STS and develop instructional goals and objectives. According to the NCSS guidelines, teachers should choose topics that

a. encourage learners to develop an understanding of themselves as interdependent members of society, and society as a responsible agent within the natural ecosystem;
b. present clearly the mutual relationships and widespread effects of science, technology, and society;
c. present clearly the relationship and effects of scientific developments and new technologies to relevant issues on local or global scales;
d. facilitate the presentation of a balance on differing viewpoints about issues and options and a critical review of the positions and sources of these viewpoints;
e. provide opportunities for learners to develop and practice problem-solving and decision-making skills;
f. provide opportunities for learners to apply the content, attitudes, and skills learned to responsible personal action and societal action or both;
g. help and encourage learners to consider an expanded perspective on science, technology, and society including issues of personal and societal values and ethics; and
h. foster confidence in the learners for handling science, technology, and society issues. (p. 190)

Similar lists are included in goal statements for Project 2061 (Rutherford, 1986), the STS project at Pennsylvania State University (National STS Network, n.d.) and the Ohio Department of Education (Ohio Department of Education, 1988). While these may provide assistance in developing specific instructional goals, it should be recognized that these are dependent on a number of factors, including the placement of instruction within the curriculum and the ability of students.

Location Within the Curriculum

An initial task for educators is to decide if STS can be included in the curriculum and, if so, where, when, and how it should be implemented. Should STS be a separate course of study or should it be infused into existing science, social studies, or industrial technology courses? Should it begin in the elementary, middle, or high school grades? Should all students be taught STS content or should it be limited to a specific school population? Will teaching materials be readily available? Will new instructional techniques be required? How will this new content affect student performance in national achievement tests?

The way in which such questions are answered will determine not only the definition of STS instruction but will shape the goals and objectives of the curriculum and the way in which instruction is carried out. The development of effective and fiscally responsible curriculum and instruction requires school administrators and classroom teachers to work in tandem. Although this article focuses on STS infusion in the classroom, infusion of any new content into the curriculum must be consistent with policy decisions made at the system level.

While views vary regarding the placement of STS instruction in the school curriculum, most publications appear to support the idea that the principal responsibility for STS instruction should be in science at the high school level (Harms & Yager, 1981; Roy, Pugh, & Waks, 1985). It is argued that STS should be positioned in new or restructured courses and that nearly all high school students, particularly the non-college bound student, should be required to take these courses. In the social studies, however, most recommendations support the infusion of STS within existing courses (Heath, 1988; Remy, 1990).

Thier (1991) suggests that high school may be too late and gives two reasons for beginning formal issues-oriented STS instruction in the middle grades. The "middle/junior high school, with its focus on the learner and its lack of strong commitment to specific subject disciplines, has the greatest capacity to change" and "this is the last time in our current educational system that all learners study science" (Thier, 1991, p. 17).

Bybee and Bonnstetter (1987) advocate a K-12 approach. From a social studies perspective, issues-oriented instruction, decision-making and citizenship education, and technological literacy should be an integral part of the curriculum throughout the elementary and secondary school years (Heath, 1988). There is little literature, however, that discusses the appropriate timing of STS instruction across grade levels. While it can be argued that the most appropriate time to present many of the skills and concepts is early in the elementary school grades, little data is available to support this position.

Another consideration regarding the placement of STS relates to the interdisciplinary and multidisciplinary nature of STS. An STS approach is multidisciplinary in that important skills, concepts, and attitudes associated with STS topics can and should be taught in most areas of the school curriculum. However, it is also interdisciplinary. Effective instruction within an STS course or unit requires students to synthesize and apply learning from many content areas (e.g., considering the impact of an acid rain issue on the economy of a certain area).

Decisions about where to locate STS in the curriculum are directly related to the way in which we determine content and the approaches we take to teaching and learning. For example, one of the commonalities of STS lessons, irrespective of the discipline, is the building of instruction around issues. The STS approach "seeks to develop in students the ability and inclination to apply knowledge from the sciences and skills from the social studies toward the resolution of science- and technology-related social issues" (Wraga & Hlebowitsh, 1990, p. 194). Students learn that technology, while best known with regard to products or artifacts, is important not only as the application of knowledge but as a systematic study of techniques and a process of solving problems (National STS Network, n.d.).

With an interdisciplinary approach, courses or units of study are organized to facilitate transfer of learning by students across disciplines and the application of this information to topics selected for investigation. An obvious difficulty is that few students at the high school level have a common set of courses from which to draw information equally. An alternate approach is to organize courses or units so that relevant information from a variety of disciplines is learned within the course or unit.

Also related to the placement of STS in the curriculum is the view, taken by many, that the content should center on its application and less on its theoretical nature. In this approach, significant effort is given to the application of material to be learned in each instructional unit, focusing on issues and problems relevant to the students. Particular emphasis is given to students' ability to collect, analyze, and apply data.

Critics of this approach argue that emphasizing applied learning in the disciplines will adversely affect students' preparation for postsecondary education and diminish their ability to solve theoretical and abstract problems. Advocates of the applied approach note that approximately 90 percent of high school students take fewer than two high school science courses and that they retain little information from these upon graduation (Roy, 1989; Roy et al., 1985).

Another issue relates to the principal discipline in which STS is or should be located and which should serve as the core subject. Should it be science, social studies, industrial technology, for example, or should a separate course of study be developed? Some STS proponents recommend restructuring school curricula around the themes of science-related social issues, science and technology literacy, and decision making for social responsibility.

Thier (1991), for example, states, "Societal Issues-Oriented Science Education will have infused all the offerings of the school and will be one of the core concepts used as the basis for organizing the school and its program (p. 17). Tanner (1990), from social studies, suggests, "Because the social problems and issues of our lives are so pervasive and interconnected with science and technology, they may well serve as focal points for school science. . . . One might conclude that in meeting the need to reconstruct the curriculum in general education, the social studies should serve as the integrating center of the curriculum" (p. 95).

A restructuring of the K-12 school curriculum to better promote student learning across traditional content areas and to increase opportunities to engage students in active learning would facilitate STS teaching and learning. However, there is little evidence to suggest that efforts to adopt interdisciplinary approaches or to combine traditional disciplines into single courses will result in massive and immediate curriculum reform. Of the efforts to date, the most common approach to STS instruction appears to be infusing STS themes into science or social studies courses at the high school level. This is frequently done by developing new units of study, modifying existing units with new material and activities, or extending units to include more opportunities for students to apply the material learned to social issues and problems.

It seems unlikely, given an already overcrowded curriculum, that STS will find wide acceptance in school curricula as a separate subject. Rather, what is being accepted is a modification of existing courses by first developing a new framework for an individual course and then developing units of study and/or modules of instruction that can be infused according to overall curriculum goals and resources of individual schools. Focusing on high school science as the core for implementing STS content, enriched by efforts to improve teaching and learning, appears to be the most common approach (Bybee, 1987; Hurd, 1983; National STS Network, n.d.). However, social studies educators are giving increasing attention to STS, particularly the treatment of science-related social issues (Heath, 1988; NCSS, 1990; Remy, 1990). This is not to suggest that STS instruction cannot or should not be included in virtually every school subject or that each area of the curriculum is not a valued contributor to STS goals. However, science or social studies courses appear at the present time to be the areas in which teachers can most effectively synthesize materials from a variety of disciplines into effective instructional approaches.

Developing an effective implementation plan for infusing STS instruction into a school curriculum requires conscious decisions regarding the STS definition, the most logical placement to accomplish goals and objectives, the identification of individuals with primary responsibility for development and instruction, the target student population, and the courses/sections involved. These decisions must draw on the collective thinking, strategies, content and materials, and energy of educators from as many areas of the school curriculum as possible.

Instructional Approaches

Three strategies for bringing STS into school programs are commonly recommended: infusion into existing courses, extending existing units, or developing new courses (Heath, 1988; Remy, 1990). While each approach has some advantages and disadvantages, the one most likely to succeed in initial attempts is infusing STS material into an existing course. The focus here, therefore, will be on considerations and recommendations for developing STS units and modules.

A number of factors must be considered prior to selecting instructional materials and strategies. The first is the requirements of STS. These include: (a) integration of content and inclusion of effective instructional strategies from different academic disciplines, (b) selection of current topics that touch on significant and relevant science-related social issues, (c) use of activities that cognitively engage students in an analysis of empirical and affective data and application of those data to simulated and real decision situations, and (d) addition of content and materials from different disciplines and programs (e.g., career awareness and education, techniques of data gathering and analysis). According to Hungerford, Ramsey, and Volk (1989, pp. 10-11) students of STS with an environmental dimension should gain (a) sound problem identification skills, (b) a degree of environmental sensitivity, (c) investigation and evaluation skills, (d) knowledge of and perceived skill in the use of citizenship action strategies, and (e) an internal locus of control (required for empowerment).

Another consideration is the basic themes of STS. Four themes or "integrative threads" are common to all STS approaches, regardless of subject or grade level placement. They are decision making, issues, career exploration/education, and technology education (Bybee, 1987; Heath, 1990, Singleton, 1988). Many themes listed on a checklist or a matrix can be helpful when organizing the scope and sequence of a unit and when integrating material from different subjects and disciplines. For example, a unit in biology might focus on key concepts in dealing with population from a historical to a present-day perspective. This study could lead to an analysis of world hunger or genetic engineering problems, and possible causes and effects related to the use of technology in resolving the problems.

A unit in economics or geography might begin with a study of the economic and regional effects of an oil spill. Lessons could be organized around a "clarification of issues and identification of occasions for decisions, collection of empirical and value related data, consideration of courses of action and their consequences, and action plans" (Heath, 1990, p. 208). Major skills and concepts from the content area are learned as they are brought to bear on the discussion of the issues and recommendations for their resolution.

A third consideration is the role of issues in STS instruction. Central to all STS instructional units is the role of current and significant issues. Using issues as a basis for instruction is perceived as a primary instructional approach, the "glue" that permits integration of teaching and learning across disciplines in such a way as to help students understand the interactions of science, technology, and society and the decisions citizens make in terms of these interactions (Heath, 1989).

Additionally, issue-oriented units of study, in either science or social studies, can result in a strong student commitment to problem solving and reasoned decision making, encourage higher-level thinking about important concepts, and promote student involvement in the resolution of science-related societal issues. While it is important that students learn content from the traditional disciplines, the challenge is to select issue-laden topics, identify components, select content, and organize instruction so that students can apply what they have learned.

STS proponents argue that STS units must include situations that are real, current, and relevant to the content under discussion and the interest of the learners (Heath, 1989; Ramsey & Hungerford, 1987). However, real-life situations and topics that focus on science- and technology-related societal issues are sometimes difficult to identify and to integrate safely and effectively into the curriculum. A challenge for teachers is that STS issues are often complex and interrelated with other issues and problems, first-hand unbiased data is difficult to obtain, and student understanding of the issues often requires that the student already posses certain knowledge and skills.

The process of selecting topics can start with a social issue or problem, technological process, or with concepts and principles from the subject or discipline. Regardless of the approach, the topics should facilitate the development of investigative skills. Students should be presented with opportunities to collect, analyze, and synthesize empirical as well as affective data, and then to use interpretive skills to apply these data to significant social problems. Criteria to consider when selecting topics include: (a) relevancy and applicability of the material to the lives of students, (b) the social maturity and cognitive development of students required by the materials, (c) the relative importance of the topic in the world today and the likelihood that it will remain important for a significant portion of the students, (d) the potential for transfer of knowledge to contexts other than the current subject or course, and (e) the students' interest and enthusiasm for the topic and its inclusive issues (Bybee, 1987; Hickman et al., 1987). Variables in the instructional setting, such as teacher background, available materials, and restrictions imposed by the school or community must also be considered.

Instructional Techniques

A discussion of the wide array of techniques and strategies that can be used successfully to teach STS is beyond the scope of this article. There are several, however, that have particular importance in STS instruction.

Simulations, models of real life, are about the most powerful instructional tools teachers have for STS teaching and learning (Heath, 1989). While not all instruction can or should center around simulations, they do permit real and contrived issue-laden situations and topics to be organized according to predetermined goals. Excellent examples can be seen in *Citizenship Decision Making* (LaRaus & Remy, 1978). These engage students in the process of decision making, considering alternatives and consequences, and deciding on an action plan after thoughtfully considering both empirical and value-laden data. Equally successful simulations can be developed by the classroom teacher.

Simulations do have limitations, however. They take significant amounts of classroom time and students frequently perceive them as contrived and unrelated to the "real" problems and issues they face. On the other hand, simulations do provide an excellent introduction to and practice with the process of decision making prior to consideration of the real and more complex decisions that may be introduced later in the unit.

A second effective STS instructional technique is the cooperative and collaborative teacher-student approach (Ramsey & Hungerford, 1987). Aimed at empowering students, this approach involves students working directly "with" teachers to collect and analyze data about real problems and issues. They then attempt to influence public policy through a variety of action outcomes (e.g., articles in papers, meeting with public officials). The success of this approach depends on the selection of relevant and important issues, the engagement of students in the learning process, including awareness and ownership, and the development of a cooperative and supportive classroom environment.

Other effective instructional techniques include debates, independent projects, small group discussions, case studies, surveys, oral presentations, and written reports. Regardless of how instructional techniques are molded into an overall strategy, unit outcomes should focus on the knowledge, skills, and values requisite to citizenship behavior, and the ability and willingness of students to make informed decisions in an increasingly technological and global society. Activities should help students learn to make responsible and ethical decisions as they deal with ever more complex and conflicting information.

A Support System

Many good STS units and programs result from individual teachers striking out on their own, filled with enthusiasm, ability, and dedication to the importance of STS, but with little support. Without the ongoing support and involvement of others, it is difficult not only to expand such efforts but to maintain existing quality instruction over time. The literature contains little discussion of support systems within the STS approach. Educators attempting to infuse STS instruction in schools should include support systems as an important component of the overall development strategy. What follows are recommendations that may act as a springboard for discussion.

Electronic networks (e.g., bulletin boards) are increasing in number and accessibility. The network on-line with the STS project at Pennsylvania State and the Sci-Net in Ohio are but two examples of ways educators can communicate electronically.[1] Another effective networking strategy is forming or joining a group of educators with common interests and problems. Whatever the approach, the idea is to create a forum for sharing and gaining access to ideas about materials and instructional approaches.

The formation of multidisciplinary and multigrade teams within the school system is fundamental for successful infusion of STS and for sustained success. Not only does STS often require the expertise of individuals beyond that of the STS teacher, but the support given by other teachers and administrators is important in making decisions regarding the allocation of resources and the definition of topics and content of STS units. For example, in a unit that requires students to write letters or reports, the cooperation and assistance of an English teacher would be appropriate.

Building partnerships with colleges or universities is one method that has been used successfully and should be strengthened. For example, involving faculty members from science, social science, and industrial technology departments and from the related departments in education, to serve on a team with classroom teachers, should enrich the base from which quality instruction could be developed. The trend toward partnerships with business and industry also appears to have merit. While the number of such programs is growing, it remains for individuals within school systems to approach organizations and develop networking capabilities.

As issues become more complex and the knowledge required to understand them continues to accelerate, educators must increasingly reach out to include those individuals and agencies that can best assist in the process of education. Simply forming an advisory group, however, is not sufficient. Partnerships must be formed that support the instructional process both directly and indirectly. This is particularly evident in STS instruction and it is vital to successful programs.

Summary

One problem with the "doing" of STS is that STS as an organized discipline or approach is still in a formative stage. How it will evolve has not yet been determined. However, it is evident that students, our future citizens, must possess the knowledge base and the skills to participate in decision making and public policy formation—to be able to think and act on developments in science and technology and their effect on the world. The infusion of STS instruction into the curriculum offers unique opportunities to achieve these goals.

In view of the constant shifts in values and the need for an increased knowledge base, STS strategies should convey knowledge while simultaneously engaging students in active participatory learning. The major responsibility for designing courses of study and units of instruction will remain the responsibility of individual and groups of teachers in local school systems. These efforts should be consistent with a framework—a strategic plan that includes a commitment and effort by key administrators and teams of teachers across disciplines and grade levels as well as groups and individuals from agencies outside the school system. Science-technology-society instruction needs to be defined by local educators and the content and instructional approaches should be thoughtfully developed with equal consideration given to the various demands placed upon schools and the important task of educating students to live in an increasingly technological world.

Note

1. For more information on these electronic networks, contact The National Center for Science Teaching and Learning, 104 Research Center, 1314 Kinnear Road, Columbus, OH 43212.

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Paul W. De Vore

Technological Literacy and Social Purpose

Throughout this century, schools have been in a state of flux as they have attempted to meet the needs of a constantly changing society. Within the field of technology, there has been considerable confusion as to direction, a confusion that has resulted from a variegated past of different curricular movements designed to serve various politically acceptable purposes. There has also been confusion about the place of technology within education as a field of study.

The context in which programs in technology education exist today presents a new challenge and responsibility. The new context necessitates not only an integration with fields of study such as science and society, but also directs attention to the evolution of the discipline and science of technology as a significant field of study mandated to meet the need for informed human action in a changing world.

A Changing World

We live in an interdependent, ever-changing world—a world of accelerating industrialization, rapid population growth, widespread malnutrition, increasing depletion of nonrenewable sources of energy, and a deteriorating environment. As the number, magnitude, and seriousness of the problems continue to increase, we have at the same time more scientists, economists, statisticians, political scientists, lawyers, and other experts and specialists than ever before. What seems to have taken place is an illusion of progress but no true progress in improving the potential for a long-term quality future for all people.

In earlier times our technical means were not as powerful and dependency on multiple subsystems was not as great. If systems were disturbed, they returned to equilibrium in a relatively short period of time and damage to human beings and the environment was limited. Not so with the technical systems of the 20th century. Eric Sevareid (Kidder, 1987) cited three problems he believes are new in history, each of which is related directly to the creation and use of technical means: "One is the leap into space. Another is the existence of ultimate weapons. And the third is the poisoning of the natural resources of life—the rivers, air, and food" (p. 6). Sevareid pointed out that he did not believe any of our real problems would be solved in outer space but rather in "inner space," within the inner person and on "terra firma."

Dependency on common sense and the folk knowledge of yesterday will not suffice in today's increasingly complex technological environment. Many years of disciplined and systematic study are required to understand the behavior of our technical systems and their impact on the human, social, and environmental realms. The context and reality are different and, thus, a different order of knowledge, know-how, and responsibility are needed.

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Kidder (1990) noted that the two major issues that will shape the next decade will be technology and ethics. He questioned where we will get the designers and engineers who are ethically sound enough and knowledgeable enough to be responsible for the technological enterprises of the future. These and other analyses have altered our thinking, changed our view of the world, and brought about a shift in our cultural paradigm.

A Shifting Paradigm

A new perspective and a new ethic have been evolving from an increasing awareness that the earth is not large enough, nor the resources plentiful enough, to tolerate a long-term escalation of our current anthropocentric and aggressive technological behavior. We have come to the realization that we inhabit a living planet that has limits to clean air, fossil fuels, potable water, waste absorbing capacity, and the resilience of its life-support ecosystems (Harman, 1977, p. 7).

The predominant world view in the West has been based on a technocratic, industrial-scientific paradigm that perceives nature as a mechanistic system that can be understood via its simple components and their external relations. The belief is that nature should be controlled for the benefit of humans and that only minor adjustments in technological systems are necessary to protect the earth's ecosystem from harm (Drengson, 1983, p. 63). When tested against the criteria of sustainability, this perception of the world seems to be lacking. The evidence is mounting of extensive, and at times irreversible, damage being done to the ecosystems that sustain and nourish life.

This reexamination of our thinking has created a shift from viewing life in instrumental ways to perceiving the intrinsic worth of all life. The challenge to educators, and to technology educators specifically, is to address the many implications this new perception has for the structure, content, and research direction of the discipline of technology.

A New Role for Knowledge

Our future and the future of succeeding generations will depend on human action based on knowing—knowing about the earth and the behavior of humans and the interrelation between natural systems and technological and social systems. Public policies and individual actions will require new levels of responsibility, a reevaluation of our ethics, and a reassessment of the nature, content, and structure of education.

The current ethic, which supports individual and collective violence against nature and humans, has brought about destructive consequences for life on earth. Jonas (1984) asserts, when "the realm of making [technological activities] invades the space of essential action, then morality must invade the realm of making, from which it has formerly stayed aloof, and must do so in the form of public policy" (p. 9). In Jonas's view, acquiring the knowledge required for intelligent human action becomes a duty beyond anything claimed for it heretofore.

Thus, the very act of creating technical means has brought about the necessity of reassessing what it means to be educated in the world today. Our technological activities have become the "infinite forward thrust of the race, its most significant enterprise, in whose permanent, self-transcending advance to ever greater things the vocation of [humankind] tends to be seen, and whose success of maximal control over things and [ourselves] appears as the consummation of [our] destiny" (Jonas, 1984, p. 9).

The new imperative calls for individual and collective understanding and control in the design, development, and use of the technical means of society in relation to the natural order of which humans are a part. This mandates a new form of literacy for citizens throughout the world, a technological literacy grounded in the context of ethical, individual, and collective responsibility.

A New Literacy

Technological literacy is a form of literacy never before provided by schools and formal education. *If* our choice is to live in a free democratic society where every individual becomes ultimately responsible for the proper functioning of the community and nation, *then* we all must be prepared for our critical roles as decision makers and contributors to the functioning of an increasingly complex world.

Two driving forces are behind the change in thinking about education in a democratic-technological society. One concerns the impact of technological illiteracy on the community or nation. The other relates to the shift in the cultural paradigm that emphasizes technological literacy as a part of basic literacy.

From a social perspective, technologically illiterate citizens affect a community and nation in many ways. Among the more critical are the following:

1. an increasing drain on the resources of a community by citizens unable to contribute in a meaningful and productive way in an increasingly technological world;
2. a loss of competitive economic potential by businesses and industries unable to obtain employees capable of functioning effectively in complex, ever-changing, technological environments;
3. a lessening of defense and disaster response potential during times of national emergency, due to a citizenry that lacks knowledge and know-how in the technologies; and
4. a growing number of citizens disenfranchised, both economically and politically, from participating effectively in the governance and management of their communities.

It is not possible to select, design, operate appropriately, or control technical means and systems without a thorough knowledge and understanding of the behavior of technological systems (*how* and *why* they work) and the relation of these systems to humans, their society, and the natural environment. The technological systems of the future will, in general, need to be more complex, not less, because of the requirement that they be compatible with the natural environment and the diverse bioregions of the earth. The systems will also be more complex and diverse in order to meet the goal of transitioning to a sustainable social-technological future.

Technological literacy has become a necessary and basic component in the education of all citizens. Such a literacy prepares citizens to be conversant in the language of technological systems and to comprehend the basic concepts required for understanding the dynamics, interrelatedness, and impacts of technical means at all levels of society and the natural environment.

Technological literacy not only prepares citizens for their responsibilities in managing their communities but also prepares them to function responsibly and effectively in the economic realm. It reconnects people to the technical systems from which they have become separated.

The Study of Technology

The nature and character of technical means have evolved over many centuries. The study of the creation and use of this reservoir of knowing and doing is the field of study called technology. Perceptions of the importance of technical means have changed as the means have changed. Perceptions about technology as a field of study have also changed. Viewpoints about technology range from technology as things or tools only to technology as a major component of the adaptive systems[1] of society. The word technology brings to mind mental constructs such as skill, artifacts, technique, engineering, a body of knowledge, a discipline, a systems of means, or an effect. Each of these viewpoints has contributed to a more complete understanding of the nature of technology as well as adding to the confusion.

Even standard definitions of technology tend to cloud the issue. The numerous dictionary definitions of the word technology include (a) the branch of knowledge that deals with the industrial arts, applied science, and engineering; (b) the science of the application of knowledge to practical purposes; and (c) the totality of the means employed by a people to provide the material objects of their culture (De Vore, 1980).

Others define technology from the perspective of their discipline. Economists define technology with reference to production; sociologists from the perspective of social relations and political structures; and engineers in terms of physical structures or technical systems. If there is an agreement, it is that the created technical means and adaptive systems are woven into the entire fabric of Western society and increasingly so in other societies as well.

The Science of Technology

The diverse and conflicting viewpoints about technology are of little help to those concerned with public policy, education, and technological literacy. The diverse viewpoints only increase the confusion and dissonance. With no common agreement on meaning, it is difficult to pursue intelligent public policy, develop valid curricula, or establish programs to attain desired levels of technological literacy.

Most unabridged dictionaries define the word science as a branch of knowledge or study dealing with a body of facts, truths, or concepts systematically determined, or as systematic knowledge of the physical, material, or natural world. There is general agreement that science means not one branch of knowledge but numerous branches such as psychology, anthropology, geology, and biology. Each of these branches of knowledge, including technology, shares a common factor—the systematic determination of facts, truths, knowledge, and understanding of the behavior of the systems being studied with the goal of being able to predict the behavior of the system (De Vore, 1988).

The intellectual endeavors involved in the choice, creation, and control of the technical means of today are of a different order from those of the craft or trade era of the past. The new modes of thinking have established the base for the new discipline and the new science. Those involved in the science of technology are concerned with investigating the processes of creating technical means and the evolution of technical means and society. They are concerned also with determining the behavior of tools, machines, and adaptive systems and the relation of these elements to humans, their societies, and the life-giving and life-sustaining environment.

Technologists base their work on information about the behavior of multiple variables and dynamic environments. Their goals are predictability, replication, reliability, optimization, the efficiency and conservation of system operations, and the compatibility of technical systems with the natural environment. Rules and systematically determined procedures are based on knowledge and understanding of the behavior of technical systems and their elements. Emphasis is on objectively determined, logical, orderly, and disciplined approaches (De Vore, 1988).

The development of the "knowing base" of the science of technology involves a number of intellectual processes including defining the problem, observing, analyzing, visualizing, modeling, computing, communicating, measuring, predicting, questioning and hypothesizing, interpreting data, constructing mathematical and physical prototypes, experimenting, testing, and designing and managing systems. These are the intellectual processes of the discipline.

Structure of the Discipline

The goals, scope, and structure of the science of technology have evolved over time. Like other disciplines, the science of technology has evolved into sub-disciplines and fields of investigation including micro and macro systems. The primary adaptive systems of human societies have been identified as those concerned with (a) the transformation of natural resources into useful products, (b) the movement of physical mass—materials, products, and people—by various technical means within the several natural environments and (c) the movement of information including the technical means of coding, transmitting, receiving, decoding, storing, and retrieving of information.

Transformation activities are classified as production systems and consist of extracting, growing, processing, manufacturing, and constructing. Those activities associated with the movement of physical mass are classified as transportation systems. Those technical activities associated with the movement and use of information are classified as communication and information systems.

These three adaptive systems exist in all human societies at some level of sophistication. These systems contain the fundamental elements that provide the technological base of any society. Within these systems are the universal technological endeavors essential to the human civilization process. These cultural universals provide the foundation for the derivation of the common learnings essential to understanding the behavior of our technological culture. Understanding the behavior of these systems is central to being culturally literate and capable of participating in a responsible way in a democratic, technological society.

In this context, the science of technology is the science whose practitioners are involved in the systematic study of the creation, evolution, utilization, and behavior of adaptive systems (tools, machines, materials, techniques, physical and biological processes, and technical means) and the behavior of these elements and systems in relation to humans, their societies, and the life-giving and life-sustaining environment. Thus, a technologist or student of technology might be involved in a number of activities including (a) creating technical devices, means, or systems utilizing specific technical means; (b) studying the behavior of various technical systems; and (c) identifying and correcting the impact of various technical means on humans, their society, and the natural environment.

One of the critical factors that affects the comprehension and understanding of human endeavors in the technological realm is that everything is related. No element or system stands alone. Each is a part of the whole and each contributes and interfaces with the total.

Therefore, curricula and programs of study in technology, designed for the purpose of attaining technological literacy, would contain the essential elements of the primary fields of endeavor noted above. Briefly, these essential elements would consist of, but not be limited to, the following categories of knowing and doing:

1. The history, evolution, nature, and development of technical means, including knowledge of the people, places, cultures, and environmental context in which the means were invented and developed;
2. Knowledge and understanding of the processes of invention and innovation, including experience in the processes;
3. Knowledge and understanding of the behavior of adaptive systems and subsystems, such as communication and information systems, production systems, and transportation systems, and the tools, machines, materials, techniques, and the biological and physical transformation and energy conversion processes associated with these systems; and
4. Knowledge and understanding of the behavior of various technical elements and adaptive systems and the assessment of the impact of these elements and systems in relation to humans, their societies, and the natural environment within agreed upon ethical contexts.

The above four categories form the primary core of knowing, doing, and understanding for programs in technology designed to contribute to the new literacy. These are the universals that form the foundation from which the common body of knowledge and cultural universals of technological literacy are derived.

Conclusion

The technical means and systems created by humans are deeply embedded in the social, economic, and cultural components of society. They have impacted greatly on the potential for human development, the nature and characteristics of societies throughout the earth, and the natural environment. Without significant changes in the selection, design, and control of technical means at all levels of human activity, the long-term prognosis for a quality human future is limited.

We have reached a critical juncture in the history of civilization, a juncture that requires a new order of knowledge and an understanding of the place of humans and their technical means in the total order of life. This new knowledge and understanding is a part of a new literacy, a technological literacy. The new literacy is grounded in an evolving paradigm that has as a central ethic the intrinsic worth of all life.

At no time in the history of education has the mission been so clear. At no time has there been such a noble and challenging opportunity for educators from many disciplines to come together in an integrated cooperative effort to contribute to their communities and the world as a whole. It is an opportunity for humans to reassert themselves as stewards of the earth. This can be done if we accept the challenge and prepare ourselves with the required knowledge.

Note

1. Major adaptive systems: production systems, including growing, processing, manufacturing, and constructing; communication and information systems; and transportation systems.

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Dennis W. Cheek

Evaluating Learning in STS Education

Our nation must have a citizenry that is prepared to understand and deal rationally with the issues and opportunities of a scientific and technological world. (National Science Teachers Association, 1990a)

American schools need to better prepare students to face the opportunities and challenges of the 21st century. Fundamental to preparation for life and living in the next century will be a tacit understanding of the nature of science and technology and their interaction with societal institutions, social mores, and people. Calls for increased scientific and/or technological literacy have come from all quarters of American policymaking, although there is widespread disagreement as to what, exactly, such literacy entails (Champagne, Lovitts, & Calinger, 1989). The stakes in educating students about science and technology have gone up and will continue to rise.

Elementary and secondary schools will bear the bulk of this increased educational responsibility. Syllabuses from a number of state educational agencies, which provide some guidance to local school districts about what they should teach, increasingly mention STS education (Cheek, 1989). Parallel to this increased focus on education about the complex interactions between science, technology, and society is a growing national movement to require schools to document progress toward national, state, and local educational goals. This raises complex issues of assessment and evaluation in regard to scientific and/or technological literacy.

The capacity of teachers and school districts to adequately assess STS education efforts in various subject areas and to defend the reliability and validity of such instruments will determine the health and future of STS education in the United States. This article outlines some general considerations and provides concrete examples from the United States and other nations of assessment measures regarding STS education.

Current Thinking About Assessment

In an era of declining fiscal resources, taxpayers increasingly want to know whether they are getting good value for their money in public and private education. Standardized testing as a quick and efficient means to get some measures that enable cross-group and cross-community comparisons has expanded into a multibillion dollar annual business. More than one community has found its economic expansion prospects deflated by comparative ranking of its school seniors' aggregate SAT scores with those of surrounding communities. Yet the mismatch between standardized testing and schooling is well known and amply demonstrated by an analysis of any standardized test versus local curriculum documents (Dowling, 1987). It

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would be improper to argue that there is no role for standardized testing, but results are usually politicized and publicized far beyond their legitimate function.

Standardized tests that include items focused on science have few, if any, items that try to assess student knowledge of STS issues, the nature of science, or aspects of science policy (Bybee, 1991). An exception to this statement is the National Assessment of Education Progress (NAEP), although even here, STS-related items have been sparse and are becoming fewer with each new NAEP (Bybee, 1991). It is a sad commentary on our present national assessment program that student understanding of technology is never assessed in any of the various content area tests, with the sole exception of computer-related technology. When we consider that technology is the warp and woof of American life, pervasive in its power and influence, this should be cause for alarm.

Recent years have witnessed a serious period of self-reflection within the psychometric community and a call for more "authentic" means of assessment (Educational Testing Service, 1986, 1988). This has been driven by a large number of factors, including general educator dissatisfaction with existing tests that measure discrete packets of information whose inherent worth is open to question—especially when unrelated to anything else. Multicultural and gender considerations have raised the issue of standardized test bias. Unsatisfactory responses from the psychometric community focus on psychometric definitions and applications rather than broader, underlying issues. More satisfactory responses have broadened the nature of test validity to encompass considerations of differential test consequences for various groups using chosen means and modalities (Cronbach, 1988; Messick, 1989).

Increasingly sophisticated statistical analysis techniques and computer programs have opened new possibilities for computer based assessment, including the use of microworlds (computer-based conceptual systems, viz. Papert, 1980) and on-screen simulations (Lockard, Abrams, & Many, 1990). Factors like these have led to a move toward NAEP items that involve paragraph answers (incorporated widely in the past 5 years of NAEP testing) and manipulative science activities followed by questions (currently in its first widespread NAEP usage).

Linking Goals, Curriculum, and Assessment

Despite changes occurring at the national level (Linn, 1991), assessment and evaluation will mainly be the province of the states, the local school district, the school building, and the individual classroom teacher. With 50 states and almost 16,000 public school districts (National Center for Education Statistics, 1990), there is wide latitude in current assessment and evaluation practices. STS education, with its focus on multidisciplinary perspectives and integrative education, poses some special problems for assessment and evaluation (e.g., American Chemical Society, 1988).

Existing state and district-level syllabi in STS education furnish useful guides for states, school districts, or individual teachers to plan, implement, and evaluate STS instruction. A close connection between syllabi (which set out expected student learning outcomes), curriculum materials (which build upon the syllabus and integrate innovative instructional strategies), and assessment instruments increases the likelihood that teachers and students will learn about the interaction between science, technology, and society.

The New York State Education Department, to cite one example, has been active in promoting STS education for secondary students for some time. A 1-year unified high school science course focused on STS is an optional syllabus available to school districts throughout the state (New York State, 1987d). A technology education syllabus for a mandated year of technology education at middle level within the state is replete with references to STS considerations (New York State, 1987c). Block J of the current middle level science syllabus for the state also focuses on STS and is designed to be woven throughout the entire 3 years of middle school science instruction (New York State, 1989d). Student understandings of concepts and principles within Block J are annually assessed as part of the Statewide Regents Competency Test in Science for ninth graders.

A new middle level science syllabus currently under development by the Bureau of Science Education will increase attention to STS education in New York State. The new syllabus will be released in conjunction with the availability of 12 supplementary STS modules under production with support from the National Science Foundation. Concepts and learning outcomes spelled out in the syllabus will, in turn, be reflected in the annual Regents Competency Test in Science that is administered to ninth graders throughout the state.

Mention should also be made of the fine syllabuses and sample examinations available outside the United States from nations that have a much longer tradition of attention to STS education in science and technology classes. The new syllabus for biology in Southern Australia lists examples of STS issues that relate to various aspects of the syllabus and specifically calls for assessment of "social implications and personal relevance" (Senior Secondary Assessment Board of South Australia, 1990). A student is expected to prepare a report for presentation at a group moderation meeting, responding to the following aspects of an STS issue:

- Why is this an issue?
- Who or what does the issue affect?
- How are they affected?
- What are the benefits of the issue?
- What are the costs of the issue?
- How can the phenomenon be managed? (p. 30)

Students are encouraged to "reflect a range of society's values and ideas" and are "expected to consult a variety of resources in producing their report" (Senior Secondary Assessment Board of South Australia, 1990, pp. 30, 31).

Various examining boards in the United Kingdom have developed a number of STS syllabuses over the years for O, A, and the newer GCE qualifications. Award of these various certificates is dependent upon performance on mandated examinations that assess student learning of content, principles, and concepts spelled out in syllabuses. Just a few examples will be mentioned here.

The Combined Sciences Certification for A level from the Joint Matriculation Board of the Northern Examining Association (1991), which covers Central England, incorporates syllabuses for both advanced environmental science and advanced science, technology, and society. The STS syllabuses aim for learner understandings in the following general areas: the nature of science; the nature of technology; the nature of social decision making related to science and technology; agriculture, technology and society; industry, technology, and society; and a series of six optional topics from which at least three must be offered by the examiner. Each syllabus calls for assessment that includes short answers, written essays, demonstration of practical skills, and some form of project. Points are weighted in favor of application, analysis, and evaluation rather than simply knowledge and comprehension.

General Considerations

The more varied measures that can be used to assess STS education, the greater likelihood that more useful information will be obtained. Limiting assessment to a set of pencil and paper, multiple-choice type items too narrowly constricts the scope of STS education and fails to capture valuable learning by students (Hein, 1990; Champagne, Lovitts, & Calinger, 1990; Rosen, 1989). Teachers and school districts can develop both formative and summative means of assessment for STS education.

Formative assessments would focus on student conceptions about science and technology and student beliefs about the manner in which these areas interact with society. Such assessments can be used to guide teacher planning for STS instruction and STS curriculum development projects (Cheek, in press). Summative assessments would be used to determine student understandings at the end of a course of STS study.

An overall district or building-level STS assessment plan should integrate the use of written reports, group and individual presentations, interviews of students and groups of students, technological design projects, student action plans and self-evaluations, observations of students in role plays and simulations, homework, student journals, standardized achievement tests, portfolios of student work, criterion-referenced tests, take-home tests, extended problem-solving projects such as field investigations, and performance tests (National Center for Improving Science Education, 1991; National Council for the Social Studies, 1990; Raizen et al., 1989).

General frameworks for such assessment instruments already exist in sufficient variety to make integrated assessments feasible (Wolf, Bixby, Glenn, & Gardner, 1991). We owe it to the present generation of students to not only educate them about STS education but also to ensure that they leave our schools with the adequate understandings we have attempted to foster. The remainder of this article gives a flavor of the different types of STS assessment techniques available to the STS educator. Existing items and instruments can serve as a useful guide to development of means and methods of STS assessment that are fine-tuned to local curriculum and instructional practices.

Assessment Via Multiple Choice Items

The most widely used and recognized form of assessment consists of batteries of multiple choice items. An example of a technology-related item from the Program Evaluation Test in Social Studies for sixth graders in New York State (1988) gives a sense of what types of STS multiple-choice items might be created by a state, school district, or school building. Presented with a drawing of three sequential photographs showing technological progression in the baking industry and a decreasing number of bakers making products, the student is asked:

Which idea is best illustrated in the drawing?

A. Changes in technology affect employment.
B. Industrialization results in higher costs of goods.
C. The use of machines requires a skilled labor force.
D. The growth of technology caused the beginning of labor unions. (New York State, 1987b, p. 13)

A sample item from a 1990 Regents Competency Test in Science for ninth graders throughout New York State shows how a similar item might look in a science area:

What does the paragraph in the box below show most clearly about the relationship between science and technology?

Engineers build a new type of spacecraft and land it on Mars. The spacecraft sends information about Mars back to Earth and scientists learn more about Mars.

1) Science and technology solve society's problems.
2) Science and technology give people more choices in their lives.
3) Science and technology create new jobs.
4) Science and technology help advance one another. (New York State, 1990; p. 25)

Open-Ended Assessment Items

Dissatisfaction with the constraints of multiple-choice items has led many examiners to prefer the use of open-ended assessment items. Use of this assessment technique trades loss of machine scoring and low processing costs for deeper insights into student understandings. An assessment item from the 1989 STS (advanced supplementary) examination from the Joint Matriculation Board in the United Kingdom begins with a reading from *New Scientist* about Ethiopia's soil-reclamation program. Students are tested on the following items with weighted point values totaling 15 points for this section of the examination:

(a) Name *two* natural features which may make soil erosion likely. (2 points)
(b) What is "food for work" aid? (2 points)
(c) Explain, in your own words, the two valid criticisms of this kind of aid programme which are mentioned in the article. (4 points)
(d) What does the writer mean by trees which can "fix" nitrogen? [not explained in the article] (2 points)
(e) Terrace building in Kenya during colonial times was responsible for much political resentment. Can you suggest any way in which this resentment might have been avoided? [no additional ways are mentioned in the article] (5 points) (Joint Matriculation Board, 1989, p. 3)

A second example is drawn from the 1987 specimen questions of the Joint Matriculation Board Examinations Council (1987b). The item begins with a paragraph that provides some basic information about acid rain and its relationship to crop diseases. Then a graph is presented on the incidence of various crop diseases as related to exposure to varied concentrations of sulphur dioxide gas. The student is asked the following questions with point allotments:

(a) (1) What general conclusions about the effects of sulphur dioxide on the health of plants can be drawn from the evidence above? (1 point)
(a) (2) Does this agree with popular belief about the effects of sulphur dioxide pollution on living organisms? (1 point)
(a) (3) Suggest a possible explanation for (1) and (2) above. (1 point)
(b) How does this example illustrate the purpose of experimental research in solving a technological problem in a social context? (2 points)
(c) Which type and range of data would you select in support of an argument that
    (1) sulphur dioxide is very harmful to plants; (1 point)
    (2) high concentrations of sulphur dioxide are beneficial to the health of plants. (1 point)

(d) It is planned to extend the research to examine the effects of acid rain on Scottish, Norwegian and Canadian species of conifer trees. Why is the origin of the trees important? (2 points)
(e) During the last 25 years sulphur dioxide levels in Britain have fallen but ozone levels have increased. Draw up an hypothesis that should be tested. (2 points)
(f) The research data above has been collected by the CEGB [Council on the Environment of Great Britain, a public advocacy group]. Does this make any difference to the quality of the work? Discuss. (4 points)
(Joint Matriculation Board Examinations Council, 1987b, pp. 3-4)

Other useful examples abound in the documents of the various regional examining boards in England, Scotland, Wales, and Northern Ireland (e.g., Joint Matriculation Board, 1983, 1984; London East Anglian Group, 1991a, 1991b; Northern Examining Association, 1989, 1990a, 1990b, 1991).

Essay Examinations

An even more labor-intensive assessment technique involves the use of a series of essay questions. Essays have a long tradition of use as appropriate examination items, especially in fields outside of the sciences. Even within the sciences, early Regents examinations in New York State in the 19th century consisted of nothing but essay questions (Cheek, 1991). A similarly long tradition exists within Commonwealth nations.

The critical issue is inter-rater reliability. A high degree of inter-rater reliability can be assured by using carefully crafted guides for marking examination essays. Students can sometimes be provided with the same criteria to assist them in crafting their answers or they can be provided copies of past exemplary and poor examination essays with marking criteria. This is common practice in areas such as English, the social studies, and course examinations in law school.

The 1989 Program Evaluation Test in the Social Studies for sixth graders in New York State contained the following examination item which focused on technology and society interactions:

People use technological developments to improve the quality of their lives. Technological developments might have both positive and negative effects on society. Some examples of these technological developments are:

- a dam
- a factory
- an airport
- an interstate highway
- a nuclear power plant
- a housing development

Write an essay of about 150 words explaining a positive and a negative effect that *three* of these technological developments *could* have on society. (New York State, 1989c, p. 1)

Students were provided with a chart in which to organize their notes before writing the essay in their test booklet. This included questions to guide formulation of their answers, although students were still responsible for framing their own answers in a coherent manner.

After studying a unit on communication, British students might encounter a series of short essay items such as the following:

(a) In the context of either the development of writing, *or* the spread of television in a developing country, write briefly about the advances in communication in terms of

(1) speed of communication,
(2) reliability of signal/noise ratio,
(3) storage of information,
(4) changes of life-style produced
(Joint Matriculation Board Examinations Council, 1987b, pp. 7-8)

Students are then presented with a comparative chart of major characteristics for agricultural, industrial, and information societies with information about a range of factors, including the importance of communication, use of time, level of urbanization, role of mass media, level of organization, population growth, importance of education, and the importance of research. They are then asked to "study the table above and choose *three* of the differences between the three types of society which seem important to you. Write briefly on each of the three giving examples which illustrate and explain these differences."

Performance Based Assessments

Too often, educators have relied on pencil and paper means to infer student understandings that involve the complex interactions between tacit manipulative knowledge and cognition. Recent years have witnessed a desire to transcend these limitations, by creating prescribed environments in which students must manipulate materials and then indicate their understandings. The State Education Assessment Center of the Council of Chief State School Officers has established an Interstate Consortium on Alternative Methods of Student Assessment (Council of Chief State School Officers, 1990b). They have recently conducted a number of surveys of state initiatives in alternative assessments that include performance based measures (Council of Chief State School Officers, 1990a, 1990c; Pelavin Associates, 1990).

New York State uses forms of performance assessment in their statewide program evaluation tests for Grade 4 in science and Grade 6 in social studies. These tests are administered annually to cohorts of over 200,000 students in Grades 4 and 6. The Elementary Science Program Evaluation Test (ESPET) consists of seven components: (a) an objective test, (b) a manipulative skills test, (c) a student science attitude survey, and (d) four science program environment surveys (New York State, 1989a, 1989b).

The Manipulative Skills Test evaluates the skills identified in the New York State Elementary Science Syllabus. Tasks, set up at a series of five different stations, evaluate a number of inquiry and communication skills (New York State, 1989b). Seven minutes per station are allotted for student completion. While the specific tasks may be new to students, they are modeled after similar tasks normally performed in the course of elementary science instruction.

A number of other states such as California, Connecticut, and Kentucky have implemented similar systems of statewide assessment or are developing them at the present time (Pelavin Associates, 1990). Additional ideas for performance-based examination items can be gleaned from the work of the Evaluation and Monitoring Unit of the School Examination & Assessment Council (1990) of Great Britain, which is responsible for developing and administering the National Curriculum and Assessment.

Performance based assessment can also be used in allocating scores for oral contributions in large and small groups during STS learning activities. The Joint Matriculation Board Examinations Council (1987a) suggests the following taxonomy to award marks for oral contributions to group work:

0-2 Makes occasional contributions.
3-5 Makes occasional significant contributions and usually listens carefully and responds to the points made by others.
6-8 Usually effective, occasionally shows the ability to analyse previous contributions and take the discussion forward.
9-10 Pertinent contributions made on a wide variety of issues in both large and small groups without overdominating, but able to lead a discussion when necessary. A good listener as well as a good talker. (p. 8)

Portfolios

Portfolios have been a part of many teachers' grading procedures for a number of years. Recent research in large scale assessment has been exploring the validity and reliability of such portfolios to document authentic student learnings in specific subject areas—including nontraditional areas for portfolio assessments such as science and social studies (Mitchell, 1992). The long history of requirements of 30 hours of satisfactory laboratory write-ups for Regents science courses is one example of a long-standing commitment to limited portfolio compilation in the sciences.[1]

The building of technological devices is one type of portfolio compilation that is particularly suited to STS education, and grading of such portfolios involves well-established procedures (New York State, 1987c; School Examination & Assessment Council, 1990). The use of reports to summarize work on projects and procedures to establish defensible grading criteria for such work are also well established, as nationwide science fairs annually demonstrate.

More problematic are projects that involve a variety of different media and that may include action components. The Joint Matriculation Board Examinations Council (1987a, pp. 2-4, 6) prefers that students report on their project using oral and written means and assigns points using a clearly framed set of procedures and guidelines. The Program Evaluation Test in Social Studies for sixth graders across New York State adopts an optional Participation Project approach that leaves resolution of scoring to local initiatives and planning (New York State, 1987d). These participation projects utilize procedures similar to science fairs with district-wide criteria being written and used to assign merit to projects.

Toward Integrated STS Assessment

School districts and STS educators need to utilize a range of assessments like those described above, coupled with additional instruments that provide insights on student understandings (both before and after instruction). At present there are no large scale ventures in using such a set of integrated assessment instruments and techniques, but clearly the potential exists (cf. Zoller, 1990).

The staff of the Science Education Center at The University of Iowa has been collecting and packaging a set of meaningful, validated instruments to assess science education in five domains: knowing and understanding, exploring and discovering, using and applying, imagining and creating, and feeling and valuing (Yager, Blunck, & Ajam, 1990). The center has used these instruments with good effect in conjunction with STS education efforts throughout Iowa through their STS Chautauqua program (Yager, 1990).

An "Actions Taken on Societal Issues" test has been developed by Weisenmayer and Rubba (1990) for use in middle grades. This instrument consists of 48 items that ask students things like: "How many times within the past *two* weeks have you . . . *reported* pollution/littering violations to proper authorities?" with students picking a response from a range between zero to 4+. The final segment of the instrument encourages students to supply additional actions they either took or did not take over the course of the past 2 weeks (Rubba, 1989).

The need to take seriously children's existing conceptions of STS, social institutions, politics, economics, and ethics and values, should not be overlooked in instruction or evaluation (Cheek, in press). Adolescent conceptions about STS education can be measured using the Views on Science, Technology, and Society (VOSTS) instrument created by Glen Aikenhead and associates at the University of Saskatchewan (cited in Bybee, 1991). A new version of a VOSTS-type instrument for middle level students has been developed by The Impact Group in Toronto for the Ontario Ministry of Education. The New York Science, Technology and Society Project at the New York State Education Department is currently conducting validation studies with New York middle level students.

Adolescent attitudes toward technology can be assessed using the Pupils' Attitudes toward Technology (PATT) instrument developed in the Netherlands (Raat & DeVries, 1986). The instrument has been adapted for use in a number of nations and biannual conferences allow researchers to discuss their findings and their implications (e.g., Raat, Coenen-Van den Bergh, DeKlerk Wolters, & DeVries, 1988; DeKlerk Wolters, Mottier, Raat, & DeVries, 1989).[2]

The STS Research Network of the International Organization for Science and Technology Education continues to explore ways in which understanding of student learning in STS can be evaluated.[3] The National Association for Science, Technology and Society is presently working on a policy document regarding STS assessment, while the National Science Teachers Association (1990a, 1990b) and the National Council for the Social Studies (1990) have already adopted position statements regarding STS education that include attention to issues of assessment. A further source of ongoing information about STS assessment is the International Network for Information in Science and Technology Education (INISTE) of UNESCO.[4]

Conclusion

Educating students about issues at the intersection of science, technology, and society is critical if students are to function effectively in the world of the 21st century. Teachers, administrators, students, parents, and the wider community all have a need to know whether students are indeed appropriately *learning* about STS interactions. Assessment tools for STS education and the generation of instruments under development that will supercede them already exist in sufficient variety and possess sufficient power to be widely implemented in K-12 education across the nation.

Notes

1. There is no written history that the author can locate for when this requirement was formally enacted. Oral history within the Bureau of Science Education of the State Education Department traces the existence of this requirement back to at least the early 20th century.
2. A version of PATT tailored for U.S. students is available from William Dugger of the Virginia Polytechnic Institute and State University.
3. Glen Aikenhead, professor of curriculum studies at the University of Saskatchewan, is secretary of the STS Research Network and editor of an occasional newsletter of the network.
4. U.S. contacts for the INISTE Network are Herbert Thier of the Lawrence Hall of Science, David Lock-

ard of The University of Maryland, and Dennis Cheek of the New York Science, Technology and Society Education Project at the New York State Education Department.

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Wanda T. May

What Are the Subjects of STS—*Really*?

Authors in the previous *Theory Into Practice* issue and this one raise questions and attempt to clarify the strengths and dilemmas of "STS"—an interdisciplinary approach to the study of science-technology-society in public schools and universities. Have they answered these questions *for* us? Can they? Should they?

However intuitively appealing and thoughtful these analyses of STS are, as educators we still are obligated to stew—individually and collaboratively—in the following questions in order to choose the best course(s) of action for ourselves in our particular educational settings: Other than science, technology, and social studies writ large, what are the subjects of study in STS? Why is STS being promoted, on what grounds, and by whom? What alternative views and arguments compete with this one and might be equally viable and persuasive? Who will benefit from STS study, and in what ways? How will we know that we/they benefit? What likely constraints should we acknowledge if we want to create, promote, and implement STS in this place where we work? And, what consequences can we anticipate if we pursue this course of action rather than another one?

The above questions are endemic to the theoretical, argumentative features of curriculum and the practical dimensions of engaging in thoughtful deliberation, building a platform, and developing a defensible local curriculum (Walker, 1990). These decisions and activities are no different from what STS asks teacher educators, teachers, and (ultimately) students to do. In the social sciences and practical professions, it is unlikely that a single theory or proposal—often constructed safely on the periphery of daily practice—can be universally applied to all settings and persons, no matter how logically persuasive the theory seems. Education is carried out in diverse contexts and circumstances among diverse teachers, learners, and their communities, with their own distinctive and collective histories. I include here universities as well as public school settings.

It is naive to claim that we lack a universal theory in education because we disagree on goals and definitions or are "immature" compared to science. Disagreement is the catalyst of all fields; it requires diverse interests, a shared understanding (agreement) about what we disagree on, dialogue, and critique, all of which maintain and transform fields. Secondly, identifying ourselves as immature implies that fields perceived to be mature have greater authority and power. Paradoxically, this sort of hero worship is immature because it is uncritical.

Finally, education has been around much longer than Newtonian physics, the scientific method, and our modern, western infatuation with science. Our appeal to science suggests that one day in education we may "get it right," once and for all. However, human history suggests that even in science, such faith or

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promise is myopic at best, and the pursuit of such a narrow interest quite often is misdirected, resulting in trivial pursuits and unethical consequences. Such is the case in education, too.

We need to remind ourselves that *we* construct science, institutions, STS, school curricula, explanations, arguments for change, policies, and practices with particular interests in mind. Neither science nor education are objects (like physical matter) or disinterested enterprises. That we are human and intentionally engage in these inventions and activities makes our motives, decisions, interpretations, and actions both "interested" and complex. We are unlikely to "get it right" once and for all, whether we "do" science, education, STS, or anything else. We can only do our best by choosing the least dangerous courses of action (Cherryholmes, 1988).

Rather than pursue certainty and tidy explanations in education, a more convincing but difficult agenda should be pursued: developing a deeper understanding and appreciation of ambiguity, complexity, relationships, and interactions, and our human capacity to envision, choose, and construct meaningful, equitable possibilities for our collective present and future. If STS were to state its primary educational goal, I think it would be this, and it matters little that the subject areas proposed are science, technology, and social studies.

Constructing such a world for ourselves requires a global, contextual, and critical interpretation of our past and present and an understanding of ourselves as active *subjects* of history—not objects. For if we perceived history as inert matters of the past and ourselves and our constructions as mere objects—dead flies caught in a web of givens—we would not know how to proceed as informed agents of the present and future. Deciding what we need to know and what is best for us to do, relationally and in all our diversity, is no disinterested, simple endeavor. Learning how to make such difficult decisions and determining which of the many ways we might gear into action as human agents are not easy for teacher educators, teachers, and students. We are more familiar with the secure, hard walls of institutional inertness than the risky, bouyant weaving of our own webs.

Acting Morally as the Subject of STS

Given the above discussion, it should be clear that the primary goals and interests of STS are essentially moral and political in nature. This may disturb those who believe they are "merely stating the facts." However, there is nothing simple, benevolent, or disinterested about STS, just as with any educational proposal. The most convincing arguments for STS rest on evidence drawn from critical analyses of our social and environmental contexts, human predicament, and the problems we have wrought for ourselves and other living things in our inescapable interdependence.

This evidence then is used to promote the study of complex issues and events, none of which can be located, studied, or resolved in single "academic disciplines" as they currently exist or as they are presented as school subjects. STS advocates use values clarification and other forms of deliberation, critical thinking, and problem-solving activities to help students locate and assess pertinent information, see important relationships, learn to make defensible decisions, consider the moral consequences of their decisions and ensuing actions, and better understand and appreciate what informed citizens of planet earth can do, individually and collectively.

In STS, *social studies* can hardly be construed as the unproblematic transmission of ethnocentric social values, patriotism, a parade of facts, and other grand narratives ordinarily understood as K-12 social studies. Particular values and issues are fostered in STS social studies, and these are critical in nature. Any curriculum that rests primarily on questions that have no fill-in-the-blank answers, particularly those located in the dynamic interface of science-technology-society, unravels weak seams and challenges politically conservative notions such as equal opportunity based on individualism, upward mobility, unlimited natural resources, and economic competition.

However, focusing on such complex issues either favors older students or subverts an antiquated K-12 curriculum model in social studies called "expanding horizons," which is based on fossilized assumptions about student development, their capacity to imagine and think critically, and the social sciences (Bruner, 1986; Levstik, 1989; Parker, 1991; Ravitch, 1987).

Primary-level students are hardly ignorant, disinterested, or incapable of understanding things beyond themselves. While the content of STS may better accommodate the more sophisticated awareness of children, most social studies educators have remained silent on their "expanding horizons" totem. Even authors of art and music textbooks have adopted this model uncritically in order to calibrate likely social studies topics at particular grade levels and to increase their marketability (May, Lantz, & Rohr, 1990). If I were a social studies educator, then, I would want to reexamine the defensibility of this model and where/if it fits in STS, not only to the benefit of my field but to those who mimic social studies uncritically.

My colleagues in *science* who have unshakable faith in their discipline as a purely apolitical haven probably are snorting with glee and relief by now at my interpretation of STS as a political proposal more akin to social education than to the other fields in the STS equation. If so, they missed the point. The fact that many scientists and science educators claim neutrality and appeal to "unbiased" explanations of how the world works illustrates the values they hold dear. All human constructions, such as science, government, art, or bridges, represent diverse discourses, truth claims, modes of inquiry, forms of representation, and practices that are inherently "interested," powerful ways of constituting and interpreting ourselves in our world (Eisner, 1985).

What STS does for science is situate its interests and activities in social context—again, a critical one. Few scientists would claim that their knowledge or work is complete, nor would they deny that their "discipline" has undergone an interesting evolution of displaced theories, reformulations, and imports (like all other disciplines). Some might even admit that science can be influenced by other disciplines and understood in new ways by borrowing from seemingly far-fetched interests (i.e.. literary criticism and poststructural critique; Fuller, 1989).

On the other hand, few scientists are likely to admit that their discipline, interests, and work are as ideological as the rest: Others misinterpret or abuse scientific discoveries and make moral choices—not scientists! However, when scientists make science, they create human possibilities, some of which have more negative consequences than others. STS, then, requires science educators to be as morally interested and responsible agents as the rest of us. They cannot see themselves only as the creators and keepers of "the light," but also must act as watchdogs of their own blind spots and warriors against the dark effects of light.

What the field of *technology education* contributes to STS is an analysis of our human imagination and its products, processes, contributions, and effects in professional fields, everyday life, and the world of work. STS requires technology educators to consider their field and work in critical, social, and historical context beyond the "quick fix." It requires "doing" in meaningful theoretical context with a critical understanding of one's own and other fields' interests, modes of inquiry, and knowledge claims. This requires as much interest in sociology, aesthetic ways of knowing, or what it means to be human as an interest in invention and how things can be made to work better.

Technology education is not just about altering our external environment and developing/using tools to our advantage as a means of survival or enhancement. Many animals do this. It is about what motivates us to do these things in the first place and the social consequences of our inventions. It is not about telling students that if they work hard enough, take the right courses, or learn how to operate computers, they are guaranteed equal access to secure jobs, high pay, and meaningful work. It is not about justifying technology to "keep up with a rapidly changing world" because our creation of technology created such changes in the first place. Technology in STS reminds us of our power to create and destroy, to humanize and dehumanize, in the name of progress and maintaining the social order. Neither progress nor the existing social order is presently equitable or humanizing for all persons.

Thus technology educators must be as concerned about who is *not* likely to benefit from their collective imagination as who will, and morally justify their public inclusions, alliances, and omissions. While technology educators may revere Dewey as an authoritative figure in their justifications, they must remember that Dewey (1902, 1916, 1929, 1938) did not separate the means-ends equation with an overemphasis on technical, prespecified objectives; extol hands-on experience for its own sake; or ignore the critical, dialogic, and public dimension of determining means and ends.

Disciplines and School Subjects as the Subjects of STS

As alluded to above, while STS educators acknowledge the complexity of their fields and the relationship of issues across disciplinary boundaries and school subjects, some paradoxically appeal to the preexistence of separate, objective bodies of knowledge (disciplines/fields) to promote their cause. This premise leads to several problems.

The Swamp

First, we tend to hold stereotypical misunderstandings of those disciplines beyond our own expertise. This lack of knowledge and uncritical stance is worrisome coming from a group advocating subject integration or interdisciplinary study. For example, several non-science STS authors claim that science is a value-neutral, disinterested, straightforward exercise in making discoveries, testing hypotheses, and generating law-like principles. School science and technology are perceived to have labs, whereas social education is seen to have none. This is because we believe that labs only involve manipulating objects and physical events, or matching boring inert facts to fun hands-on activities, or creating cause-effect exercises that have correct answers—all external to the manipulation of ideas and beliefs. Social studies is viewed as a dynamic place where contemporary issues and historical events are encountered and debated critically, when this is hardly typical practice in schools (Goodlad, 1984; Stodolsky, 1988).

Thus, requests for interdisciplinary study are based on misconceptions of what constitutes a discipline in the first place, its boundaries, and modus operandi. Given the diverse interests within any so-called discipline and the fact that disciplinary constructions occur temporally in sociopolitical, institutional contexts, these are more alike and mutually productive/reproductive than not. This suggests that we may never have an accurate picture or handle on what constitutes a discipline—our own or anyone else's. Some STS educators seem to have a low tolerance for ambiguity, confusion, and multiple emergent goals concerning STS; this may stem from the misguided belief that all experts within their given fields agree on who they are and what they are about.

Finally, many of us may assume that school subjects are miniature replications of university disciplines, repeating the faulty assumption above. However, K-12 school subjects are different constructions than those found in universities. School subjects have long histories only loosely tied to disciplinary knowledge. They are more strongly related to popular social movements and public values about what counts as legitimate knowledge, and for whom. The formation and maintenance of school subjects accommodates multiple, socially reproductive goals and interests (i.e., primarily for White middle class); their creation and maintenance are quite dissimilar from knowledge creation/production in universities, but similar in their accessibility (Cohen, 1985; Goodson, 1985; Kliebard, 1986; Popkewitz, 1987).

In their presentation, school subjects are selective, superficial versions of the many narratives we have created and claim to be disciplines or fields in academe. Thus, a direct correspondence between "the disciplines" and school subjects is illusory. The meanings of subjects are mediated and dispersed through the cultural metaphors, language, material artifacts, and strategies we use in their presentation in university and school classrooms, popular culture, mass media, and other social institutions. In sum, whether we speak of disciplines or school subjects, we are speaking of arbitrary, amorphous, and temporal human constructions.

Turf

Why have science, technology, and society been selected as the subjects of interest in STS and not, for example, the arts, humanities, or some other legitimate interests? We need to question why particular STS issues have been selected in lieu of others, indicating what is/is not valued or to be acted upon, when, and by/for whom. We ought to think about who was privileged to generate and determine those issues that others are now being urged to study. These questions were raised eloquently by Carter (1991) in the previous issue. Are teachers and students incapable of generating worthwhile issues of local relevance? Must these issues be prepackaged and handed down to them?

Why does science head the STS equation rather than one of the other two subjects, particularly when the STS agenda is more visibly sociopolitical in character? In the creation of such semantic equations, the first term usually is valued more than the other(s) (Derrida, 1972/

1981). This preference represents a more subtle but perverse phenomenon: competition for scarce resources and power (Rouse, 1987). Skirmishes between fields over turf, position, and power to obtain limited resources and to secure staffing, students, and programs are common in both academe and public schools.

In the university pecking order, for example, a school of education is one of the least valued and ill-supported fields among its contenders (whether academic or professional), and there are historical, political, and economic reasons for how institutions constitute power (Foucault, 1980). Obviously, even in public schools, more persons might respond positively to science's clarion call than to technology or social studies. Historically, these areas are considered to be weak and unimportant subjects in the greater "academic" scheme of things.

However, during an economic recession and in politically conservative times, something like STS can be tolerated and loosely supported—at least as a rhetorical idea—because it suggests that STS addresses several perceived national and educational crises (Herron, 1988; Wexler, 1987). The technology and cooperative learning components of STS would appeal to business leaders and politicians who complain that we are preparing a poor workforce. Those who claim that we have lost our competitive edge in the world market—particularly when competition is perceived to rely on knowledge in science, mathematics, and technology—would consider STS a wise use of fiscal resources for addressing problems of employability and national welfare.

School managers would like the potential efficiency of an interdisciplinary STS curriculum because it requires no additional resources in staffing, funding, or time; demonstrates a "lean" approach to an already crowded school curriculum (if STS is not introduced as a separate K-12 program of studies); and is more apt to attract external funding from the private/business sector in yet another fertile moment called "business-education partnerships." The latter is attractive because of STS's rhetorical attachment to technology (computers in classrooms), "cooperation" (something promoted by management for softening adversarial management-labor relations), and "critical thinking" (on-the-job troubleshooting and problem solving).

I point out these narrow interpretations of STS to encourage STS educators to be more critically self-reflexive and to see how they have/have not positioned themselves politically in their own workplaces, disciplines, professional organizations, and communities. There are finite resources, serious constraints, and Darwinian-like struggles over the survival of the fittest goals, subjects, and political agenda in the name of education. Even if STS were sincerely conceived as a promising means toward humane ends, STS must resituate its interests reflexively, contextually, and historically by critically reexamining how it argues its cause beyond fluff and rhetoric in the realities of the ideological marketplace.

Curricular Reform as the Subject of STS

Most STS proponents seem to approach curriculum reform naively, modestly, and cautiously. That is, the school curriculum is seen to be an inanimate structural system of interchangeable parts with a few empty spaces available for the installation of additional parts: a little STS here, a little STS there. Few STS educators argue for a radical restructuring of the entire K-12 curriculum to accommodate sustained, integrated study of science, technology, and society. Why is this? Most STS proponents are not only savvy about the ideological marketplace described above but also are realistic about existing school structures and constraints that seem impervious to change. Such a radical overhaul is tempting because we know that if any significant change is to occur in practice, much more than tinkering, tune-ups, and mandates will be required (Cuban, 1984; Lortie, 1975; Sarason, 1990; Schaffarzick & Sykes, 1979). However, stymied by the odds, we choose the line of least resistance: tinkering.

Some of the obvious constraints to curriculum and pedagogical reform are: public values concerning what knowledge is of most worth; the bifurcation of academic and vernacular/public knowledge; fear of controversy and censorship; the fragmentation of knowledge into arbitrary disciplines, isolated school subjects, and time slots; the press for content coverage; hyperspecialized preparation of secondary-level teachers and superficial subject-matter preparation of elementary teachers; shallow conceptions of K-12 curriculum in various subjects in terms of their important "big ideas" and interesting ways these could be related and spiraled vertically; and poor horizontal articulation across subjects within grade levels resulting in recreational occasions rather than meaningful learning.

Policies influence funding and resources, scheduling, tracking and sorting students, staffing, the uncritical adoption/use of commercial curriculum materials, ubiquitous inservice, and testing and accountability in their many oppressive forms. For example, in today's climate of accountability, if "technology" is not on an achievement test, it is not apt to be taught. If teachers are evaluated by their students' performance on standardized tests and must demonstrate Hunter's methods of teaching, then multiple responses to a complex issue that cannot easily be tested or scored, and instruction modeling inquiry, socratic dialogue, inductive methods, cooperative learning, and open-ended outcomes are not likely to be viewed favorably nor adopted by teachers (Cuban, 1984). Without significant changes in the calcified structural features of schools in conservative times and sustained collaborative work with teachers in their schools, our "reforms" are but slick ideas against the grain.

Teachers as the Subjects of STS

Astute STS educators know that teachers are not likely to be the key linchpins of change because they are not in full control of the above constraints nor in any secure position to alter them. While we would like to believe that teachers are autonomous in their decisions and practice and can—often do—act as change agents, we can only expect so much of them, given the political context of schools and the built-in uncertainty and complexity of their work (Lortie, 1975). Unlike making Ford motors, teachers never know with any certainty what impact they have on all their students, even though teaching youngsters has its immediate, psychic rewards.

Those who view teachers as "set in their ways" and resistant to change need to reexamine their own resistance. Like it or not, we are collectively responsible for the cumulative effects of what teachers think about and do as a result of their formal education (K-12 and university) and their work experiences, roles, and contexts (Beyer, Feinberg, Pagano, & Whitson, 1989). To be fair, we need to reconsider reform from the teachers' perspective, the culture of teaching and the contexts in which they learn and work, and research on teachers' beliefs, knowledge, and concerns situated in actual practice. STS educators are seriously remiss and insular in their proposals and complaints if they are unfamiliar with the professional literature, which is easily accessible (Houston, 1990; Wittrock, 1986). Research in subject-specific education can be linked to research in professional education for more powerful analyses of current proposals and persistent problems (May, 1989).

Calls for reform in practice are numerous and most often originate externally to teachers, their particular schools, their students, and their work. Nevertheless, we believe our requests are reasonable and require only minor changes/modifications in beliefs and practice—if only teachers would demonstrate a little interest and willingness to try something "new." We forget that in today's hypercritical climate of public school- and teacher-bashing, there are multiple requests of teachers, tugging at them simultaneously and from all directions. Many of these requests are not worthwhile, and several are downright oppressive and miseducative. We do nothing to change the constraints and contexts in which teachers learn and work. What teachers find interesting and worthwhile in this clutter of demands and dilemmas, and what they choose to invest their energy in, are pragmatic choices (Berlak & Berlak, 1981). Unfortunately, the constraints, character, and organizational structure of the work environment often make teachers engage in a kind of "vulgar pragmatism" that values functional efficiency (Cherryholmes, 1988). This uncritical pragmatism is premised on "unreflective acceptance of explicit and implicit standards, conventions, rules, and discourses-practices" that we find all around us (p. 151).

Our concerns about implementation, logistics, and teachers' fidelity to the particular ways we have envisioned change are *not* the central concerns of teachers. Requests for fidelity deskill and decenter teachers from conceptualizing their own goals and work, learning from their own practice, and refining their own theories of practice (Apple, 1986; Bolin & Falk, 1987; Lieberman, 1988). We risk objectifying teachers in the same way we conceive of curriculum as a system of interchangeable parts. Teachers are viewed as bad parts, their beliefs and attitudes in need of radical "restructuring," and their practice in need of quality control. Viewed this way, teachers become obstacles to manipulate or overcome if we only want to successfully implement the changes *we* envision, without admitting that *our* vision and practices also should be altered in the process.

If we are not interested in altering or refining our *own* vision and practice, we are not genuinely interested in learning. Too often, we also engage in "vulgar pragmatism." The irony here is to think about what constitutes professional activities and improvement. Surely, university educators, researchers, curriculum developers, and inservice leaders also are expected to learn from their practice because this practice is inextricably bound to the promises, problems, and practices of public schools. Practical professions such as ours rely on the interplay of grounded theory and critical praxis. Theories are meaningless unless they are derived from intimate knowledge of practice and its complex features. Routinized practice—without the love of conflicting ideas and complex puzzles or a concern for social equity and moral consequences—is not praxis (Carr & Kemmis, 1986; Dewey, 1929).

In sum, learning the subjects we teach and the artful and moral dimensions of pedagogy is not an applied science. Educating is a lifelong endeavor of learning or situated inquiry, regardless of our professional roles and locations. Our challenge is to develop our own and others' expertise and dispositions toward inquiry that respect and celebrate diverse questions of personal and professional interest. Thus, curriculum reform or development is—first and foremost—professional development, and as professionals we can hardly exclude ourselves from this endeavor. Rorty (1989) reminds us that we need to work more toward inclusion and solidarity by staying on the lookout for marginalized people, "people whom we still instinctively think of as 'they' rather than 'us.' We should try to notice our similarities with them" (p. 196) and create a more expansive sense of solidarity than we presently have.

Students as the Missing Subjects of STS

For the most part, students are not the central subjects and beneficiaries of STS—at least in terms of their "here and now"; diversity by gender, social class, ethnicity, and culture; likely interests; and powerlessness as youths to undo adult wrongs. Topics and issues in STS tend to decenter students from their lived world in the name of rational decision making and civic rights and responsibilities as adults. With its agenda to develop informed adult citizens and its presentation of weighty issues, STS hurls students into the distant future and far reaches of the world beyond their immediate problems, interests, and experiences.

Even where some curricular and pedagogical examples are grounded in students' intuitive knowledge, interests, and experiences, proposed topics and activities often mask the potential for fun, pleasure, community or solidarity, and the creative construction of objects, ideas, and action. Most STS authors avoid any discussion of the powerful, creative dimensions of their subject areas and activities perhaps because it is unpopular in today's political climate to suggest that learning should be fun, engaging, accessible, and applicable to real life and what humans enjoy thinking about and doing. I appeal as much to a serious review of Dewey's (1938) theory of experience as to more recent discussions of human intelligence, imagination, and learning that may help STS educators overcome omitting this important dimension in their proposals (Bruner, 1986; Bruner & Haste, 1987; Egan, 1986; Egan & Nadaner, 1988; Gardner, 1983).

In Vandenberg's (1990) proposal for general education as a human right, the arts, crafts, trades, and sports/dance ("the ACTS") are no less superior or important than the academic disciplines. He argues his position on phenomenological grounds, or a bodily basis of "being in the world." Drawing on the work of Berger, Berger, and Kellner (1981), Vandenberg's point is that the ACTS prevent overdistancing students from the world and their having a "homeless mind":

> The regions that should be explored to become home in the world . . . include the tactile, manipulable world; the play world; nature; society; the lived world; and the worlds of book and numbers. . . . The child's exploration of the things in the manipulable and play worlds is chronologically and phenomenologically prior to any conceptualized exploration of things in the natural or social worlds. (p. 201)

The ACTS (presented K-12) tether being and learning in the play world, natural world, social world, and lived world. One doesn't *have* a body: one *is* a body, and a *somebody* at that, as Merleau-Ponty (1945/1962) pointed out. Our body is not only "our general medium for having a world" (p. 146), it is "our anchorage in a world" (p. 144). According to Vandenberg (1990), the ACTS connect us viscerally to our world and what we think/make of it. He argues that knowledge in the curriculum is phenomenologically relevant "when it is related to the students' perceptual world and their search for truth" (p. 235). He continues:

> Students who are attracted by the perceived qualities in the lived world, in society, in nature, or in one or more of the ACTS, should be allowed to realize value where they can and orient their search for being to the regions of the world in which they find themselves most at home. (p. 235)

What seems most ironic about STS is its attempt to foster cooperative strategies, activities, and decision making in competitive, oppressive school climates over which students and their teachers have little control. How STS can acknowledge large sociopolitical issues and ignore those directly related to schooling remains a mystery to me. There is a dual message here that subverts any serious claim regarding students' power and rights as responsible citizens and members of a lived community.

A true test of our understanding and commitment to STS would be instigating fundamental changes that enhance the opportunities and lives of all children in our classrooms, schools, and communities through active participation in problem definition, creative construction, decision making, agenda setting, and "doing" in the present. (Interestingly, parents seem to be omitted in the STS discourse of participation, education, and change.) Anything less than this, in my opinion, is merely "doing school" with insignificant benefit to students and their/our future.

STS activities risk being artificial exercises if they are not well-designed, sustained, and penetrating. Vicarious, occasional academic study of *others'* hypothetical problems, actions, and consequences hardly represents students' examining their own lived experience, what they cherish, what they are willing to negotiate and why, what they are committed to change, what they have the power to change, and how they can act together and learn from their experience. Group decision making and action should always be required in an STS curriculum, and this should not be an esoteric exercise stripped of its emotional, creative, and imaginative portent and context. Action should not always *follow* some formulaic analytical trip through an issue as a mere application or extension (Dewey, 1938).

Despite all of our educational efforts to raise public awareness and to change public policy, we continue to live in a culture of mass consumption, corporate takeovers, and poverty, of which youth are as much consumers and victims as adults. Learning in school about the importance of saving trees while living in urban decay are separate realities. Learning about organic farming while one's family farm is being repossessed is another contradiction. Learning about why people go to war while playing Nintendo games or watching professional wrestling on TV are separate realities. Somehow, youngsters' faith in themselves, in their present and future, and their positive regard for others must be nurtured inside this incredible mess we have created for them. While stuck helplessly in our mess, we are asking them to work their way out of it and clean it up. We ask them to do this by doing school or STS, but not by critiquing school or by engaging in the kind of community and activities that might diminish the bifurcation of learning in school and in life.

STS educators need to think more seriously about their conceptions of civic and moral education and students' moral development and reasoning by reviewing current literature that more visibly and strongly supports STS's implicit values and goals (Bowers, 1987; Bowers & Flinders, 1990; Gilligan, Ward, & Taylor, 1988; Martin, 1981; Pratte, 1988; Purpel, 1989; Vandenberg, 1990). This literature may help STS educators revise their proposals and research in significant ways. Since STS pivots so significantly around developing moral responsibility and an ethic of care, more scholarly attention needs to be devoted to this area in reframing STS values, curricula, and pedagogy. STS educators then will better understand how they may be promoting and perpetuating (unwittingly) the very values and practices they reject—or that got us into this mess we are now collectively in.

For example, a major problem in many STS proposals is an emphasis on "rational" decision making, developing logical arguments, and relying on formal modes of discourse (written essays) as proof of learning or "critical thinking," particularly at the secondary level. This practice reflects a masculine, scientific, modern, western view. Such thinking not only is valued over other legitimate forms of understanding and being in the world, but it is assumed that this approach will ensure social progress or change. However, this strategy decenters and distances students, as Vandenberg (1990) reminds us:

> The immediate, familiar worlds of manipulation and play are overlooked by the methods of the natural sciences that distance themselves from the object of inquiry to obtain the proper objectivity and intersubjective validity of their knowledge. (pp. 212-213)

Vandenberg speaks not only of learning science here, but modernist, scientific ideology and methods artificially imposed on any subject or activity of interest.

STS educators might critically examine Brady's (1989) conception of selecting, organizing, and integrating the curriculum. This proposal integrates areas such as patterns of action, cultural premises, environment, and demographics around a hub called "systemic relationships." While the proposal is conceptually interesting and intellectually appealing because it presents "bigger ideas" and principles than are evident in most written curricula (lofty goals and limp, disjointed, unimaginative objectives), it still risks construing knowledge as received rather than reflexive. STS's contribution to such a proposal could be to find ways to embody such a framework with STS topics while making students central in the active, reflexive construction of knowledge.

Summary

Bowers and Flinders (1990) remind us of the thin line we walk as educators because we are as much a part of our culturally embedded, *modernist* pattern of thinking as are our students:

> The most basic assumptions of the dominant culture—how we understand ourselves as individuals, the nature of the rational process, what constitutes success, the uses of technology, the value of work, the way we resolve the tension between science and moral values, and so forth—provide the conceptual and moral framework upon which materialistic and technologically driven cultural practices are based. (p. 247)

Berger et al. (1981) note that our modern minds are homeless because vast, historically profound changes have secularized us and the world. We have technologized production, bureaucratized government, mass educated, had great social and geographic mobility, and developed a private sphere of life (pp. 94-95). Our modern consciousness is functionally rationalized and adapted to a mobile, migratory existence. "Lacking substantive rationality, the individual person is intellectually homeless," constructing a private life and do-it-yourself universe in order to create a home (Vandenberg, 1990, p. 200).

But, we live in *postmodern* times. A postmodern approach to STS would promote an ecological, moral, cultural, pluralistic, and spiritual perspective, an "ethic of caring," and a critical pragmatism based on contingencies that make our decisions and tasks all the more complex but necessary if we are to create a better world for ourselves. Rorty (1989) suggests a difference between a modern and postmodern view: The characteristic mark of modernity is that a large number of people are able to *separate* the question "Do you believe and desire what we believe and desire?" from the question "Are you suffering? . . . This is the ability to distinguish the question of whether you and I share the same final vocabulary from the question of whether you are in pain" (p. 198). Dancing around vocabularies, making such distinctions, and trying to be more human are quite different agendas. One (modern) keeps us safely at bay in discourse; the other (postmodern) requires our caring in the first place and our thoughtful response to and relation with others.

It will be extremely difficult for science, technology, and social studies educators—of all people—*not* to perpetuate a modern, western worldview in postmodern global times. In our traditional separations and interests, we have been guilty of rationalizing and simplifying the most intriguing and complex human endeavors and problems. This is why reflection and critical dialogue are so important. Working with each other across arbitrary subject boundaries and special interests is an excellent way to make our assumptions more visible and problematic—to ourselves and others.

STS educators are to be commended for taking a courageous first step in the right direction, however tenuous the step and uncharted the direction. Our not knowing exactly where all this may lead should not deter us from trying to do our best. Our best is choosing the least dangerous and cruel of alternatives in an earnest attempt to educate ourselves and others about how to make a home in our world. In conclusion, we are the subjects of STS.

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