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ABSTRACT

Designed to help educators address science-related social issues, this publication considers: (1) major challenges associated with science-related social issues; (2) the extent to which these challenges are being met; (3) ways in which educators can improve the education of citizens in science, technology, and social issues; and (4) promising practices that can contribute to building connections between social studies and science curricula. Three challenges outlined in the first of five sections include: (1) informing citizens about complex social issues and decisions, (2) connecting diverse fields of knowledge in school curricula, and (3) resisting antagonists of science and technology. In order to determine the extent to which these challenges are currently being met, the second section examines: goal statements in curriculum reports and major reports in the social studies and the sciences; research findings on student knowledge and attitudes regarding science, technology, and society; and analyses of current curricula and textbooks. The third section describes ways in which "integrative threads" can be used to provide common learning experiences within and between distinct courses in the social studies and sciences. The fourth section presents promising practices that can contribute to this building of connections between social studies and science curricula; the use of "decision trees" and case studies, the use of role play and simulation, and the use of instructional television and microcomputers. Concluding observations in the final section and a bibliography listing over 170 publications conclude the document. (LH)

CONNECTING SCIENCE, TECHNOLOGY, AND SOCIETY IN THE EDUCATION OF CITIZENS

by

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CONTENTS

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FOREWORD

The improvement of communication and integration among diverse sectors of the educational community has been the major objective of the Social Science Education Consortium since it was formed in 1963. At least some small contribution has been made to the working relationships among academicians in different disciplines and between schools and universities.

As new needs for integration among different disciplines arise, SSEC tries to meet those needs. Such a need now is the imperative of informing teachers and students about the increasingly important connections between the natural and social sciences with respect to managing the social consequences of our increasingly complex technologies.

In this publication John J. Patrick and Richard C. Remy make a significant contribution to educators who need help addressing the issues and the ways in which the issues can be approached. They analyze the need for better-informed citizens on issues that involve science and society, review the status of students' knowledge and of educational materials related to those issues, and suggest ways in which the serious shortcomings that exist can be reduced.

Patrick and Remy are eminently qualified for the task they undertook in researching and writing this book. Patrick has an outstanding record as a teacher at the high school and university levels, as an educational consultant, and as the writer of many articles and books in the areas of citizenship and history. Remy is also highly qualified, as a teacher of political science, educational consultant, and author of numerous publications on citizenship and government. Their expertise has been combined in a publication that many educators will find interesting and useful.

Irving Morrissett
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1. CHALLENGES OF EDUCATION FOR CITIZENSHIP IN AN AGE OF SCIENCE AND TECHNOLOGY

Education for good citizenship has been a prime goal of schooling in Western civilization from Plato's Republic to Toqueville's Democracy in America and beyond. In this report we consider new challenges for citizenship education being posed by modern science and technology; we examine the extent to which these challenges are being met by existing and proposed curricula; and we discuss possible strategies for building connections between and within social studies and science curricula.

Development of competence for self-government has become enormously complicated in modern times due to the dynamic social effects of science and technology. Citizenship educators today face at least three new kinds of challenges, which are associated with the pervasive influences of science and technology in modern American society. These are:

(1) the challenge of informing citizens about complex social issues and decisions related to advances in science and technology,

(2) the challenge of connecting in the school curriculum diverse fields of knowledge relevant to understanding decisions about complex social issues,

(3) the challenge of resisting antagonists of science and technology in our society, who threaten the integrity and success of scientific and technological endeavors.

Our ability to meet these challenges in the general education of citizens may determine whether the American ideal of popular participation in government is practicable in our era.

Informing Citizens About Complex Social Issues and Decisions

From classical Greece to contemporary America, civic education in free societies has stressed the rights and responsibilities of self-government. In Plato's Republic, however, only an enlightened elite had the liberty and duty to participate in decisions about public policy. A contrasting ideal of popular participation in civic affairs was advocated by Thomas Jefferson in the early years of the American Republic. "Every government degenerates when trusted to the rulers of the people alone," said Jefferson. "The people themselves, therefore, are its only safe depositories. And to render even them safe, their minds must be improved."[1]

Jefferson had faith in the power of schooling to educate citizens to think for themselves about issues, policies, and officials in government. From Jefferson to Horace Mann to John Dewey, Americans have believed that schools can prepare masses of people to exercise rights and responsibilities of citizenship. In Democracy and Education (1916), Dewey argued forcefully that popular participation in government through universal suffrage must be connected to universal public education. If not, the results would be, at best, a caricature of democracy.[2]

American society, however, has changed a great deal since Dewey's time. The public policy agendas of the 1970s and 1980s have been filled with issues generated by advances in science and technology, which range in complexity from the health hazards of fumes emitted by internal combustion engines to depletion of the ozone layers. Consider the various types of complex science/technology/society issues that face citizens today as exemplified by this brief list: experimentation with recombinant DNA, *in vitro* fertilization, control of nuclear weapons, disposal of industrial wastes, euthanasia, limits to industrial development, and the sources and uses of energy--especially nuclear power.

Social issues related to advances in science and technology involve knowledge and ethics; both factual judgments and value judgments are part of decisions made in response to these issues. Thus, knowledge produced through scientific inquiry is necessary, but not sufficient to the resolution of complex issues of public policy.

Decisions about science/technology/society issues often require "trade-offs" between conflicting values in which there is no clear view of right or wrong. Many environmental issues, for instance, force citizens to choose either clean air and water or production and jobs. Most people agree that pollution by factories is bad; they also tend to agree that unemployment and a big drop in factory output are bad. At times, the problem has been to decide how to limit pollution enough to protect health and environment while still maintaining production and jobs. Making a decision in a conflict between economic and ecological values requires careful consideration of alternative factual and ethical claims. The eventual choice may result from a compromise between conflicting positions about values.

A political trend of the 1970s and 1980s has been a proliferation of initiatives and referendums about issues related to science and technology. In the 1980s propositions have appeared on ballots in more than 20 states and 100 cities, as citizens have voted on returnable bottles and disposable cans, nuclear freeze resolutions, preservation of wilderness areas, restrictions on urban development, and the use of nuclear energy.

By 1982, more than 40 million Americans had cast votes for or against the use of nuclear energy, which became the most controversial question to appear on the ballot in local and state elections.[3] The interaction of knowledge and values in this type of decision is shown by disagreements among scientific experts.[4] The National Academy of Science, for example, held a meeting of 61 experts on energy to discuss the pros and cons of nuclear power. Their inability to agree led these scientists to this conclusion: "The public will have to choose between energy sources based on individual values and beliefs about social ethics--not on the advice from technical experts."[5]

The trend to confront voters with science/technology/society issues, such as the use of nuclear energy, is both gratifying and alarming. It is gratifying for people affected by decisions to have a significant part in their resolution. At the same time, it is alarming to contemplate the lack of information and skill that the majority of citizens are likely to bring to these decisions.

According to one nuclear physicist, "The human race has never had such bountiful technological benefits as today. But there has also never been a time when the technological risks were greater. It is impossible to weigh benefits against risks without knowledge, and in a democratic society, that means knowledge for everyone, not just the experts."[6]

The challenge of acquiring and using this knowledge is critical to effective participation in government. As James Madison emphasized long ago: "Knowledge will forever govern ignorance: And a people who mean to be their own Governors must arm themselves with the power which knowledge gives."[7] However, the challenge of becoming an informed citizen in a highly technological society may be overwhelming to most Americans. Many experts doubt the possibilities of improving the scientific and technological sophistication of the majority of citizens. Dr. Bowen R. Leonard, a nuclear physicist, says that "it is hopeless to educate the public on atomic energy, considering that the public is so uneducated in other subjects."[8] Dr. Leonard's viewpoint is a challenge to citizenship educators to sustain the Jeffersonian ideal of self-government in our modern society.

Consequences of public ignorance in a society with democratic ideals are discussed by Professor D. Allan Bromley of the physics department at Yale. He fears that in our modern democracy, "where the questions of consequence increasingly have scientific and technological aspects, if our public cannot at least appreciate the nature of the issues, quite apart from contributing to their resolution, they inevitably will tend to become alienated from the society. This is a trend that no nation can long endure."[9] Can development of this trend be blocked through citizenship education?

James Botkin, an expert on technology in society, notes the potentially negative consequences of ignorance in legislative decision making. He estimates that "half of all bills before Congress have a strong technological component, but only 2 out of 535 congressmen [in 1982] have engineering training. I'd hate to give a quiz to the other 533 congressmen and ask them what a semi-conductor is."[10]

The democratic tradition of majority rule is threatened by massive ignorance of significant public issues related to science and technology. Political scientist Jon Miller, in a thorough analysis of existing survey data on the topic, concludes that only 7 percent of the American public could be classified as scientifically literate.[11] Ignorant constituents are unable to offer intelligent advice to their representatives in government, and uninformed public officials are unable to represent their constituents wisely. Widespread ignorance of constituents and representatives could make both groups dependent upon a few experts, who would wield disproportionate power that could undermine democratic traditions.

The challenge this situation poses to citizenship educators is how to disseminate widely among the American people knowledge and information that is needed for intelligent participation by the majority in decisions about social issues related to science and technology. Failure to meet this challenge of informing the majority of citizens about complex social issues and decisions certainly will compromise severely, if not defeat, fulfillment of Jefferson's ideal of the people as the "only safe depositories" of their government. Can this challenge of informing the public be met through the general education of citizens? If so, how?

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Connecting Diverse Fields of Knowledge

The academic chasms that separate different fields of knowledge have been obstacles to public enlightenment about issues rooted in science and technology. A generation ago, C.P. Snow coined a phrase--"the two cultures" --to describe the gap between scientific and humanistic communities.

Snow and others recognized how the sciences and humanities have evolved into distinct ways of seeing the world and of communicating about it. The sciences are present and future oriented; the humanities are concerned with the classic, and where we have been. The language of science is technical, descriptive, precise; the language of poetry is in complete contrast, with its use of the figurative and metaphorical. Science has no sacred truths, every idea is subject to challenge; the arts have traditionally perpetuated society's myths, religions, and dominant social faith. Scientists ask limited questions and usually proceed through a series of experimental procedures and systematic exclusions toward precise proofs and laws; humanists often ask general questions and rely on methods that are allusive and interrogative. Scientists excel at precisely defining standards of error; humanists have developed a more general and qualitative concept of criticism.

Lord Snow emphasized the severe risks inherent in continued separation of his "two cultures." He said: "It is dangerous to have two cultures which can't or won't communicate. In a time when science is determining much of our destiny, that is whether we live or die, it is dangerous in the most practical terms. Scientists can give bad advice and decision makers can't know whether it is good or bad."[12]

Margaret Mead concurred with Snow: "We are becoming acutely aware that we need to build a culture . . . within which interrelated ideas and assumptions are sufficiently widely shared so that specialists can talk with specialists in other fields, specialists can talk with laymen, laymen can ask questions of specialists, and the least educated can participate, at the level of political choice, in decisions made necessary by scientific or philosophical processes which are new, complex, and abstruse."[13] Participation "at the level of political choice" requires scientific knowledge to understand alternatives and consequences. It also involves insights about values, derived from the humanities, to guide appraisal of the alternatives and consequences, and to justify one choice as better or worse than another one. Unfortunately, citizens are often unable to apply distinct and complementary fields of knowledge, the sciences and humanities, to decisions about complex social issues related to science and technology. Thus, they fail to cope with the "two cultures" challenge.

Problems and possibilities of connecting the "two cultures" in debates about public issues are shown by the publication and subsequent criticism of a best-selling book, The Fate of the Earth by Jonathan Schell, a popular writer and nonscientist.[14] Schell presented an alarming account of the disastrous effects of nuclear war, which was celebrated widely in popular magazines and newspapers. Schell's assumptions about technology in society are critical to his conclusion that nuclear war between the super-powers would destroy all humankind. However, Freeman Dyson, a professor of physics at Princeton University, charged that Schell's technological assumptions are untenable. Dyson agreed only with Schell's intentions, which he found laudable, if naive.

In his new book, Weapons and Hope, Professor Dyson wrote, "I fully share Schell's moral indignation and I believe his major thesis is valid independently of the technical details."[15] Dyson continued: "To the extent that our collective society is endangered by nuclear war, Schell's nightmares have a basis of reality."[16] However, Dyson claimed that Schell's ignorance of science and technology flawed his conclusion about the destiny of humanity.

Christopher Lehmann-Haupt, a book reviewer for the New York Times, discussed implications of Dyson's critique. "If Professor Dyson is right," wrote Lehmann-Haupt, "then The Fate of the Earth is really no more than an expression of emotion, and, as Professor Dyson reminds us in Weapons and Hope, emotion is not a useful tool in the dialogue between those who oppose and those who favor the deployment of nuclear weapons."[17]

The challenge to effective participation by the majority of citizens in public debates about complex science/technology/ society issues, signified by Lord Snow's "two cultures" metaphor, is exemplified by the initial public acceptance of Schell's book, Dyson's subsequent criticism of it, and Lehmann-Haupt's reaction to the controversy. Most citizens, including intelligent nonexperts (such as eminent book reviewers of the New York Times) are unable to make independent judgments about the technical validity of books like The Fate of the Earth. Thus, the majority of citizens rely on the motivation and ability of concerned experts, such as Freeman Dyson, to communicate clearly to them the terms of social issues related to science and technology. According to Lehmann-Haupt, Professor Dyson "is one of those rare creatures who really is bridging the gap between Lord Snow's two cultures."[18]

How can more and more scientists be educated to "bridge the gap" between diverse fields of knowledge relevant to public decisions about science/technology/society issues? How can the majority of citizens be educated to participate aptly in public dialogues with scientists and technologists and other laypersons? Success in meeting this challenge is likely to determine whether democratic ideals about citizen participation in government will survive into the 21st century.

Educators today generally acknowledge the importance of trying to bridge Snow's "two cultures." Furthermore, they have noted other connections that need to be made in the general education of citizens. Several scientists, humanists, and civic educators have argued that citizens need to understand better the distinctions and connections between the process of science and the processes of technology in order to comprehend the effects of these different but related enterprises.[19] Lack of public understanding of the distinct nature of science and of technology may explain partially the difficulties in public discourse that impede resolution of certain public issues and policies.

Science is a process of inquiry that yields knowledge about physical, natural, or social phenomena. It is a way of knowing and a producer of knowledge. By contrast, technology is a process for using knowledge to alter the world to satisfy human needs or desires. Science is the pursuit of principles and theories that explain and predict phenomena. By contrast, technology is the search for means to use scientific formulations to devise implements for the control of nature. It is common to view technology only in terms of machines or other physical tools, but knowledge used to modify the world may also be exemplified by the organization of people and materials. Thus, technology can refer to more than the systematic use of people, materials, and machinery in a factory.

Differences in means and ends have led some observers to perceive "opposite cultures of science and technology."[20] Others have emphasized the "snyergistic" or "symbiotic" relationships of the distinct and complementary processes and products of science and technology.[21] Kneller notes that contemporary science is "regarded as the partner of technology and, in this respect, as a utilitarian as well as a contemplative enterprise."[22] In a similar vein, Hurd recognizes that contemporary technology "refers to a system that combines science and technological innovations and social arrangements in ways that give people greater control over nature and human affairs and the direction of our society."[23]

While the differences of science and technology are important, the interrelationships of these two endeavors must also be recognized in the general education of citizens. The main reason is that the application of science to society through technology is the source of significant social change and controversy.

The challenge of connecting diverse fields of knowledge, the sciences and the humanities, thus includes the need to understand the connections between science and technology, and their applications within human societies. Meeting this challenge involves perception of the complementary aspects of distinct endeavors. Citizens need to know how science, technology, and the humanities can be used in combination to understand and make decisions about pressing social issues.

The significance of this challenge for the perpetuation of democratic ideals and practices was stated perceptively by a Nobel laureate, Herman J. Muller, on the occasion of the award he received for excellence in genetic inquiry. In words reminiscent of Jefferson, Muller explained the need to educate citizens "in all the fundamentals of modern knowledge.... This implies a more effective, more informed, and more direct participation than exists in most places, on the part of what are now the fourth and fifth estates, in the making of decisions affecting themselves and the community. For human nature has never proved altruistic enough to allow the interests of one group to be successfully entrusted to another one."[24]

Resisting Antagonists of Science and Technology

Perhaps the most fundamental challenge to education for responsible citizenship is posed by antagonists of modern science and technology. They undermine scientific values and attitudes through espousal of anti-scientific or pseudo-scientific beliefs. How serious is this challenge?

Novelist James Michener fears that an "anti-science epidemic" threatens the American public in the form of "an anti-science vote" in public elections.[25]

Philosopher Paul Kurtz notes "the tenacious endurance of irrational beliefs throughout history down to the present day--and in spite of the scientific revolution." Kurtz asks: "Should we assume that the scientific revolution, which began in the sixteenth century, is continuous? Or will it be overwhelmed by the forces of unreason."[26]

Scientist V.V. Raman laments that "science as an intellectual enterprise has had little impact on the way people in general look at things. It is a sad but not surprising spectacle when . . . school systems are urged to teach mythologies in science courses, because many parents and teachers are convinced that ancient views on the origins of life or of the planet have the same validity as any modern scientific theory."[27]

S.E. Luria, winner in 1969 of the Nobel Prize in medicine for his inquiries in molecular biology claims: "The failure to understand science leads to such things as the push to give creationism the same standing as the theory of evolution."[28]

"Scientific-creationism" provides an informative case study of the educational turmoil that can result from a lack of understanding of the basic nature of the scientific enterprise. Since the 1960s "scientific creationists" have been advocating "equal time" in schools to compare their view of human and planetary origins with the standard conceptions of the scientific community. The argument for "equal time" has been expressed concisely by Wendell R. Bird, a lawyer who supports the inclusion of creationism views in the curriculum. "Whatever his or her personal viewpoint is, a fairminded individual will want public schools to teach both the scientific evidence for evolution and the scientific evidence for creation. Academic freedom demands giving students a choice. Government neutrality requires presenting both sides."[29]

The majority of citizens seem to agree with Bird's view of fairness and freedom of choice, regardless of their beliefs in the "evolution-creationism" debate. A recent public opinion poll indicated that 76 percent of Americans favored the teaching of both viewpoints.[30]

Leading scientists have disagreed vehemently, with the "equal time" argument. They view the "theory of scientific creationism" as pseudoscience and therefore not comparable with scientific theories of evolution.

William V. Mayer, former director of the Biological Sciences Curriculum Study, is one of many science educators who argue that to teach "creationism" as science is educational malpractice. "As evolution is moot on religion, the equal time argument is specious," says Mayer. "As creationism involves the intercalation of supernatural explanations into science, it is epistemologically unsound and scientifically invalid."[31]

The legal issue in evolution versus creationism was settled, at least for now, by Federal Judge William Overton in a U.S. District Court. Overton decided in 1982 against an Arkansas law (called Act 590) that required public schools that teach the "theories of evolution science" to also teach the "theories of creation science." The judge based his decision on evidence that the Arkansas law violated the First and Fourteenth Amendments to the U.S. Constitution. His 38-page opinion was hailed by major science educators as a lucid exposition on creationism as a pseudo-science.

Judge Overton wrote:

> The two model approach of the creationists is simply a contrived dualism which has no scientific factual basis or legitimate educational purpose. . . .
>
> Creation science . . . is not science because it depends upon a supernatural intervention which is not guided by natural law. It is not explanatory by reference to natural law, is not testable and is not falsifiable. . . .
>
> The methodology employed by creationists is another example which is indicative that their work is not science. A scientific theory must be tentative and always subject to revision or abandonment in light of facts that are inconsistent with, or falsify, the theory. A theory that is by its own terms dogmatic, absolutist and never subject to revision is not a scientific theory. . . .
>
> While anybody is free to approach a scientific inquiry in any fashion they choose, they cannot properly describe the methodology used as scientific, if they start with a conclusion and refuse to change it regardless of the evidence developed during the course of the investigation. . . .
>
> In any event, if Act 590 is implemented, many teachers will be required to teach material in support of creation science which they do not consider academically sound. Many teachers will simply forego teaching subjects which might trigger the "balanced treatment" aspects of Act 590 even though they think the subjects are important in a proper presentation of a course.
>
> Implementation of Act 590 will have serious and untoward consequences for students, particularly those planning to attend college. Evolution is the cornerstone of modern biology, and many

courses in public schools contain subject matter relating to such varied topics as the age of the earth, geology and relationships among living things. Any student who is deprived of instruction as to the prevailing scientific thought on these topics will be denied a significant part of science education. . . .[32]

Judge Overton, and others, claim that the "scientific creationism" movement could subvert the science curriculum in schools.[33] There is evidence to support this claim: Professor Gerald Skoog analyzed the content of high school biology textbooks in use from 1973 to 1983 and found a significant decrease in coverage of evolution. Skoog compared six leading biology textbooks published between 1973-1976 with revised editions published between 1980-1983. The treatment of evolution was substantially changed in four of the six books; the decrease in coverage of evolution ranged from 17 percent to 79 percent. The coverage of evolution was unchanged only in two books--both were developed by the Biological Sciences Curriculum Study with support from the National Science Foundation. Neither "evolution" nor "Darwin" are listed in the index of any of the current high school biology textbooks.[34]

Decline in textbook coverage of evolution is traced to guidelines for textbook adoption in large states, such as Texas. An "anti-evolution" guideline was added to the Texas Administrative Code in 1974 This rule states that textbooks treating the theory of evolution "shall identify it as only one of several explanations of the origins of humankind and avoid limiting young people in their search for meaning of their human existence." The rule also requires that discussions of evolution be written in a manner "not detrimental to the other theories of origin."[35]

Publishers have been influenced by this textbook adoption rule, because Texas alone accounts for about 10 percent of all biology textbook sales. However, countervailing pressures have been introduced recently. In New York City, educators rejected for use in schools biology textbooks that fail to cover evolution substantially and validly.[36] Even more significant, the Texas State Board of Education repealed its "anti-evolution" rule in April of 1984. This action responded to a ruling by the Texas Attorney General, Jim Mattox, that the 1974 regulation was unconstitutional. In words similar to those of Judge Overton in the Arkansas case, Attorney General Mattox concluded that the evolution rule violated the First and Fourteenth Amendments to the U.S. Constitution. This rule, said Mattox "can be explained only as a response to pressure from creationists."[37]

The National Academy of Science and many prominent science educators have led the opposition to "equal time" for creationism in the science curriculum. In science, they argue, every idea or hypothesis is not considered to be equally worthy and thereby deserving of "equal time" in the classroom. Science (unlike politics) is not an exercise in balancing opposing viewpoints to maintain harmony among clashing groups. In science, there can be no political compromise in the search to know how the world really works. According to the scientific community, theories are included in the curriculum of schools because they satisfy standards having to do with investigation and validation, which define science as a scholarly endeavor. Thus, science is conceived as a system of inquiry about reality that transcends particular social or cultural boundaries. The findings of science are equally valid or practicable for any ethnic, national, or religious group choosing to use them. If creationist ideas have a place in the curriculum of schools, it is in the humanities or social studies, not in science (unless as an example of pseudo-science). One might appropriately study religious doctrines about human origins in a history or sociology course. Likewise one might study religious writings on this and other subjects in a literature course.

Despite recent legal setbacks, and renewed opposition to their ideas by the scientific community, creationists seem ready and willing to continue their challenge to science education in schools. Furthermore, their efforts will be abetted, if unwittingly and inadvertently, by various antagonists of science and technology. For example, there has been extensive anxiety, even fear, of science and technology in the American society which leads to "anti-science" responses. In a recent nation-wide public opinion poll, 65 percent of the respondents said that scientists should be restrained from doing certain types of research viewed as involving too many public risks or dangers.[38] The city council of Cambridge, Massachusetts acted on these fears when, by democratic vote, regulations were passed that limited for more than a year any research on recombinant DNA at Harvard. Professor D. Allan Bromley, a scientist at Yale, commented on the confounding of political and scientific decision making in this instance: "There is substantial question as to whether any member of that council had any real idea of what the vote implied or that the vote might well delay a possible cure for cancer much more probably than unleash any danger on the citizens of Cambridge."[39]

The public has held ambivalent attitudes about the social effects of science and technology; there is a paradoxical blend of dread and anticipation, of fear and hope. Public enthusiasm and respect for the authority of science and the fruits of technology are countered by fears and mistrusts.[40] Dorothy Nelkin, a political scientist who has studied public controversies associated with science and technology, crisply describes those mixed feelings of citizens about advances in science and technology.

> . . . belief in technological progress has been tempered by awareness of its ironies. Technological 'improvements' may cause disastrous environmental problems: Drugs to stimulate growth of beef cattle may cause cancer; 'efficient' industrial processes may threaten worker health; biomedical research may be detrimental to human subjects; and a new airport may turn a neighborhood into a sonic garbage dump. Even efforts to control technology may impose inequities, as new standards and regulations pit quality of life against economic growth and the expectation of progress and prosperity.[41]

Citizens may choose to emphasize their fears instead of their hopes in science and technology when they participate as voters in referendums and initiatives, as members of political interest groups, or as public officials. Jon Miller's analysis of recent national survey data found, for example, that 40 percent of individuals classified as "non-attentive" to science, "agreed that future scientific research is more likely to cause more problems than find solutions to current problems: an extremely pessimestic view."[42] This situation is disturbing because heightened political activity by citizens could be a force for the crippling rather than the enhancement of scientific and technological work. It also can be a boon or a detriment to public well-being. Thus all citizens, scientist and layperson alike, have a big stake in improvement of the quality of public participation in decisions related to science and technology.

The hope is that increased knowledge and understanding of science and technology are likely to improve the quality of citizens' participation in policy decisions. This prospect leads to a proposition with implications for education: Citizens who know the basic concepts of science and technology, and their centrality in the American heritage, are much less inclined to hold beliefs or attitudes, such as "scientific creationism," which are hostile to scientific and technological endeavors. An educational implication of this proposition is the need to emphasize in the general education of citizens the concepts of science and technology as symbiotic enterprises, their origins and development in Western civilization (and particularly in American history), their functions in contemporary American life, their power and limitations in solving problems, and the benefits and risks associated with their applications to society.

<u>Summary</u>

Education for good citizenship, a primary goal of American schools, has become extremely complicated in modern times due to the pervasive, powerful effects of science and technology in society. Educators today face three major challenges in preparing citizens to exercise their rights and responsibilities of self-government.

The first challenge is informing citizens about complex social issues related to advances in science and technology. Decisons about these issues involve knowledge and ethics, and often require "trade-offs" between conflicting values in which there is no clear view of right or wrong. Public ignorance of these issues, and how to make decisions about them, threatens the democratic tradition of majority rule. To meet this threat, all citizens, not merely an enlightened elite, need to learn knowledge and skills required for competent participation in decisions about science/technology/ society issues.

A second major challenge of citizenship education today is to connect distinct fields of knowledge in the school curriculum in order to maximize citizen understanding of the social effects of science and technology. Citizens need to "bridge the gap" between diverse fields of knowledge, such as the sciences and humanities in order to cope more effectively with decisions about complex social issues. Furthermore, they need to understand the symbiotic relationship of science and technology in order to understand the social context and effects of these distinct and complementary enterprises. Citizens need to synthesize knowledge from the sciences, humanities, and technology to cope with decisions about many current public issues.

Antagonists of science and technology pose a third, and most critical, challenge to education for good citizenship in our democracy. These antagonists attempt to subvert science education in schools and threaten to limit or overturn projects in science or technology that contradict conventional wisdom. The political pressure of "scientific creationists" to modify the school curriculum in behalf of their doctrine is a prime example of this insidious challenge to the science education of citizens. Thus, it is also a threat to enlightened public participation in decisions about social issues related to science and technology. To meet this challenge, educators must communicate broadly and effectively to citizens a valid conception of science and technology as human endeavors, a sense of science and technology as integral to their heritage in Western civilization, and a realistic vision of the social promises and perils of science and technology in contemporary American life.

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2. THE STATUS OF SCIENCE, TECHNOLOGY, AND SOCIETY IN THE EDUCATION OF CITIZENS

Dynamic social effects of science and technology have posed critical challenges to citizenship educators. To what extent are these challenges being met? One indicator of a response by educators can be found in the goal statements in curriculum reform reports, curriculum guides, and professional association proclamations. What do current statements of educational goals reveal about emphases on science, technology, and society in the education of citizens?

Another indicator of how well educators are meeting new challenges is provided by assessments of learners. To what extent are students learning knowledge and attitudes conducive to competent participation in decisions about social issues related to science and technology? To what extent is the performance of students congruent with the goals of educators?

A third indicator of the quality of education in science, technology, and society is provided by assessments of textbooks and other curriculum materials. What needs or problems relative to challenges and goals of citizenship education are indicated by various assessments of science and social studies curricula in schools?

New Goals of Citizenship Education in an Age of Science and Technology

Curriculum reformers have been recommending new goals about the social effects of science and technology in citizenship education. These new goals can be found in general curriculum reform reports and curriculum documents and reports of educators in the social studies and sciences.

Goals in General Curriculum Reform Reports. Publication of A Nation At Risk, in April of 1983, sparked a new period of concern for educational reform in the United States.[1] More than a dozen major curriculum reports have followed the highly publicized report to Secretary of Education Terrel H. Bell on the quality of education in American schools.

A common recommendation of these reports is the need to improve dramatically education for effective citizenship in our complex modern democracy. As discussed previously this involves knowledge and interest about the effects of science and technology on our way of life. The National Commission on Excellence in Education, for example, recommends this content for high school courses in science:

> The teaching of science in high school should provide graduates with an introduction to: (a) the concepts, laws, and processes of the physical and biological sciences; (b) the methods of scientific inquiry and reasoning; (c) the application of scientific knowledge to everyday life; and (d) the social and environmental implications of scientific and technological development. Science courses must be revised and updated for both the college-bound and those not intending to go to college. An example of such work is the American Chemical Society's "Chemistry in the Community" program.[2]

Notice the emphasis on science as a way of knowing and thinking, on the uses and effects of science and technology on society, and on education about science/technology/society for everyone, not just those headed for college.

The National Commission's recommendations for the social studies curriculum are complementary to those in science:

> The teaching of social studies in high school should be designed to (a) enable students to fix their places and possibilities within social and cultural structures; (b) understand the broad sweep of both ancient and contemporary ideas that have shaped our world and (c) understand the fundamentals of how our economic system works and how our political system functions; and (d) grasp the difference between free and repressive societies. An understanding of each of these areas is requisite to the informed and committed exercise of citizenship in our free society.[3]

An emphasis on the "the broad sweep of both ancient and contemporary ideas that have shaped our world" implies a central position for lessons about science and technology as fundamental forces in the development of Western civilization and the American nation. An emphasis on "how our economic system works" requires teaching about the productive uses of human and natural resources through application of modern science and technology to solution of economic problems. An emphasis on "how our political system works" involves treatment in the classroom of means and ends associated with decisions about social issues rooted in science and technology.

The Carnegie Foundation's report on secondary education in America, by Ernest L. Boyer, elaborates upon many goals and concerns discussed briefly in A Nation At Risk[4]. In science, Boyer's goal is to foster "scientific literacy" which, he claims, is a prerequisite to "becoming a responsible citizen in the last decade of the twentieth century. . . ." In social studies, he would have all students learn about their common heritage, which includes extraordinary and extensive achievement in science and technology from the 16th century in Europe to the 19th and 20th centuries in the United

States. Furthermore, he would require a course in technology to bridge the gap between science and social studies in the curriculum. Boyer writes: "We recommend that all students study technology: the history of man's use of tools, how science and technology have been joined, and the ethical issues technology has raised. It is increasingly important for all students to explore the critical role technology has played throughout history and develop the capacity to make responsible judgments about its use."[5]

Boyer and other contemporary curriculum reformers stress the importance of connecting diverse learning experiences in school within an extensive and coherent "core curriculum"--the learning experience required of all students that would constitute at least two-thirds of secondary school coursework. According to Boyer, in the Carnegie Report, "The basic curriculum should be a study of those consequential ideas, experiences and traditions common to all of us by virtue of our membership in the human family at a particular moment in history. The core curriculum must extend beyond the specialities and focus on more transcendent issues, moving from courses to coherence."[6]

Thus, Boyer and others argue that knowledge of connections between science, technology, and society is a basic part of the general education of citizens because these relationships are among the most important "ideas, experience and traditions common to all of us." Furthermore, public controversies generated by advances in science and technology are certainly "transcendent issues" of the modern world. Therefore, the connections of science, technology, and society should be a substantial part of the "core curriculum" and a primary goal in the general education of citizens.[7]

Reports in Social Studies and the Sciences. There are educators in the social studies and sciences who might disagree about the value of a "core curriculum" or about the best means to organize and present lessons on science, technology, and society to students. However, educators in both areas agree that citizens need to know and care about public issues and policies associated with scientific and technological activities. And there seems to be growing agreement among educators in social studies and in science on the need to improve the curriculum, in one way or another, to include this critical aspect of citizenship education.

In 1978, The National Council for the Social Studies (NCSS) published a curriculum bulletin that criticized "conventional curriculum patterns that isolate the study of science from the study of society."[8] In 1983, the NCSS issued "Guidelines for Teaching Science-Related Social Issues."[9] These guidelines are designed to help teachers choose appropriate topics for inclusion in the social studies curriculum. In addition, the guidelines emphasize development of various cognitive skills in the organization and interpretation of information. In particular, the guidelines call upon teachers to "provide opportunities for students to use various valuing, decision models. . . ."[10]

Educators in the humanities--a field that includes such staples of the social studies as history and moral philosophy--have made an especially strong case for goals that interrelate the humanities, social science, science, and technology. The Commission on the Humanities has stated this major goal of general education in schools: "Courses in the humanities [including history] should probe connections between the humanities and other fields of knowledge. For example, humanistic questions are inherent in--and should foster an awareness of--the moral dimensions of science and technology."[11]

Science educators have also been proclaiming goals that pertain to the science/technology/society theme. As long ago as 1959, President Eisenhower's Science Advisory Committee issued a report, Education for an Age of Science, which stated the following main task of schools: "To understand that the advances of science and technology need special attention to the end that (a) all citizens of modern society acquire reasonable understanding of these subjects and that (b) those with special talents in these fields have full opportunity to develop such talents."[12]

More than 25 years after the "Eisenhower Committee" report, science educators are proclaiming similar goals with renewed vigor and urgency. One difference is a much greater emphasis on education in science and technology for citizenship. Thus, the National Science Board Commission, in a major report on education, proclaimed these goals (along with the more traditional outcomes) for grades 7-8:

--Recognition of societal issues related to science and technology.

--Growth in problem-solving and decision-making abilities.

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--A beginning understanding of the integration of natural science, social science, and mathematics.[13]

Goals for the high school biology course, which is a standard item in the curriculum of most American students, included these statements:

--Understanding of biologically based personal or social problems and issues such as health, nutrition, environmental management, and human adaptation.

--Ability to resolve problems and issues in a biosocial context involving value or ethical considerations.[14]

Finally, the National Science Board Commission recommended: "Appropriate instruction in technology should be integrated into the curriculum for grades K-12." They posited three major goals in this domain of the curriculum, which are to equip students:

--To use technology to improve the quality of many personal and professional technology-based decisions.

--To participate intelligently as informed citizens in the transition from an industrialized society to a post-industrialized service and information age.

--To be more active in shaping public policy, which often involves the use of sophisticated technology.[15]

Goals and concerns similar to those of the National Science Board Commission can be found in several other timely and cogent curriculum documents. The Biological Sciences Curriculum Study, for example, made a report on science in middle schools and junior high schools, which called upon teachers to seek outcomes related to (1) the social effects of science and technology, (2) decision making about science-and-society-related issues, (3) values and ethics in scientific and technological activities, (4) science as a process for producing knowledge, and (5) the powers and limitations of science to solve problems.[16]

The National Science Teachers Association (NSTA) has gone so far as to urge that the primary emphasis in school science today should be the science/technology/society connection. In 1982, a NSTA curriculum report boldly stated:

> The goal of science education during the 1980's is to develop scientifically literate individuals who understand how science, technology, and society influence one another and who are able to use this knowledge in their everyday decision-making. The scienti-

fically literate person has a substantial knowledge base of facts, concepts, conceptual networks, and process skills which enable the individual to continue to learn and think logically. This individual both appreciates the value of science and technology in society and understands their limitations.[17]

The most insightful statement of purposes in education about science, technology, and society is made by Paul DeHart Hurd in a recent occasional paper of the Council for Basic Education.[18] Unlike most current curriculum reformers in science, Hurd perceives the common concerns and complementary goals of the social studies and sciences in the education of citizens.[19] He recognizes that the social studies and sciences can be connected in the school curriculum through common emphases on decision making about public issues and certain content themes about science and technology in history and contemporary society.[20] Hurd sees content in technology as a strong connection between courses in science, social studies, and the humanities. He claims: "Technology has a greater capacity to integrate subjects in the total school curriculum than does science by itself."[21]

A final insight of Hurd is this acknowledgement: "People in the social sciences and humanities must share in choosing the knowledge in science that has social and cultural importance."[22] Shared responsibility for a common image of citizenship education is a means to maximize chances for successful curriculum reforms.

Various curriculum reform reports indicate strong support for goals that address major challenges in citizenship education, which are associated with the dynamic, pervasive effects of science and technology in modern American society. To what extent have these new goals been met? How large is the gap between new goals and old practices in the education of citizens?

Student Performance and New Goals

Research on student knowledge and attitudes regarding science, technology, and society provides one indicator of how well new goals are being met. Are students achieving the types of goals proposed by educational reformers? Three nationwide assessments of learning suggest that needs have not been met relative to new goals regarding the role of education about science and technology in preparation for citizenship. These studies are: (1) the National Assessment of Educational Progress (NAEP) study of "Attitudes Toward Science" conducted in 1976-77 and reported in 1979, (2) the Science Assessment and Research Project (SARP) 1981-82 study "Images of Science" reported in 1983 and (3) the National Public Affairs Study (NPAS) titled "Citizenship in An Age of Science" based on a 1978 survey reported in 1980.[23]

These three assessments are widely cited by science educators and educational reformers concerned with improving education about the relationship of science, technology, and society. The NAEP assessed attitudes and knowledge about science of nationally representative samples of 9-, 13- and 17-year-olds, and young adults. The SARP study was conducted with support from the National Science Foundation and technical assistance from NAEP as a follow-up to previous national assessments in science. The SARP study consisted of a sample of 18,000 students (9-, 13-, and 17-years old), on a variety of indicators of the current status of science literacy and determined how these data compared with the NAEP results obtained in 1976-77. The NPAS study surveyed a nationally representative sample of three thousand 10th, 11th, and 12th grade students in public high schools as well as a sample of college students. Indications of science and society concerns studied by NPAS included interest in and knowledge about science-related social issues, and efforts to acquire information regularly about science and public policy issues.

In what follows we briefly survey key results on four dimensions relevant to educational progress in science, technology, and society concerns. These dimensions are: (1) understanding of the scientific process, (2) confidence in and support for science, (3) personal involvement in science and society issues, and (4) knowledge of science and society issues. Race and sex differences in the research and implication for reform are also discussed. Readers should turn to the original research for more details on the general trends discussed here.

Understanding of the Scientific Process. Scientific literacy includes an awareness of the norms and methods of science as a human endeavor: how science and scientists work. Such understanding is related to the citizen's ability to comprehend the dynamics of science and society issues and the proper role of science and technology in such issues.

While the NAEP and SARP assessments indicate students do grasp the empirical nature of science, studies also document continuing declines in significant areas. With respect to basic science knowledge, 17-year-olds declined 2 percent from 1977 to 1983 in science achievement questions. This drop follows previous declines found by NAEP of 2.8 and 1.9 percent on the 1973 and 1977 assessments. Thirteen-year-olds recorded no gains on scores treating science achievement in the 1982 study.

The NPAS study confirms this lack of basic knowledge. NPAS investigators studied student comprehension of four basic science concepts and found "a surprisingly low level of current substantive science information" among both college and non-college bound high school students.[24] Further, NPAS found no growth in concept mastery, "suggesting a minimal impact from formal science instruction during the high school years."[25]

In addition, assessment data indicate large numbers of students fail to understand the dynamic, self-correcting nature of science and the role of scientific theory in making predictions. In 1977, for example, only 37 percent of the 17-year-olds agreed that "science is a self-correcting enterprise."[26] Little apparently has been done since to deepen students' understanding, as the 1982 SARP results show declines in student achievement on related questions. "In general," SARP researchers conclude, "students in 1981 were less likely to question scientific findings and more likely to perceive scientific knowledge as stable rather than tentative."[27]

Confidence in and Support for Science. New educational goals include calls for citizens who value and will support science while displaying a realistic appreciation of the relationship of science and technology to the generation and resolution of societal problems. What are young people learning in this regard? Do they have confidence in and value science and technology?

Both the NPAS and NAEP studies found youngsters to have positive general attitudes about science and technology. Perhaps as a reflection of this, more than 75 percent of the 13- and 17-year olds in the NAEP study expressed support for scientific research. Support was much stronger for "applied" than for "basic" research. Similarly, teenagers were less supportive of research involving "controversial issues." About half the NAEP teenagers also responded negatively to the question: "Do you think scientists should be allowed to try to do any kind of research they want to do?"[28]

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Uneasiness about science also manifests itself in the NAEP study in other ways. Only 36 percent of the 13-year-olds and 37 percent of the 17-year-olds thought science and technology had changed life for the better. Similarly, satisfaction with the rate of change brought about by science and technology declined from age 13 to 17 to young adult. Sixty percent of the 13-year-olds thought the rate of change about right, but only 48 percent of the 17-year-olds and 40 percent of the young adults agreed. Finally, when asked if science and technology had changed life for better or for worse, only about one-third of the teenagers thought life had been changed for the better. Across the board less than 20 percent of the students at any age felt science will at some time solve all the nation's problems.

Since the 1977 assessment, education and events have apparently done little to instill greater appreciation for science and technology. The 1982 SARP study documents a noticeable decline in positive attitudes toward science and technology. From 1977 to 1982 there was a 4.2 percent decline in 13-year-olds' and a 6.6 percent decline in 17-year-olds' overall appreciation for science as measured by items dealing with support for research, beliefs that science is useful, and use of science information in daily life.

The SARP investigators termed these declines "discouraging." They concluded the results could "signal a future decline in support for scientific research and development."[29] They speculated that, "if attitudes are valid predictors of future science achievement and technological development, then the change data results are very disturbing."[30]

Personal Involvement in Science and Society Issues. Several emerging educational goals focus on preparing students to be active citizens willing to contribute to the solution of science-and-technology-related social problems. Both the 1977 NAEP and the 1982 SARP assessments measured students' sense of efficacy with respect to such problems as pollution, energy waste, food shortages, and depletion of natural resources. The studies also examined students' willingness to take steps in their own lives to solve such problems and the self-reported extent to which they actually took some personal action such as helping with a litter clean-up.

The results are hardly encouraging for science and social studies educators. Only 38 percent of the 13-year-olds surveyed expressed belief they could help solve science/technology/society problems. These youngsters were least confident in their abilities to curb overpopulation and disease and to preserve natural resources. Seventy percent claimed they were willing to do various things to help solve such problems such as drive or ride in an economy car. However, only 43 percent reported they actually engaged in constructive activities such as separating trash for recycling.

As for the 17-year olds, fewer than half, 43 percent, felt they were able to solve such problems. As with the 13-year olds a large percentage, 75 percent, claimed willingness to help solve problems but only 41 percent reported behavior along those lines. The 17-year-olds were most confident in their ability tc help with pollution, energy waste, and accident resolution, and least confident about disease and natural resources.

A similar disparity between willingness to help solve problems and actual help in terms of self-reported behaviors was found in the 1977 NAEP study. Several prominent science educators observed:

> This disparity, combined with the relatively low performance on cognitive items . . . leads to the conclusion that positive attitudes about willingness to help in well-known 'popular' problem areas are largely not internalized, and that these attitudes might not lead to future patterns of behavior that will be helpful in solving societal problems.[31]

The trend data from 1977 to 1982 on the cluster of attitudes toward science, society, and personal responsibility are even less encouraging. Significant, and in some cases, dramatic declines for all three age groups have occurred in students' perceptions of their ability to help resolve persistent science, technology, and society problems. For example, 13-year-old students' sense of efficacy declined by 7.5 percent from 1977 and their willingness to engage in helpful activities dropped by 3.5 percent. Seventeen-year-olds' scores on the "can you solve" scale have plunged by 12 percent since 1977 causing the SARP investigators to conclude that 1982 teenagers "feel impotent in their ability to resolve persistent societal problems."[32]

Knowledge of Science and Society Issues. The capacity to exercise competent citizenship with respect to science and technology issues presumes that citizens possess some basic level of information about such issues as pollution, alternative energy sources, and population growth. How knowledgeable about social issues involving science and technology are youngsters? To what extent are they attentive to science/technology/society issues?

The NPAS study found that less than 10 percent of college-bound high school students could be classified as aware of, or attentive to, science-related social issues. For non-college-bound high school students the figure was less than 5 percent. Reviewing this data the NPAS researchers concluded: "For high school students not planning to attend college, attentiveness to science issues is virtually nonexistent."[33]

What makes students attentive to science and technology issues? The NPAS report showed that courses in school were reasonably effective transmitters of science information, but were ineffective stimulators of interest in science-related social issues and related public policy concerns. Yet those few students with high levels of interest and knowledge about science-related social issues tended to have the most positive attitudes about the scientific enterprise and to be the strongest advocates of public support for scientific inquiry. This finding would seem to highlight the importance of new educational goals calling for more emphasis on the science/technology/society theme in the curriculum.

Both the NAEP and subsequent SARP study investigated the level of students' knowledge about a very wide range of science and technology issues. As might be expected from the attentiveness data, student performance on these items was generally disappointing. As importantly, with a few fascinating exceptions, performance has not been improving since 1977.

The NAEP study found, for example, that only about one-third of those surveyed knew that automobiles are the major source of air pollution in most cities. As for energy issues, only 23 percent of the 13-year-olds and 36 percent of the 17-year-olds knew that limitation of supply is the basis of the long-term fossil fuel problem. Similarly, students displayed lack of knowledge of basic facts about food supply and population problems. For instance, only 21 percent and 32 percent of the 13- and 17-year-olds, respectively, realized that more people can be supported by eating grain directly than by eating the animals that eat the grain.

Overall, the SARP study shows a 2.8 percent increase in 9-year-olds' science/technology/society scores but no statistically significant changes in the scores for 13- and 17-year-olds between 1972 and 1982. Results for the 13-year-olds, however, present some exceptions to the overall lack of improvement to test scores.

The 13-year-olds did register some large gains on understanding of several issues which, while not generally covered in the junior high/middle school curricula, have received considerable attention in the mass media. Some of these issues and the gains recorded were: nuclear reactor wastes as pollutants (+32.4 percent), acid rain (+12.2 percent), sunlight as an energy source (+12.4 percent) and coal as an energy source (+11 percent). At the same time, scores on issues or problems receiving little or no media attention did not change. The SARP researchers speculate that "the lack of science and society issues in the junior high/middle school curricula may be the reason why."[34]

Do students gain by learning about science and technology issues through the mass media instead of through school? The SARP study concludes:

> Facing complex social issues, particularly as they are presented in the media, may be overwhelming for 13-year-olds. Their ability to examine critical problems is limited, and they see adults disagree over which solutions are viable. As the image of science becomes more complex--as nuclear arms, Three Mile Island, and Times Beach dominate the news--the frustration and apathy of youth may continue to grow.[35]

In conclusion, the implications of the assessment findings on the knowledge dimension are that students continue to display a low level of knowledge about persistent science/technology/society problems. It seems that students have been learning much more traditional science subject matter than content pertaining to the science/technology/society theme. They display little knowledge of how science can be used to improve the quality of human life, or the connections between advances in scientific research and technological progress.

Race and Sex Differences. Both national assessments have found significant race and sex differences on most of the dimensions we have been reviewing. For example, in the NAEP study blacks and those living in disadvantaged urban areas consistently performed lower than the national average. In 1982 males outscored females on achievement items by 3.3 percent for 17-year-olds and 3.4 percent for 13-year-olds. These figures indicate only very slight improvement since 1977. SARP concludes, "the achievement gap between races and sexes persist."[36]

At the same time, the SARP results offer some encouragement to educators that systematic efforts to address such disparities can make a difference. The 1982 females displayed considerably more positive attitudes toward the value of science, science classes, and science careers than 1977 students. SARP analysts state "these gains reflect the increased attention given to female students in recent years... the good news for science educators is that their efforts to encourage females to pursue science careers may be having an effect."[37]

Such modest successes notwithstanding, the implications for citizenship of continuing race and sex differences in science/ technology/society education are clear. Leaders in both the public and private sectors of our society are increasingly likely to be drawn from those who possess scientific and technological literacy and abilities. Young men and women lacking such capacities will have little chance to participate fully and positively in the governance of their own society.

Implications For Reform. The assessments of learners we have reviewed seem to clearly support the need for the new goals of citizenship education in response to the challenges of a scientific age. The summary statement of the SARP study presents a clear warning and challenge for both social studies and science educators.

> Major declines in students' willingness to support science research, to use science information, and in their perception of themselves as change agents for socio-scientific problems are most disturbing. Perhaps young adults do not have enough science knowledge to face complex technological problems, and feel less certain that they--or anyone else--can solve these problems as a result. If so, we may be moving dangerously away from the enlightenment Jefferson felt was so critical for citizens to maintain if society was to preserve control over its processes.[38]

Curriculum, Textbooks and New Goals

Curriculum surveys and textbook analyses have revealed another type of evidence about the emphasis (or lack of it) in schools on new goals related to science, technology, and society. What findings of these various studies pertain to the concerns and challenges of citizenship educators?

The NSF Curriculum Studies. From 1976 through 1979, the National Science Foundation sponsored nationwide studies of precollege curricula in science, mathematics, and social sciences. The research methods included a series of case studies conducted by the Center for Instructional Research and Curriculum Evaluation at the University of Illinois, a national survey of opinions of educators conducted by the Research Triangle Institute, and a survey of literature for the period 1955-1975 done by the Center for Science and Mathematics at Ohio State University and the Social Science Education Consortium of Boulder, Colorado. The literature survey included a synthesis of findings of school textbook assessments in science, mathematics, and social science/social studies.[39]

Additional curricular assessments have been carried out to synthesize and elaborate upon the NSF studies. For example, the Social Science Education Consortium was commissioned to synthesize and elaborate upon the original NSF studies in terms of social studies education.[40] Likewise, Norris Harms directed a survey of science education curricular patterns.[41] Hurd, Bybee, Kahle, and Yager have used findings about science curricula to describe the status of precollege biology education and to identify trends and needs.[42]

The various studies of current curricula have revealed scanty coverage of science/technology/society issues in both science and social studies textbooks. Little textbook emphasis was found on rational decision-making strategies as a way to systematically examine and respond to public issues and policies. Finally, observations of teaching uncovered very little attention to these matters in teacher-initiated classroom work. These findings contrast sharply with the strong support of prominent educators in the sciences and social studies for new goals about connections of science, technology, and society in the education of citizens.

Another curriculum assessment, sponsored by the NSF, examined the status of science education in middle schools and junior high schools. The findings were similar to those of other studies. The researchers report: "Science/society/technology issues are not an important nor an integral part of any program examined at this level. . . . What is communicated by the program materials is that science is a body of factual information and interesting things to do in the laboratory, but it has little or no relationship to our everyday lives and problems."[43] Furthermore, this assessment of middle school/junior high school curricula revealed that most teachers avoid the teaching of highly controversial issues in science "on the grounds that there are no appropriate curricular materials for doing so. Thus, science/ technology/society problems have not found a place in science textbooks or science classes, although a majority of students feel they should have an opportunity to deal with controversial issues."[44]

Faith Hickman's survey of high school biology teachers in Colorado reveals several obstacles to infusion of social issues into the science curriculum. More than half of Hickman's respondents report that they do not have time to teach about science and society issues. Other obstacles mentioned prominently by respondents are lack of resources and training needed to teach about these issues. Hickman presents a pessimistic conclusion: "What appears to emerge from these data is a portrait of biology teachers who while espousing the goals of citizenship education, find turning theory into practice difficult if not impossible."[45]

Textbook Assessments in the Social Studies. Educators in the social studies have given much less attention (than their counterparts in science) to science/technology/society interrelations in their studies of the curricula. There are very few textbooks analyses, for example, that bear directly on this aspect of citizenship education. The review of literature on social studies textbook assessments conducted by Project SPAN uncovered very little discussion of science/technology/society themes.[46] Likewise, Frances FitzGerald's study of secondary school American history textbooks barely touched on this topic.[47] FitzGerald merely notes that the textbooks tend to be "evasive or misleading in their social analysis" and in treatments of public issues, but she does not extend her inquiry from the general categories of social analysis and public issues to instances of science and technology as social history or to examples of public issues in science and technology that are avoided or discussed ineptly.[48]

It is reasonable to speculate that the textbooks in American history have little commentary on science as a fundamental force in the development of American civilization or on issues in American history pertaining to the uses of science and technology. A cursory look at tables of contents and indices of leading textbooks suggests omission of science as a major element of the American heritage.

A recent study of high school world history textbooks lends credibility to speculations about inadequate treatments of science in American history. This study found sparse coverage of science in the development of Western civilization from the 16th century to the present and of the global extension of Western science in the 19th and 20th centuries. Coverage ranged from 1½ pages in one textbook to 23 pages in another book. The average number of pages given to the science and society theme from 1500 A.D. to the present was 15. Thus, it is apparent that students exposed to these textbooks will not receive an overdose of knowledge about the scientific revolution of the 15th and 16th centuries and the subsequent development of modern science in western civilization and the rest of the world.[49]

Another serious weakness of the world history textbooks is little or no discussion of relations between Western scientific achievements and the aspiration of many non-Western peoples.[50] Modern science is the only aspect of Western civilization that has permeated other civilizations on a global scale. Herbert Butterfield, the late eminent British historian, said it well: "And when we speak of Western civilisation being carried to an oriental country like Japan in recent generations, we do not mean Graeco-Roman philosophy and humanist ideals, we do not mean the Christianising of Japan; we mean the science, the modes of thought and all that apparatus of civilization which were beginning to change the face of the West in the later half of the seventeenth century."[51] Students and teachers who rely on widely used textbooks in their studies of world history will search in vain for this insight about the trans-cultural power of modern science, which Butterfield expressed so nicely. Likewise, students who use these textbooks will find scanty treatments, at best, of various science-related social problems that have global ramifications.

An extensive recent analysis of high school social studies textbooks reinforces the findings of the world history textbook study.[52] This analysis of 63 textbooks in American history, world history, geography, civics, and economics was conducted by the Hudson Institute. It focused on treatments of "limits-to-growth" issues in the areas of population growth, resources, environmental problems, and economic development. Four of the textbooks in this study failed to treat any of these issues. Thirty-two textbooks dealt with all four of them to some extent, although most of the texts treated these issues with only "moderate-to-broad" coverage.

Among the types of issues covered in this study, only the "energy crisis" was reported as being treated objectively and informatively in most of the textbooks. By contrast, the other types of issues were presented more or less inadequately in the majority of textbooks, especially those on geography. The researcher noted that "misrepresentation of facts, expert estimates, concepts, or theories" marred all of the books, although in varying degrees.[53] The Hudson Institute study concludes: "How likely is it that students during a high school career will encounter or accumulate a solid, elementary education on the demographic, economic, scientific, and other basics that underlie global issues?" The answer to this leading question is a criticism of textbook treatments of certain types of global issues related to the social effects of science and technology: "We are forced to conclude that no combination of basal history, geography, civics, and economics texts fully meets this need. And a great many combinations will repeatedly expose the students to erroneous information."[54]

Analyses of social studies textbooks, although limited in number and scope, suggest that new goals of citizenship education, which pertain to science/technology/society themes and issues, have not become prominent in main-line courses--American history, government, civics, geography, world history--where they could be related logically to traditional content. It has become trendy to proclaim these new goals at conferences and in professional journals, but they have not yet become a national trend in the curricula of our schools.

Summary

Major curriculum reform reports have proposed new educational goals that respond to the key challenges facing citizenship education we have identified. These reports stress the need to include significant attention to the connections of science, technology, and society in the general education of citizens. Scientific literacy is seen as a prerequisite for responsible citizenship in today's complex, high-tech world.

Many distinguished science, social studies, and humanities educators have put forth similar recommendations. Science educators, in particular, have called for specific curriculum changes that would increase students' ability to make thoughtful decisions about science/technology/society issues and would help students see the role of science and technology in generating and resolving such issues. In short, new goals calling for an understanding of the social dimensions of science and technology as a key component of education for citizenship are being widely accepted in theory.

Practice, however, is another matter. Research on student knowledge and attitudes, and on the content and method of instruction points to a large gap between new goals and classroom realities. Recent national assessments of learners suggest students lack an understanding of the nature of science as a human endeavor, confidence in and support for science, a commitment to dealing with social problems generated by science and technology, and basic knowledge of key science/technology/society issues. Similarly, studies of curricular patterns and extensively used materials reveal lack of attention to science/technology/society issues and to instructional strategies that could connect learning in science and social studies.

NOTES

[1]National Commission on Excellence in Education, A Nation At Risk: The Imperative for Educational Reform (Washington, D.C.: U.S. Government Printing Office, 1983).

[2]Ibid., 24.

[3]Ibid., 25-26.

[4]Ernest L. Boyer, High School: A Report on Secondary Education in America (New York: Harper & Row, Publishers, 1983).

[5]Ibid., 101-111.

[6]Ibid., 302-303.

[7]In addition to the "Carnegie Report" and A Nation At Risk, various other reform reports of the recent past and present have recommended an extensive "core curriculum" that includes emphasis on science, technology, and society: notable examples include the Harvard Committee, General Education in a Free Society (Cambridge, Mass: Harvard University Press, 1945); Rockefeller Brothers Fund Panel on Special Studies, The Pursuit of Excellence: Education and the Future of America (Garden City, New York: Doubleday and Company, 1958); Educational Equality Project, Academic Preparation for College: What Students Need to Know and Be Able to Do (New York: The College Board, 1983); John I. Goodlad, A Place Called School (New York: McGraw-Hill Book Company, 1984).

[8]Cheryl Charles and Bob Samples, Science and Society: Knowing, Teaching, Learning (Washington, D.C.: National Council for the Social Studies, 1978).

[9]Science and Society Committee, "Guidelines for Teaching Science-Related Social Issues," Social Education 47 (April 1983): 258-261.

[10]Ibid., 261.

[11]Commission on the Humanities, The Humanities in American Life (Berkeley: University of California Press, 1980), 46.

[12]Portions of the "Eisenhower Committee" report are quoted in Richard C. Atkinson, "Education for an Age of Science," Science 223 (30 March 1984): editorial page.

[13]National Science Board Commission, Educating Americans for the 21st Century (Washington, D.C.: U.S. Government Printing Office, 1983), 97.

[14]Ibid., 98.

[15]Ibid., 101.

[16]Paul DeHart Hurd, James Robinson, Mary C. McConnell, and Norris M. Ross, The Status of Middle School and Junior High School Science

(Louisville, Colorado: Center for Educational Research and Evaluation of the Biological Sciences Curriculum Study, 1981).

[17]This quote from an NSTA working paper appears in Robert E. Yager, "Toward New Meaning for School Science," Educational Leadership 41 (December 1983/January 1984): 14.

[18]Paul DeHart Hurd, Reforming Science Education: The Search for a New Vision (Washington, D.C.: Council for Basic Education, Occasional Paper 33, 1984).

[19]In this perception, Hurd (a science educator) agrees with Ernest L. Boyer (a curriculum generalist), who wrote High School, the Carnegie Foundation Report on secondary education.

[20]Hurd, Reforming Science Education, 15.

[21]Ibid., 8.

[22]Ibid., 11.

[23]National Assessment of Educational Progress, Attitudes Toward Science: A Summary of Results From the 1976-77 National Assessment of Science, Report No. 08-5-02 (Denver: Education Commission of the States, 1979) referenced in text as NAEP; Stacey J. Hueftle, Steven J. Rakow, and Wayne W. Welch, Images of Science: A Summary of Results from the 1981-82 National Assessment in Science (Minneapolis: Science Assessment and Research Project--Minnesota Research and Evaluation Center, 1983) referenced in text as SARP; John D. Miller, Robert W. Suchner, and Alan M. Voelker, Citizenship in an Age of Science: Changing Attitudes Among Young Adults (New York: Pergamon Press, 1980) referenced in text as NPAS.

[24]NPAS, 94.

[25]Ibid.

[26]NAEP, 44.

[27]SARP, 41.

[28]NAEP, 35.

[29]SARP, 59.

[30]Ibid.

[31]Norris Harms, Roger Bybee, and Robert Yager, "Science and Society: A Review of the National Assessment Data for 13- and 17-Year Olds With Implications for Policies and Research," in NAEP, 69.

[32]SARP, 94.

[33]NPAS, 128.

[34]SARP, 66.

[35]Ibid.

[36]Ibid., p. 98.

[37]Ibid., p. 93.

[38]Ibid., p. 98.

[39]Discussion of findings and implications of these NSF curriculum studies can be found in the following volumes: (a) National Science Foundation, What Are the Needs in Precollege Science, Mathematics and Social Science Education? Views from the Field (Washington, D.C.: U.S. Government Printing Office, 1979); (b) Karen B. Wiley, The Status of Pre-college Science, Mathematics, and Social Science Education: 1955-1975, Volume III, Social Science Education (Boulder, Colorado: Social Science Education Consortium, 1977).

[40]Irving Morrissett, ed., The Current State of Social Studies: Project SPAN Report (Boulder, Colorado: Social Science Education Consortium, 1982).

[41]Norris Harms and Robert E. Yager, What Research Says to the Science Teacher, Vol. III (Washington, D.C.: National Science Teachers Association, 1981).

[42]Paul DeHart Hurd, Rodger Bybee, Jane Kahle, and Robert E. Yager, "Biology Education in Secondary Schools of the United States," American Biology Teacher 42 (October 1980): 388-409.

[43]Hurd and others, The Status of Middle School and Junior High School Science, 16.

[44]Ibid., 13.

[45]Faith Hickman, "Education for Citizenship: Issues of Science and Society," The American Biology Teacher 44 (September 1982): 364-365.

[46]John J. Patrick and Sharryl Hawke, "Curriculum Materials," in The Current State of the Social Studies, edited by Irving Morrissett (Boulder, Colorado: Social Science Education Consortium, 1982), 105-158.

[47]Francis FitzGerald, America Revised: History Schoolbooks in the Twentieth Century (New York: Random House, Vintage Books, 1980).

[48]Ibid., 113.

[49]This study of world history textbooks is reported in John J. Patrick, "Science and Society in the Education of Citizens," BSCS Journal 3 (December 1980): 3-5.

[50]Ibid., 5.

[51]Herbert Butterfield, The Origins of Modern Science (New York: The Macmillan Publishing Company, 1957), 191.

[52]Jane Newitt, The Treatment of Limits-to-Growth Issues in U.S. High School Textbooks (Croton-on-Hudson, New York: Hudson Institute, 1983).

[53]Ibid., 8.

[54]Ibid., 9.

3. IMPROVING THE EDUCATION OF CITIZENS ABOUT SCIENCE, TECHNOLOGY, AND SOCIETY

In response to critical challenges posed by the dynamic social effects of modern science and technology, citizenship educators have stated new goals for courses in the social studies and sciences. Assessments of learners and curriculum materials, however, suggest that there is a rather large gap between the new goals of educational leaders and common classroom realities. In general, there are few meaningful connections of science/technology/society either within or between the social studies and science curricula of schools. The ability to connect things, which seem superficially to be discrete, is a sign of higher order cognition and learning. Our ability to make such connections is a key to effective education for citizenship in our complex world of high technology and scientific progress.

More than 40 years ago, Mark Van Doren recognized the primacy of teaching and learning about connections in the general education of citizens. He wrote in Liberal Education that "the connectedness of things is what the educator contemplates to the limit of his capacity. . . . The student who can begin early in life to think of things as connected, even if he revises his view with every succeeding year, has begun the life of learning.[1] Ernest Boyer agrees with Mark Van Doren that helping learners to connect apparently discrete phenomena is the goal of common learning.[2] How can educators make these necessary connections, so that prospective goals about science/technology/society can be transformed into curriculum patterns and classroom realities?

The Search for Integrative Threads to Connect Science/Technology/Society in the Curriculum

"Integrative threads" are means to link learning experiences about science/technology/society within and between the social studies and science curricula. An integrative thread is any theme, concept, principle, or method of thinking that links learning experiences within or between separate academic disciplines or broad fields of knowledge.[3] Useful integrative threads are generalizable; they can be applied broadly to various learning experiences. They also can be applied cumulatively and flexibly; that is, they can be elaborated upon and modified to fit various learners and activities at different levels of complexity.[4]

Pitfalls in the Search for Integrative Threads. The search for integrative threads in the curriculum has been frustrated by "pitfalls" that have trapped more than one generation of innovative curriculum developers during the 20th century. From the 1920s to the 1980s, there have been calls, often strident, to develop interdisciplinary curricula based on decision making about social problems and issues.[5] Educators should know about the history of these curriculum reforms to avoid past mistakes and to build upon earlier achievements. Hazel Hertzberg's history of curriculum reform in the social studies discusses attempts to integrate courses both within and between various disciplines or fields of knowledge.[6]

An important part of Hertzberg's history concerns the formidable problem of conceptualization that has hindered interdisciplinary curriculum reform. She says:

> The conceptual problem in combining subjects within the social studies had always been a difficult one that remained largely unresolved. . . . When to the usual problems of fusing the social studies were added subjects not so obviously related, the difficulties became even more formidable. The 'personal/social needs of adolescents' approach could easily degenerate into . . . a formless curriculum from which students learned little and which bored them.[7]

There is no broad theory of knowledge that incorporates the sciences and social studies. There is no universal framework, which could be the foundation for a comprehensive interdisciplinary curriculum. Given these conceptual limitations, educators ought to proceed cautiously in their attempts to integrate the sciences and social studies. Lessons from history show that it has been much easier to dismantle the curricula of separate subjects than to reassemble them along comprehensive interdisciplinary lines.

Hertzberg offers this explanation:

> The school subjects are derived from organized bodies of knowledge--the disciplines--which comprise cores of information, theory, interpretation, and methodologies which can be adapted for instructional purposes. The unitary-field advocates have no comparable basis on which they can build a curriculum.[8]

Students in poorly organized interdisciplinary courses have often floundered. In a study of courses organized around social problems and decision making, Arno Bellack concludes:

> Difficulties in this approach soon became apparent, not the least of which was the students' lack of firsthand acquaintance

with the disciplines that were the source of the concepts and ideas essential to structuring problems under study. Without adequate understanding of the various field of knowledge, students had no way of knowing which fields were relevant to problems of concern to them.[9]

Teachers confronted with the demands of an interdisciplinary curriculum have often been overwhelmed. In his prize-winning history of progressive education, Lawrence Cremin concludes: "'Integrated studies' required familiarity with a fantastic range of knowledge and teaching materials. In the hands of first-rate instructors, the innovations worked wonders; in the hands of too many average teachers, however, they led to chaos."[10]

The Commission on the Humanities recognizes the pitfall of failing to provide appropriate conceptual and factual foundations for studies of problems, issues, and values.[11] Paul DeHart Hurd, too, warns educators to provide solid conceptual contexts and principles rooted in academic disciplines in conjunction with lessons on social issues and decision making about public policies. Hurd writes: "Knowledge confined to one discipline is too narrow in scope to be the sole basis for dealing with either science and technology, social problems, or problems of the individual . . . . A fair amount of the subject for a science course, however, should include that which illustrates the basic principles, theories, methodology, and conceptual nature of its parent discipline. Without this background, students have no way to judge the validity of the information they will be using."[12] Hurd's note of caution is applicable to the non-science areas of the curriculum too, especially to the social studies.

Another pitfall associated with courses based on contemporary social problems and issues, whether in the sciences or the social studies, is lack of historical perspective. Current issues and policies related to science and technology have a past that must be understood if one is to be a capable decision maker about these matters. Jacob Bronowski aptly argues for an historical dimension in the science education of citizens:

> A knowledge of history . . . gives us the backbone in the growth of science, so that the morning headline suddenly takes its place in the development of our world. It throws a bridge into science from whatever humanist interest we happen to stand on. And it does so because it asserts the unity not merely of history but of knowledge. The layman's key to science is its unity with the arts. He will understand science as a culture when he tries to trace it in his own culture.[13]

A British professor of physics, John Ziman, strongly agrees with Bronowski: "To make sense of the present state of science, we need to know how it got like that; we cannot avoid an historical account."[14] However, a celebrated historian of science, Colin A. Ronan, laments that the history of science has not been used to illuminate other dimensions in the development of civilizations even though science is thoroughly interrelated with them. He charges that the history of science is neglected in professional literature and school books.[15]

Serious difficulties, such as neglect of historical perspectives and conceptual contexts, have impeded the search for integrative threads in the school curriculum. These difficulties, however, do not preclude renewed efforts to interrelate courses within and between the sciences and social studies. Rather, the history of curriculum reform in the 20th century reveals pitfalls to avoid and promising avenues to pursue.

<u>Toward the Location and Successful Use of Integrative Threads</u>. A fruitful way to seek integration of courses is to avoid extreme positions: the choice is not either a comprehensive interdisciplinary curriculum or rigid compartmentalization of academic disciplines. There are ways to connect subjects within and between the sciences and social studies that stop short of a fruitless search for comprehensive integration or fusion of subjects in the curriculum. Consider this position of a social studies educator in another era. Rollo Tyron wrote in 1935:

> The day of isolation [between subjects] is probably gone in theory, even though it still remains in practice. The future will probably see more and more emphasis on the interrelationships of the social sciences. This, of course, does not mean that history, political science, economics, and sociology will necessarily disappear as independent subjects of study in the schools. It simply means that as independent subjects each will be expected to live other than a hermetic life. The services of each to all will be central in organizing them for teaching purposes.[16]

There has been much less interrelationship of the social sciences in the schools than Tryon predicted. Furthermore, we have not progressed very far in linking the sciences and the social studies. However, Tryon's view about seeking connections mainly between distinct subjects--rather than melding them comprehensively--is compatible with several current calls for curriculum reform. For example, a national conference of science educators recommends the following curriculum reform:

Societal issues must be raised as an integral part of the present courses in chemistry, physics, biology, general science, and earth science, not as separate courses. Conferees were well aware that if material is added to a course, already crowded, that something must be dropped. An infusion of perhaps 10% seemed appropriate and feasible.[17]

In a similar vein, the Commission on the Humanities urges curriculum connections between distinct, complementary subjects in the humanities and sciences. The Commission describes a physics course in Vergennes, Vermont where "students consider questions arising from the convergence of science and the humanities." In this case the scientific concepts needed to understand Galileo's discoveries are taught along with some of the human implications of those discoveries, such as Galileo's personal dilemma and the philosophical and religious controversy of the period.[18]

In the preceding examples, a curriculum innovation--decision making about social issues related to science and technology--is presented in terms of the conceptual frameworks and knowledge bases of standard science courses. A similar strategy could be used to infuse lessons on social issues and decision making pervasively into both science and social studies courses and thereby highlight the applicability of one set of content themes and skills to distinct subject-matter areas. These content themes and skills would constitute integrative threads that could be woven into the core curriculum of precollege students.

The use of such integrative threads--cognitive skills in decision making and content themes pertaining to social issues in science and technology--can be strengthened by including historical and global perspectives in science and social studies courses. Herbert Butterfield argued that "it is hardly possible to doubt the importance which the history of science will sooner or later acquire both in its own right and as the bridge which has been so long needed between the Arts and Sciences."[19] In line with Butterfield's view, decision making about issues in science/technology/society should be a priority in history courses as well as in courses primarily about the present, whether in the sciences or social studies. To make sense of the current status of American society one needs to know how science and technology have influenced social development from Europe in the 16th century to the world in the 20th century.

Americans are heirs of the scientific revolution which began to transform Europe in the 16th and 17th centuries. Colonizers of North America brought European ideas about science and technology to their "new world"; these ideas contributed substantially to the origins and foundations of American civilization. By the middle of the 18th century, North Americans were making their own important contributions to scientific thought. From that time until the present, the perspectives and products of science have been basic elements of the American way of life. A primary characteristic of the American people has been proficiency in science and technological innovation. Thus, to know and appreciate adequately the American heritage, one must understand how science and technology have contributed to the development of the United States.

The products and procedures of modern science and technology have also forged links between Americans and other peoples of the world. Global connections between various peoples and places are facts of contemporary life, as are the cross-cultural movements of scientific and technological knowledge and products. As world leaders in science and technology, Americans have traditionally enjoyed a central position in this global exchange. To understand adequately how Americans are connected to one another and to other nations, one must know about the centrality of science and technology in American life in the past and present.

In one form or another, social issues related to science and technology have been perennially a part of the American experience in domestic and international affairs. Thus, knowledge of science and technology in America's past is a minimal condition for meaningful involvement of citizens in public policy discussions about the issues of modern life.

Students who learn how to make decisions about social issues of the past and present in their science and social studies courses have common learning experiences in separate subjects with distinct conceptual frameworks. These common learning experiences are integrative threads that give coherence to the study of diverse fields of knowledge in the curriculum.

Decision Making As An Integrative Thread

Lessons in decision making might be the strongest integrative threads in the curriculum. These lessons should be grounded in a systematic and generalizable strategy for deliberation about social issues. Thus, we offer an extensive discussion of decision making as a basic conceptual and cognitive connection in the curriculum. What are the essential elements of this concept? What cognitive operations are involved in a generalizable decision-making strategy? Why is a generalizable decision-making strategy the most fundamental connection between the sciences and social studies in the precollege curriculum?

Essential Elements of Decision Making. A decision is a choice from among two or more alternatives. Thoughtful decision making involves a conscious search for alternatives and assessment of the consequences of alternatives in light of the decision maker's values and preferred goals.

We can identify four irreducible elements of decision making that may be applied to science/technology/society issues.[20] These four elements comprise a useful conceptual map for helping students understand the process whereby society makes public decisions about science and technology. They may also be used to help students analyze and better understand historical decisions and events relevant to science and technology. Finally, they form a generalizable problem-solving routine which students may use as they confront personal, life-style decisions generated by science and technology.

The four elements are (1) confrontation with the need for choice--an occasion for decision, (2) identification of values and goals that pertain to the occasion for decision, (3) identification of alternative responses to the occasion for decision, and (4) prediction of the positive and/or negative consequences of alternatives in terms of values and goals.

1. Confrontation With the Need for Choice--An Occasion for Decision. An occasion for decision is a problem situation where the solution is not obvious and choice may be required--including the possibility of doing nothing in response to the problem. For example, the Mayor of Cambridge, Massachusetts learns that Harvard University plans to renovate one of its old laboratories to conduct recombinant DNA research. Some members of Harvard's biology department oppose the renovation. They argue that DNA research is risky and should not be carried out in a densely populated area. The mayor calls a city council meeting to review the situation.

An occasion for decision includes the social context of a decision problem at a particular point in time. This context will shape actors, perceptions of the decision problem. Thus, in the Harvard DNA case, the Cambridge City Council meeting had been preceded by more than three years of nationwide scientific debate, Congressional testimony, and increasing public concern over the risks and benefits of recombinant DNA research.

2. Determination of Important Values and Goals Affecting the Decision. Making a social decision always involves a consideration of goals and values. For example, in the DNA case, a goal of the city council was to prevent the accidental spread of dangerous toxins into the environment. Some relevant values were public health, freedom of scientific research, and self-regulation of science.

Values are normative standards that influence choices among alternative courses of action.[21] Goals are outcomes desired by the decision maker. Values are involved when decision makers identify goals to be achieved, and when they appraise the consequences of various alternative courses of action.

3. Identification of Alternative Courses of Action. Decision making involves choosing among alternative courses of action. Most decision situations--even very simple ones--contain more than two alternatives. There are almost always intermediate possibilities. Thus the Cambridge City Council might do nothing, pass an ordinance placing certain limits on DNA research, or ban such research altogether.

Decision theorists point out that for the purposes of formulating a decision problem one should state alternatives in mutually exclusive terms. In addition, they note that it is extremely difficult for most individuals to deal with more than three or four alternatives and the associated value calculations in any given decision problem.[22]

4. Prediction of the Positive and/or Negative Consequences of Alternatives in Terms of Stated Goals or Values. Consequences are the outcomes or results of choosing an alternative course of action. Consequences may be viewed as negative or positive depending upon goals and values. Thus, passing an ordinance regulating all recombinant DNA research conducted in Cambridge could interfere with the process of scientific inquiry, a negative consequence for those valuing freedom of scientific research and the autonomy of science.

The four key elements of decision making may apply unequally in different situations. In some instances decision makers may readily identify available alternatives but it may be very difficult to clarify values and prioritize goals. In other situations, the heart of the decision-making task may be to think creatively of alternatives for reaching a clear and long-standing goal. In yet other situations, alternatives and goals may be clearly known, but the real challenge is to predict accurately the consequences of alternatives. In short, making decisions about complex social issues is not a mechanical, linear process to which one simply applies a formula.[23] Rather, it is a dynamic task, involving the simultaneous consideration of facts and values in light of a given problem.

The Role of Facts, Uncertainty, Risk, and Science. We can readily see that both facts and values are involved in decision making about science/technology/society issues. Facts are involved in the identification of alternatives. Thus, we may ask what alternatives are available for the storage of nuclear wastes. Factual claims are also involved in predicting the likely consequences of alternative solutions to decision problems. Proponents of nuclear power for example, may assert that the risk of long-term radiation leakage from nuclear waste storage is minimal.

Decision making about science/technology/society issues nearly always involves uncertainty about the likely social or environmental consequences of alternative courses of action. Decision theorists refer to such situations as decision making with risk.[24] By "risk" they mean that one only has sufficient knowledge to assign probabilities to the likelihood of particular consequences for an alternative. Thus, while certainty is not possible, a surgeon may know the probability of a postoperative recurrence of cancer given certain surgical procedures. Decision making with risk falls between the idealized extreme of decisions under complete certainty (when one can accurately predict the consequences of every alternative) and decisions under conditions of total uncertainty.

Advances in scientific knowledge and technology can and regularly do help reduce uncertainty in decision situations. For example, until fairly recently there was considerable uncertainty in administering isoniazed--an antibiotic used to treat tuberculosis--because some patients absorbed and eliminated the drug three times faster than others. For them, treatment with the usual doses was a failure. Now a simple test indicates which patients assimilate the drug rapidly and their dosage can be adjusted. Uncertainty has disappeared.[25] As one prominent scientist explains: "New scientific knowledge . . . usually leads to a better way of predicting consequences and sometimes also to an ability to do something that one could not do before."[26]

In the absence of certain (or nearly certain) knowledge, disagreements may, and frequently do, arise over what the consequences of different alternatives are likely to be. Indeed, uncertainty as to consequences has become the hallmark of many, if not most, science/technology/society issues. For example, in a recent controversy over the construction of a dam on the Black River in Vermont, proponents of the project claimed it would lower electricity rates by 12 percent; opponents claimed rates would rise by 81 percent.

The director of the Environmental Protection Agency (EPA) recently pointed in dramatic fashion to the need for citizen understanding of the role of uncertainty in public policy decisions related to science and technology. In a controversy involving conflicting evidence on the extent of cancer danger posed by emissions from a Tacoma, Washington smelting plant, the EPA director invited the community to help make the decision as to whether to close the plant. Said he:

> People need to hear more of what the administrator of this agency hears from the scientists: mainly, that we have lots of gaps in our knowledge. Most people think the facts are clear, but it is often true that there is enormous dispute over what the facts are. And we just can't sit there and let nature take its course.[27]

As a result of such uncertainty, scientists have been increasingly drawn into the politics of the decision-making process. Contending groups often attempt to marshal technical and scientific expertise to support their value position on an issue. Environmentalists hire experts to present data about the likelihood of thermal pollution. Power plant supporters have their own experts to testify to the technical feasibility of a project. The result is that decision making about many science/technology/society issues is marked by conflicting testimony from experts, including scientists.

In taking part in decisions about science/technology/society issues, scientists are fulfilling an important duty. At the same time, they are placing themselves in a situation that requires them (and one hopes the public) to be absolutely clear about the relationship between their scientific information and the values involved in the social decision process. As Anna Harrison, a chemist and recent president of the American Association for the Advancement of Science (AAAS) explains:

> Scientists, either individually or collectively, as scientists have the responsibility to provide technical expertise . . . in a manner comprehensible to those who need the information. In the role of experts, scientists do not have the right to make a value judgment and then selectively present scientific information to support that value position. To do so is to negate the integrity of science.[28]

It is perhaps inevitable that uncertainty and the resultant use of technical expertise to support both sides of a controversy tends to polarize and stimulate political conflict. The existence of conflicting expert opinion calls public attention to the limited ability to control risks and the technical complexities surrounding many science/technology/society issues. The result is to fuel demands for greater public participation in what were once viewed as strictly technical decisions.

Thus, after listening to more than 120 scientists argue over nuclear safety, the California state legislature recently decided that the issues were not, after all, resolvable by expertise. The lawmakers concluded: "The questions involved require value judgments and the voter is no less equipped to make such judgments than the most brilliant Nobel laureate."[29]

<u>The Role of Values and Ethics</u>. Values and goals pl·· a critical role in making decisions about science/technology/society issues. Decision makers express value judgments when labeling consequences as positive or negative. When establishing goals, decision makers engage in a clarification of values. This requires the ranking of values. Such thinking about values is at the heart of ethical reasoning.[30] It involves asking--"What do I want, and what is right or wrong in this situation?"

Decisions about science/technology/society issues often involve tough choices between conflicting values in which there is no clear right or wrong solution. The conflict over the use of the chemical vinyl chloride illustrates the possible "trade-offs" or compromises between different values that may be involved in such decisions. When a number of workers in polyvinyl chloride production plants died of cancer, labor unions called for strict government regulation of workplace exposure to vinyl chloride. As government hearings progressed, it became clear there was uncertainty over exactly what constituted safe exposure levels. At the same time, industry claimed that very strict regulations would result in the loss of over one million jobs in related industries and a $90 billion drop in domestic production.[31]

The decision problem became a conflict between the value of protecting workers' health versus the value of protecting jobs and production. Most people agreed that exposure to health hazards from vinyl chloride was bad; they also agreed that unemployment and a big drop in factory output were bad. Eventually government regulations were developed that sought to limit exposure enough to protect the workers' health while still maintaining production and jobs. Making a decision in such circumstances requires careful consideration of alternative factual and ethical claims.

The vinyl chloride case also illustrates that equally informed people can make very different value judgments and take radically different positions in regard to a given decision, particularly when the choice is made under conditions of uncertainty. This is because different people, or groups of people, may rank their values quite differently.

Even when decisions are made under conditions of reasonable certainty people may opt for various solutions because they value the outcomes differently.[32] At the personal level, some people will choose to smoke cigarettes and others will not in the face of known health risks. At the societal level, some groups argue for continued federal government subsidies for tobacco farmers while others call for an end to such subsidies. In the latter case few seriously dispute the growing scientific evidence on the health dangers of smoking. However, people do value public health and promotion of a segment of the economy differently.

Indeed, value positions rather than technical considerations often dominate decision making about science/technology/society issues. In disputes over fetal research, in the controversy over so-called "creation science," and in various power plant siting disputes, no amount of factual data could resolve the fundamental value conflicts. When basic value conflicts arise, technical information is used mainly to legitimate positions based on existing value priorities.

Connecting Distinct and Complementary Fields. Thus, decisions about science/technology/society issues (almost all of which occur under conditions of risk and uncertainty) cannot be resolved solely on the basis of technical information. As one scientist explains:

> Today's problems certainly will require the methods and results of natural science, but they cannot be solved by these methods alone . . . the problems are to a great extent social and

political, dealing with the behavior of man in complicated and rapidly evolving situations. These are aspects of human experience to which today's methods of natural science are not applicable.[33]

Decision making about science/technology/society issues connects the social studies and the sciences precisely because the insights and results of both are needed in making such decisions. The distinct ways of knowing and thinking characteristic of each field are complementary, not mutually exclusive, when dealing with social decisions involving science and technology. Each has a necessary but in itself incomplete perspective to contribute to such decisions.

Science, or more precisely the methods and results of the many sciences, contributes vital knowledge about the possible consequences of science- and technology-related decisions. The social studies contributes ethical and values perspectives to the decision-making process. They shed light on the moral, social, and human values outside the realm of science that are involved in such choices. They can help decision makers--whether they be individuals or groups--rank and select among preferred outcomes and make value judgments. They can also contribute knowledge about the history of an issue and the public policy processes associated with it.

Implications For Citizenship Education. As a powerful integrative thread between science and social studies, decision making is a means to sound thinking about social issues involving science and technology. By giving systematic attention in the curriculum to decision making about science/technology/ society issues, educators can take an important step toward responding constructively to the three challenges to modern citizenship education we have identified.

Attention to decision making responds to the challenge of informing citizens about complex social issues related to advances in science and technology in at least two ways. First, by studying various issues students can acqui e basic concepts relevant to a better understanding of the dynamics of science and technology in modern society. In addition, they can develop some rudimentary factual information about key, enduring issue-areas such as pollution, energy, and the like.

Perhaps more importantly, educators can equip students with intellectual skills and with a flexible but organized y of thinking about social decision making that can be applied to the variety of science and technology issues they will encounter as citizens. This seems critical since neither social studies nor science educators can provide students with all the specific knowledge they will need to stay informed about science/technology/society issues that are likely to arise in their lifetimes.

As a result, students must develop competence with the task of managing the information overload of a modern, free society. Jon Miller discusses the citizen's challenge to keep up with current events in terms of "political specialization."[35] This is the result of a process whereby the range of public policy issues at any given time far exceeds the ability of any citizen to stay informed about more than a very small subset of such issues. As the complexity of issues increases and the volume of available information grows, even the most concerned citizens can only follow a narrower range of issues. This is particularly the case with science/technology/society issues, where rapid advances in knowledge cause the continual addition of exotic new items to the public policy agenda.

Systematic instruction related to decision making could be well-suited to help students develop competence with managing information. Appropriate decision-making models can capture key elements of the process involved in making decisions about science/technology/society issues. Such models can be a generalizable framework, a conceptual map of social decision making, that citizens--young and old--apply repeatedly to a wide variety of issues and decisions at both the personal and societal level. Students who acquire such a conceptual "map" of decision making can use it throughout their lives.

Appropriate study of decision making can also help build students' skills in analysis and appraisal. Consideration of alternatives, consequences and goals requires students to learn and apply skills needed to acquire, organize, and appraise information about factual claims. At the same time, it requires students to clarify, rank, and judge values in the context of factual claims. These skills are means to independent thinking and learning, which are essential qualities of competent citizenship.

Attention to decision making also responds to the challenge of connecting in the school curriculum diverse fields of knowledge in the sciences and social studies. Appropriate decision-making strategies for studying about science, technology, and society in both past and present could be used in science and in social studies courses at various age/grade levels.

By infusing lessons in decision making into existing science and social studies courses, educators can provide common learning experiences that highlight links between these separate subjects.

Finally, attention to decision making responds to the challenge of resisting antagonists of science and technology in our society. Appropriate instruction about decision making incorporates, indeed requires, a consideration of both the powers and limitations of science and technology in making decisions about science/technology/society issues. Thus, it can help students develop a real understanding of just what science can and cannot contribute to the social decision-making process. This understanding is a necessary condition for informed participation in decisions about public issues and a vital component of the scientific literacy called for by various curriculum reports.

In this same vein, the inherent logic of an decision-making framework requires students to make intellectual moves that can prevent the development of a crucial disability of citizenship in a free society. Since we rarely talk of educational goals in terms of prevention, this last point requires some clarification.

The process of identifying numerous alternatives and consequences in an occasion for decision demonstrates the complex and multifaceted nature of science/technology/society issues. It can give students experience in spotting and examining alternatives and in dealing with different points of view. It can demonstrate that people may reasonably come to different conclusions about the same issue. As a result, it can help students avoid a rigid, dichotomous, doctrinaire way of thinking about their social world. There is, perhaps, no better preparation for citizenship.

Summary

Attainment of new goals regarding science/technology/society will require making connections between and within the social studies and the sciences. The history of curriculum reform efforts indicates there are many pitfalls that can hinder efforts to link more closely the social studies and science curricula. Chief among these is the lack of an overarching conceptual framework upon which to build a comprehensive, interdisciplinary curriculum. Without a broad theory of knowledge that connects the sciences and social studies, it is not possible to provide the conceptual and factual foundations needed to build an interdisciplinary curriculum around science/technology/society issues.

However, useful connections between the social studies and the science curriculum are possible through the use of "int grative threads." These are concepts, principles, and/or methods of thinking that can link learning experiences in different fields of knowledge. The cognitive skills and content themes associated with decision making about science/technology/society issues constitute a powerful integrative thread.

The essential elements of decision making comprise a series of cognitive operations applicable to the study of social problems in both science and social studies courses. Application of these elements to social issues generated by science and technology draws upon the insights of both the social studies and science. The sciences can contribute vital knowledge about alternatives and consequences. The social studies contributes understanding of the social-political decision process and insight into the ethical and values components of such decisions.

NOTES

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4. PROMISING PRACTICES IN TEACHING ABOUT SCIENCE, TECHNOLOGY, AND SOCIETY

Up to this point we have examined major challenges to education for citizenship in the modern age of science and technology; the extent to which current educational goals, classroom realities and student achievement are meeting such challenges; and pitfalls and opportunities associated with connecting science and social studies curricula. In this section we consider some types of instructional practices that would seem to have the potential for improving learning experiences about science/technology/society issues. We also describe projects which aim to identify exemplary instructional programs dealing with such issues and which might serve as a useful model for social studies educators.

Thomas Edison said there is merit in knowing what does not work. However, he went on, knowing what does work is a much more direct route to success.[1] Three types of instructional practices seem to hold considerable promise for building connections between and within social studies and science curricula. These are the use of decision trees and case studies, the use of role plays and simulations, and the use of instructional television and microcomputers.

Using Decision Trees and Case Studies

Decision making as we have seen can be a powerful integrative thread for building curriculum connections. At the individual level, however, decision making involves abstract mental processes that occur inside a person's head where, in effect, they cannot be "viewed." At the public policy level, decision making can involve many contending groups, vast amounts of technical information, a usually not well-known historical context, and arcane legislative or regulatory procedures. How can such a complex, multifaceted process be concretized for students so they can learn systematically about and develop competence with decision making?

One promising strategy is a procedure called the decision tree. This device was originally created by Roger LaRaus and Richard Remy as an adaptation for precollege students of the more complex problem-solving routine of the same name that is widely used in social science decision-theory, engineering, management science, and increasingly, medical science and education.[2] Since its creation John Patrick and Richard Remy have successfully applied the decision tree procedure in several curriculum projects.[3]

For pre-college students the procedure can be represented by a chart in the form of a tree with several branches, which suggest the connections between various alternatives, consequences, and values of the decision maker. By using a chart depicting a decision tree, students can practice skills in clarifying and making choices about science/technology/society issues and policies.

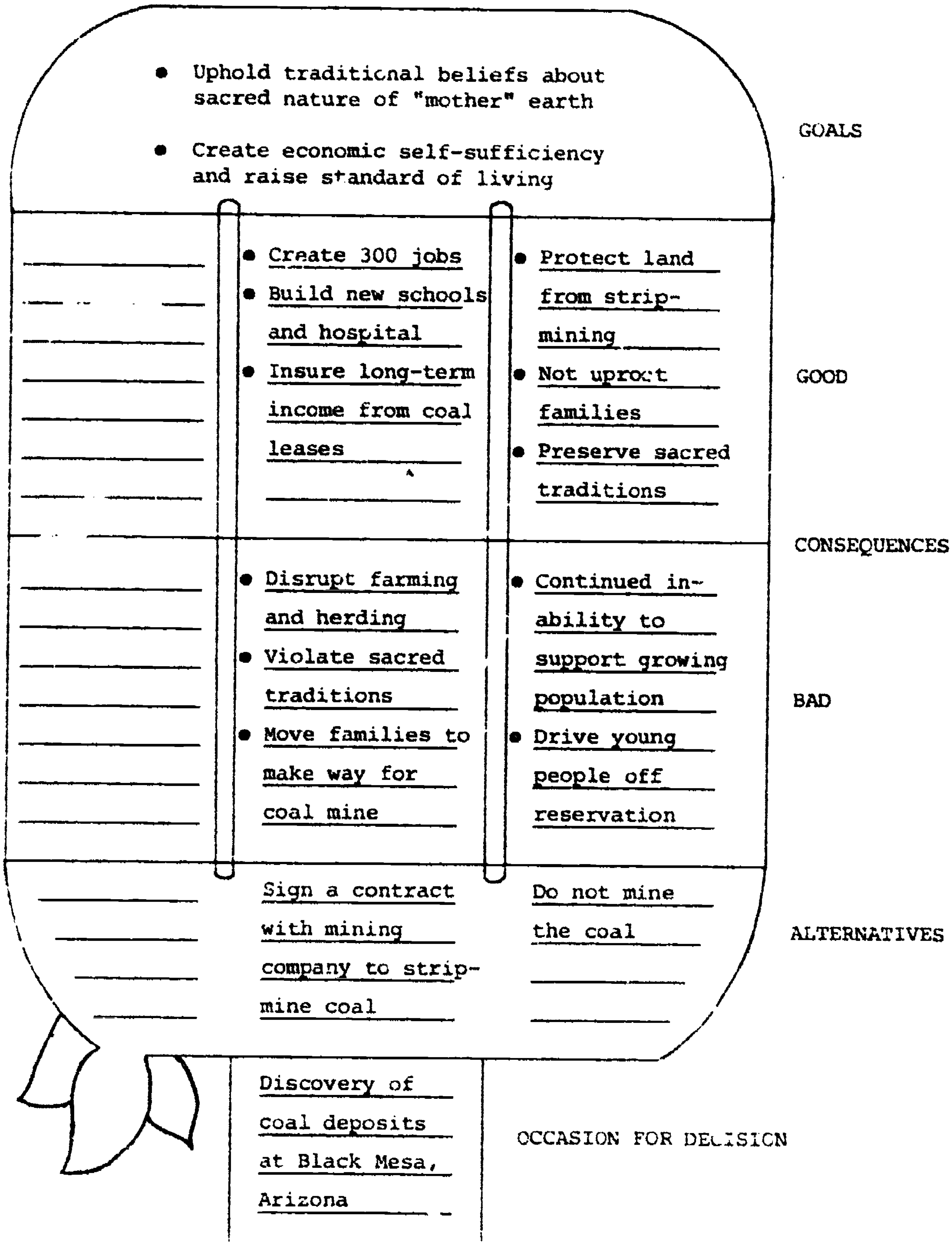
As shown in Figure 1, the decision tree includes the four essential elements of decision making we discussed previously. These elements are (1) an occasion for decision, (2) values and goals that pertain to the occasion for decision, (3) alternative responses to the occasion for decision, and (4) likely consequences of the alternative choices. These elements, of course, involve the interlacing of knowledge based on the sciences and social studies with the arts of critical thinking and judgment. Thus, students who use the decision tree are exposed to complementary characteristics of the sciences and social studies.

The decision tree in Figure 1 has been filled in with reference to a case study about a science-related social issue. The decision tree and case study in Figure 1 are parts of a textbook in junior high school civics.[4] Similar case studies and decision-making strategies have been included in secondary school science courses. One interesting example is a module on land use developed by the Biological Sciences Curriculum Study.[5]

Figure 1 shows moves learners make to analyze a land-use decision faced by the Navajo in Black Mesa, Arizona. Learners start at the trunk or "occasion for decision"--in this instance the discovery of a huge, shallow vein of low-sulfur coal on the Navajo reservation. They next identify the alternatives considered by the Navajo and then move into the branches to map possible negative and positive consequences of each alternative. When considering these consequences, they make factual judgments about the likely outcomes of each alternative. They also consider what is good or bad about these consequences in terms of values and goals they have assigned to the problem at the top of the tree. This consideration of good and bad requires critical thinking, ethical reasoning, and value judgments by the learners.

Learners may use decision trees working individually or in large or small groups to:

Figure 1: THE DECISION TREE



The decision-tree device used on this page was developed by Roger LaRaus and Richard C. Remy. The device is used in this text with their permission.

(1) Study and analyze complex science/technology/society issues (e.g., Should we move ahead with the development of nuclear power as an energy source? What are the good and bad consequences of using such power plants?).

(2) Practice and apply critical thinking/information acquisition skills in a real context (e.g., How do we acquire and evaluate information about the consequences of nuclear power and about alternative sources of energy?).

(3) Study the decisions of others (e.g., What factors were involved in the decision to close a particular nuclear power plant?).

(4) Practice making their own decisions regarding real or simulated science/technology/society issues (e.g., Should I join the pro-nuclear power demonstration to be held in the community next week?).

Providing students with these types of learning experiences responds directly to new goals for science and social studies education that focus upon the citizen as a non-specialist decision maker regarding science and technology. Paul DeHart Hurd explains:

> In our civic and personal affairs, the cognitive processes that we most frequently use are those of decision making. Practically every day we are faced with a choice of actions that require a knowledge of science if we are to make a responsible decision. Such decisions may range from a consideration of whether to purchase megavitamins, support pollution controls, buy a home computer, avoid 'junk' foods, or contribute funds to cancer research. The educational goal, then, is to teach students how to marshal, organize and analyze information leading to a choice of action and to recognize the probable consequences.

Decision trees or similar analytic procedures and case studies are complementary instructional practices. Case studies--a device long familiar in schools of business, law, and medicine-- can provide the actual problems and issues to which learners can apply skills associated with decision making. In an observation that applies equally to social studies, Hurd states, "To achieve its goal, the reform of science education will require that a substantial part of the curriculum be organized in terms of science/technology/society problems, case studies, and historical presentations."[7]

Case studies can take a variety of forms including court cases, open-ended episodes, interpretive essays, cases based on documents, eyewitness accounts, chronicles, and the like.[8] Sources for creating case studies on science/technology/society issues are everywhere and include newspapers, magazines, novels, reports, committee hearings, and research reports. Case studies illustrating how technology influences human affairs might, for instance, examine the impact of the automobile on transportation and American life-styles, or the impact of antibiotics on the reduction of disease.

Students who use decision trees (or similar procedures) and case studies to study decision making about science/technology/society issues in their science and social studies courses can have common learning experiences in separate subjects with distinct conceptual frameworks. These common learning experiences may help them understand the complementary characteristics that link subjects with distinct perspectives on the world.

Using Role Play and Simulations

Simulations have emerged as important research and teaching tools in the social sciences.[9] A simulation is "a device for achieving an understanding about some domain of interest by representing crucial features (entities and/or relations) of that domain through deductive and/or analogous systems."[10] A simulation abstracts from reality and simplifies for purposes of study and analysis. Role playing is a key feature of most simulations, particularly at the elementary and high school level. Role playing gives students a chance to act out their versions of individuals who operate in the social process being studied.

Role play and simulation activities about science/technology/society issues can incorporate the decision tree or similar strategies for making choices under conditions of uncertainty and risk. For example, Irving Morrissett and colleagues at the Social Science Education Consortium (SSEC) have designed a set of simulations titled "Creative Role Playing Experiences in Science and Technology (CREST)." These materials consist of ten units, each focused on a particular science/technology/society issue. Issues covered by the materials included disposal of toxic chemical wastes, the storage of spent nuclear fuel, acid rain, mining the seabed, and auto emissions standards.

The SSEC project also includes a risk management model to help students assess the costs and benefits associated with alternative courses of action posed by their simulations. The model, which is similar to the decision tree, emphasizes identification and minimization of potentially adverse outcomes. (See Figure 2 for a diagram of the risk management model.)

One example of a CREST simulation involving risk management and choice concerns debate in Congress about the Coal Pipeline Act.[11] Students take roles as members of the House Subcommittee on Surface Transportation and as agents of various groups trying to influence the subcommittee. Role players participate in a simulated subcommittee hearing. They consider arguments about the potential risks and benefits associated with slurry pipelines. Then the subcommittee must decide by majority vote whether to approve the Coal Pipeline Act as written, to approve the Act with specific changes, or to reject the Act. After the decision is reported, students hold a debriefing discussion to analyze their experience in decision making about a science-related social issue.

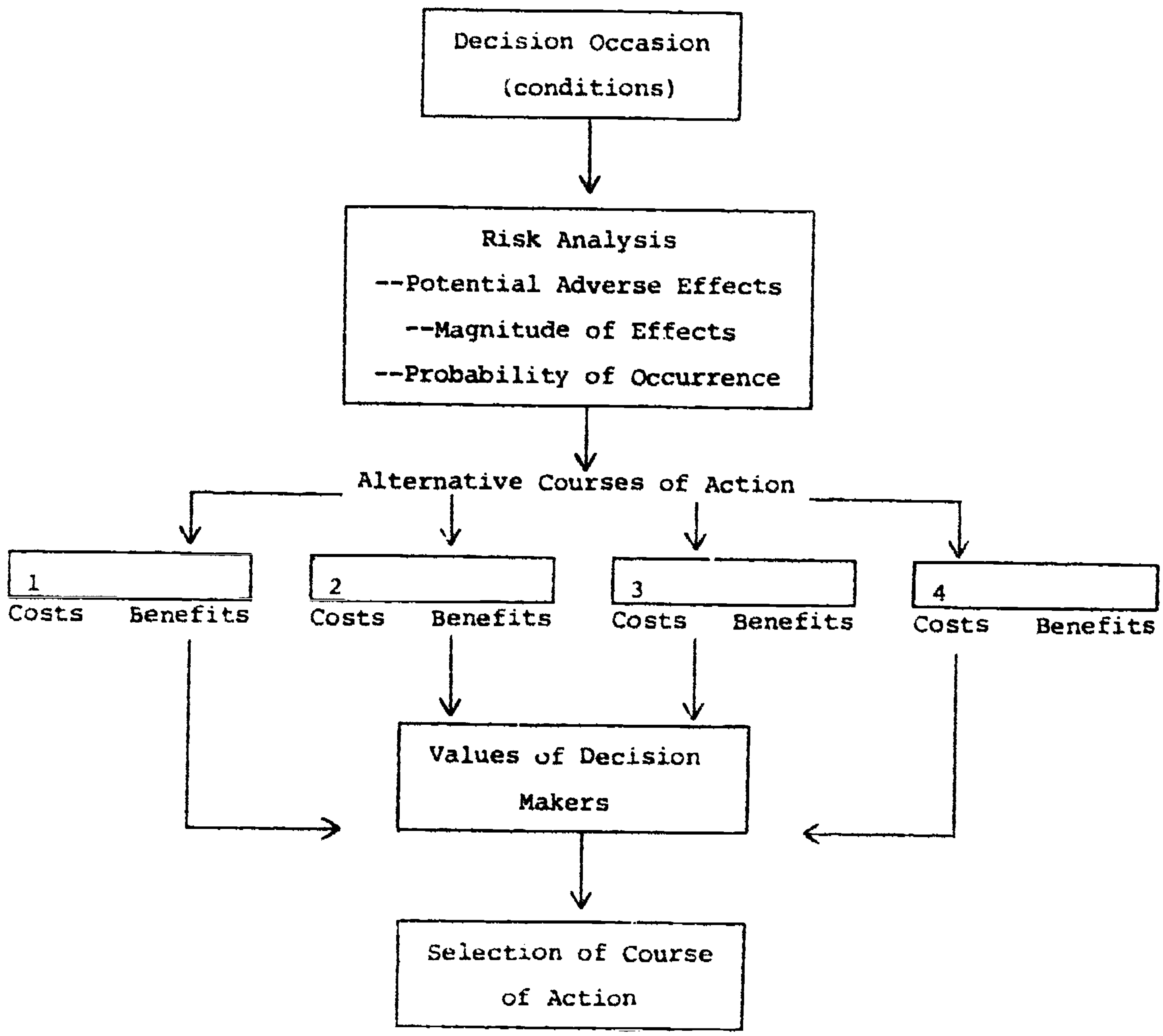
The SSEC project was supported by the National Science Foundation and involved a large number of curriculum developers and field-test personnel. Some individual social studies educators, however, have also developed more modest exercises that illustrate how science and social studies can be connected by role plays and simulations. Phyllis Maxey, for instance, describes a simulation which involves high school students in social studies courses in deciding whether to build a nuclear power plant in the California desert.[12]

A main goal of these decision tree, role playing, and simulation lessons is to teach about the relationships of knowledge and values in making complex decisions under conditions of risk and uncertainty. Such instructional strategies seem well suited to helping students learn about the uses and limitations of science in providing knowledge about the consequences of various alternatives in an occasion for decision. They can also help students learn that science cannot tell them exactly what they ought to choose. Rather, they must learn how to use perspectives of both the social studies and science to consider conflicting and complex judgments about right and wrong, better or worse. Through these experiences, students learn that decisions involving uncertainty and risk combine the arts of critical thinking and judgment with systematic use of knowledge.

Using Educational Technology

The various educational technologies seem to hold great promise as tools for helping forge common learning experiences for students centered

Figure 2: A RISK MANAGEMENT MODEL



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around science/technology/society issues. Instructional television can infuse learning experiences about such topics into the on-going social studies and science curricula in many ways. For example, instructional television can serve as a "springboard" into such topics by focusing students' attention on new learning objectives, by interesting them in the subject matter, by motivating them to raise questions, or by getting them to speculate about events and trends.

One interesting project is a set of two 20-minute video programs and accompanying materials for high school students entitled "You, Me, and Technology."[13] These materials aim to develop technological literacy by having students examine the interaction of technology, society, and individuals, as well as the costs and benefits in developing and using technologies.

The materials were produced by the New Jersey Network for Temple University, with support from the National Science Foundation. The first program in the series, "Living With Technology," focuses on consumerism and technology. The second program "Decisions, Decisions, Decisions," has students examine decisions people are confronted with because of technology. The program dramatizes the distinct contributions of the sciences and the arts to decision making by showing that while machines such as computers are making increasingly complex decisions for people, machines cannot make value judgments. Students learn that personal, social, political, and ethical decisions can only be made by people. Creating machines to enhance society, the program teaches, does not absolve citizens from assuming responsibility for making decisions that govern society.

The Agency for Instructional Television (AIT) of Bloomington, Indiana is nearing completion of a major instructional television series on the principles of technology for use with students. This project--undertaken in cooperation with the Center for Occupational Research and Development (CORD) in Waco, Texas--will provide about 500 minutes of video and nearly 260 total hours of instruction in the mechanical, thermal, electrical, and fluidal systems that are the foundations of high technology.[14]

The project aims to help vocational educators better meet the challenges of high technology and increasingly rapid technological advancement. Rather than prepare students in a single speciality likely to become rapidly outdated, the project seeks to prepare young citizens who want to be technicians and operators to understand the entire system with which they work and the technical principles governing the various devices within the system.

The advent of microcomputers in schools opens additional exciting possibilities for improving learning experiences about science/technology/society issues and decisions. The Minnesota Educational Computing Consortium, for example, has developed a simulation for American history courses, which involves decision making by pioneers on the Oregon Trail[15]. The computer program provides information about food supplies, weather, camp sites, and so forth. Students apply these facts to life and death decisions of the sort that challenged westward moving pioneers of the 1840s.

Unfortunately, there is too little computer courseware that fosters higher level cognition and learning, such as skills in problem solving and decision making. This deficiency is especially acute in the social studies.[16] However, the future seems to offer hope to curriculum reformers. For example, Stephen Willoughby, a mathematics educator, projects an exciting image of computer-assisted learning. He writes:

> Ideally, every high school graduate should have learned at least one computer language and should have plenty of opportunity and incentive to use a computer to solve problems relating to science, social science, mathematics, language, and other fields of thought. With the reduction in cost of small computers and computer terminals, this is not an unrealistic prospect now, and it will become even more reasonable with each passing year.[17]

The Agency for Instructional Television is trying to transform images about computer-assisted learning into classroom realities. AIT has launched a project that uses microcomputers in combination with other instructional media. Educational television, printed materials, and microcomputers are being used to form an instructional system for teaching skills in problem solving and decision making in different subjects at the intermediate grades.[18]

Here is a general description of how different instructional media would be linked to teach skills in problem solving and decision making.

> Students working on a computer in groups of two or three try to devise a solution to a problem presented in a television sequence. At their option, they may respond to the computer's prompts, either individually or as a group. The computer will help them decide on useful and efficient techniques to solve the problem. They discuss their efforts throughout the program and refer to the information in the Unit Guide and on their worksheets. The computer dialogue is

built around a specific problem-solving model but it is designed to accommodate divergent or creative strategies employed by the students.

The consequences of using each strategy are simulated by the computer, providing useful feedback. At several points the students can ask the computer for a review of their progress. Such a review is provided at the end of each sequence, and the students are asked to evaluate their performance, draw conclusions, or redefine the problem, as appropriate. Student data at each review stage can be stored for eventual retrieval by the teacher. The teacher is then likely to reinforce the problem-solving skills and processes included in the computer-based materials and help the students apply these skills and processes to everyday problems in and out of school.[19]

The microcomputer holds great promise as an instructional medium that can connect learning experiences in the sciences, the social studies, and other subjects. Through multi-colored graphics, animation, and instant responses, the microcomputer can provide dynamic lessons in decision making about science/technology/society issues. Students working alone or in groups can have similar computer-assisted learning experiences in their science and social studies courses. They can be exposed in a most dramatic way to the complementary aspects of distinct subjects. Thus, in the near future, computer-assisted learning experiences are likely to strengthen considerably the links now forming between precollege education in the sciences and the social studies.

Identifying Promising Practices

Decision trees, simulations, instructional television, and microcomputers are promising means of connecting social studies and science curricula. These are likely additional instructional practices that are equally promising. However, in our decentralized, pluralistic educational system it is difficult to keep track of innovative practices developed in local classrooms and school districts. Science educators have initiated two projects which aim to identify promising practices in education about science/technology/society issues. These projects suggest the possibility and need for complementary efforts by social studies educators.

The first effort is the "Search for Excellence in Science Education" sponsored by the National Science Teachers Association (NSTA), the Council of State Science Supervisors (CS^3), and the National Science Supervisors

Association (NSSA).[20] This national project has sought to identify in school systems across the country examples of excellence in science education programs that could guide and provide support for other innovative efforts.

The Search For Excellence project has sought out and assessed local science programs in terms of criteria for excellence in science education developed by Project Synthesis, one of the follow-up studies to the recent National Science Foundation curriculum assessments. Some of the criteria used pertain directly to the challenges and concerns of citizenship educators, such as these:

--Exemplary programs in elementary science should recognize human effect on environment and vice versa.

--Exemplary programs in biology should focus on current issues and deal with morals, values, ethics, and aesthetics.

--Exemplary programs that deal with the interaction of science/technology/society should use knowledge to improve students' personal lives and to cope with cur increasingly technological/societal issues and focus on decision making.[21]

The Search for Excellence Project selected 50 science programs around the United States for special recognition as "national exemplars." Ten of these programs were identified as exemplars of the science/technology/society focus. These outstanding programs excelled in connecting science and technology to social contexts and in developing skills through extensive practice in decision making about social issues. The exemplary programs, though few, represent an important beginning in designing curricula that are likely to foster achievement of new goals that respond to the challenges and concerns of citizenship educators. Complete descriptions of the "national exemplars" are being published as a series of monographs by the NSTA.[22]

The Search for Excellence project included collection of data about teachers in the programs being assessed as well as data about the programs themselves. Penick and Yager describe four characteristics that tended to recur among the exemplary programs. First, many of the programs were initiated by a science supervisor or master teacher who subsequently enlisted state-level, university, and community support. Second, many of the participating teachers received released time to work on curriculum and nearly all programs involved extensive inservice efforts. Third, the programs used locally developed curricula with standard textbooks playing a secondary role as resources and references. Fourth, program developers paid little attention to formal evaluation of the programs or teachers within programs.

Social studies educators should note that Penick and Yager report additional benefits from the Search for Excellence project beyond identification of exemplary programs. They report increased enthusiasm among teachers and students seeking to develop similar programs, increased interest in local support for science education, and a greatly increased number of requests to the local programs themselves for information about their efforts.[23] Analagous results in the social studies would be most welcome.

A second project just getting underway is "Teaching Science via Science, Technology and Society" (S-STS).[24] This national effort is headquartered at the Pennsylvania State University's Science, Technology and Society Program and has been funded by the National Science Foundation. The project's premise is that science instruction "is best accomplished by grounding such teaching in societally relevant issues--where science and technology impact students' lives and their day-to-day world."[25] Science/technology/society subject-matter is seen by the project "as a badly needed integrative theme in education and preparation for twenty-first century citizenship."[26]

The project has ambitious goals. It seeks to promote greater attention to science/technology/society subject matter in the junior and senior high school science curriculum. A project brochure states that the S-STS Project will:

> Create a network of all persons interested and active in the field.
>
> Inventory all existing relevant S-STS teaching materials.
>
> Create topical and regional task forces to determine the most timely S-STS subject areas, develop new instructional modules. . ..
>
> Disseminate information on the availability of existing and new S-STS teaching materials . . ..
>
> Hold national and regional workshops . . . to engage users, producers, and researchers in mutual learning . . ..
>
> Establish a national evaluation process . . ..[27]

The Search for Excellence and S-STS projects have strong potential for encouraging and strengthening instruction about science/technology/society issues and subject matter. They are, however, directed primarily toward science educators. Social studies educators should consider the possibilities associated with developing and undertaking parallel or complementary efforts. This could be a useful step in helping build the connections vital to education for citizenship we have discussed in this report.

Summary

Decision trees, role plays, and simulations organize subject matter and involve cognitive operations in ways that can help learners apply the perspectives of both the social studies and science in studying complex social issues. Thus, these instructional strategies are useful tools for building connections between social studies and science education. Proper application of such techniques can help students develop decision-making skills and acquire basic information about science/technology/society issues in distinct science and social studies courses.

Instructional television and microcomputers are also capable of connecting learning experiences in social studies and science. Television can dramatize issues and problems. Microcomputers can give students, working individually or in groups, the opportunity to work in dynamic ways on decision-making problems.

Science educators are undertaking systematic efforts to locate exemplary instructional practices relevant to teaching about science, technology, and society. In the process they are identifying common characteristics of successful programs and generating enthusiasm for this curriculum reform.

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NOTES

[1]John E. Penick and Robert E. Yager, "The Search for Excellence in Science Education," Phi Delta Kappan 64 (May, 1983), 621.

[2]Roger La Raus and Richard C. Remy, Citizenship Decision-Making: Skill Activities and Materials (Reading: Addison-Wesley, 1978). The technical literature on decision making is voluminous. For an introduction see: Percy H. Hill and others, Making Decisions: A Multidisciplinary Introduction (Reading: Addison-Wesley, 1979); Howard Raiffa, Decision Analysis: Introductory Lectures on Choices Under Uncertainty (Reading: Addison-Wesley, 1970); Robert Bell and John Coplans, Decisions Decisions: Game Theory and You (New York: W.W. Norton & Company, Inc., 1979); Samuel A. Kirkpatrick, ed., "Political Decision-Making: Interdisciplinary Developments from a Microanalytic Perspective," Special Issue American Behavioral Scientist 20 (September/October 1976).

[3]John J. Patrick and Richard C. Remy, Civics For Americans (Glenview, Illinois: Scott, Foresman and Company, 1982); John J. Patrick and Richard C. Remy, Lessons on the Constitution (Washington, D.C.: Project '87, American Historical Association, American Political Science Association, 1984).

[4]Patrick and Remy, Civics For Americans, 31-35.

[5]Faith M. Hickman, "Investigating the Human Environment: Land Use," BSCS Journal 2, 7.

[6]Paul DeHart Hurd, Reforming Science Education: The Search for a New Vision (Washington, D.C.: Council for Basic Education, Occasional Paper 33, 1984), 13.

[7]Ibid., 14.

[8]See, Fred M. Newmann and Donald W. Oliver, "Case Study Approaches in Social Studies," Social Education 31 (February 1967): 108-113; M. Eugene Gilliom, "Case Studies" in Practical Methods For the Social Studies ed. M. Eugene Gilliom, (Belmont, California: Wadsworth Publishing Company, Inc., 1977), 14-50.

[9]The pioneers include: Harold Guetzkow, ed., Simulation in Social Science (Englewood Cliffs, New Jersey: Prentice-Hall, 1962); Clark C. Abt, Serious Games (New York: Viking, 1970); Sarane S. Boocock and E.O. Schild, eds., Simulation Games In Learning (Beverly Hills, California: Sage Publications, 1968).

[10]Richard A. Brody and Charles N. Brownstein, "Experimentation and Simulation," Strategies of Inquiry, vol. 7 of Handbook of Political Science, ed. Fred I. Greenstein and Nelson W. Polsby (Reading: Addison-Wesley, 1975), 222.

[11] "Pipe Dreams: The Coal Pipeline Act," a unit in Creative Role-Playing Experiences in Science and Technology (Boulder, Colorado: Social Science Education Consortium, Inc., 1982). These materials are not commercially available.

[12] Phyllis F. Maxey, "Teaching About Nuclear Power: A Simulation," Social Studies Review 19 (Winter 1980): 43-46.

[13] Minaruth Galey, Project Director, You, Me, and Technology (Produced by New Jersey Network for Temple University; available from Agency for Instructional Television, Bloomington, Indiana, 1983).

[14] Newsletter, Agency for Instructional Television, XV (Winter 1984).

[15] H. Bernstein. "Computers in the 'Soft Subjects.'" Basic Education 26 (1981), 8.

[16] Charles S. White, "Citizenship Education Software: A Selective, Annotated Bibliography of Microcomputer Programs for the Social Studies," Social Education, 47 (May 1983): 338-343.

[17] S. Willoughby, Teaching Mathematics: What is Basic? (Washington, D.C.: Council for Basic Education, Occasional Paper 31, 1980), 1.

[18] "Advancing the Use of Computers in Schools," (Bloomington, Indiana: Agency for Instructional Television, 1982).

[19] Ibid., 8.

[20] Penick and Yager, "The Search for Excellence in Science Education," 621-623; in addition, see Norris Harms and Robert E. Yager, What Research Says to the Science Teacher Vol. III (Washington, D.C.: National Science Teachers Association, 1981).

[21] Penick and Yager, "The Search for Excellence in Science Education," 623.

[22] Publications currently available are: John E. Penick, ed., Science As Inquiry (Washington, D.C.: National Science Teachers Association, 1983); John E. Penick, ed., Elementary Science (Washington, D.C.: National Science Teachers Association, 1983); John E. Penick, and Ronald J. Bonnstetter, eds., Biology (Washington, D.C.: National Science Teachers Association, 1984); Ronald J. Bonstetter, John E. Penick and Robert E. Yager, eds. Teachers in Exemplary Programs: How Do They Compare (Washington, D.C.: National Science Teachers Association, 1984); Robert E. Yager, ed., Exemplary Programs in Physics, Chemistry, Biology and Earth Science (Washington, D.C.: National Science Teachers Association, 1984); Robert E. Yager, ed., Center of Excellence: Portrayals of Six Districts (Washington, D.C.: National Science Teachers Association, 1984).

[23] Penick and Yager, "The Search for Excellence in Science Education," 623.

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[24] Brochure, "Teaching Science via Science, Technology and Society Material," Pennsylvania State University, 1984. For further information contact Rustum Roy, Director, S-STS Project, The Pennsylvania State University, 202 Materials Research Laboratory, University Park, PA 16802.

[25] Ibid.

[26] Ibid.

[27] Ibid.

5. SOME CONCLUDING OBSERVATIONS

What is the impact of modern science and technology on education for citizenship? Our effort to give a reasoned response to this question has included an examination of major curriculum reform reports, reports by professional education associations, assessments of student achievement and curriculum, research on citizen participation in the public policy process, literature on the relation of science, technology, and the humanities, as well as literature on the history of curriculum reform.

What have we learned? The outcome of our analysis is spelled out in detail in the preceding sections. Here we draw together some key ideas to depict major challenges and opportunities posed for educators by the dynamic social efforts of science and technology.

1. <u>Education for competent citizenship must equip individuals with the basic understandings and capacities they need to follow and to participate in decisions about complex social issues related to science and technology.</u>

Long-standing democratic traditions of majority rule are threatened by the increasing complexity of science and technology issues seemingly understandable only by a handful of elites. Complexity will continue to grow. The alternative to complete domination of public policy-making by elites is to educate citizens who are scientifically literate and have the decision-making capacities to think intelligently about social issues.

Scientific literacy entails basic understanding of the norms and methods of science, some knowledge of scientific constructs, and awareness of the impact of science and technology on society and the policy choices that must inevitably emerge. Decision-making competence entails an ability to think systematically and flexibly about alternatives, consequences, and goals associated with complex social issues.

Major curriculum reform reports as well as reports by social studies and science educators support such goals. These reports stress the need to include significant attention to the connections of science, technology, and society in the education of citizens. Assessments of student achievement, however, clearly indicate the majority of students are not developing desired understandings. In addition, achievement of such educational goals, as well as public support for science and technology, is continually endangered by antagonists of science. The educational turmoil that can result from their efforts is well illustrated by the "scientific creationism" controversies.

2. Education for competent citizenship should connect distinct fields of knowledge in the school curriculum to maximize students' understanding of and capacity to think about the social effects of science and technology.

The social studies and the science curriculum are currently mutually isolated from each other. National curriculum assessments as well as textbook analyses indicate little attention is currently given to science, technology, and society subject-matter in existing courses and instructional materials. Further, there is little evidence of widespread use of instructional strategies which connect lessons in science and the social studies. Yet attention to science/technology/society issues by both fields is essential to achieving desired citizenship education outcomes.

The social studies and the sciences have distinct but complementary contributions to make to student learning about the social effects of science and technology. The social studies contribute to an understanding of the ethical and value components of science and technology issues. As scientists themselves readily point out, the moral, social, and human values dimensions of decision making about such issues are outside the realm of science. Science, on the other hand, contributes vital knowledge about alternative courses of action and their likely consequences. Scientific knowledge is essential to weighing the validity of competing factual claims about complex issues. Citizen appreciation of both the contribution and limitations of science in the resolution of science/technology/society issues rests on an understanding of the complementary nature of the sciences, the humanities, and the social sciences.

3. In order to substantially connect the social studies and the sciences in the school curriculum educators must find and use "integrative threads" upon which to build an interdisciplinary curriculum.

However we might wish otherwise, there is no broad theory of knowledge that incorporates the social studies and the sciences. As a result there is no organized body of facts, concepts, and theory upon which to build an interdisciplinary course focused on social problems. The history of curriculum reform clearly indicates that past efforts to create such courses have met with little success. Such efforts typically suffer from the inability of teacher and students to deal with vast amounts of raw information without the organizing help of a disciplinary approach and from the lack of historical perspectives on the problems under study.

To recognize these difficulties does not mean the only alternative is rigid compartmentalization of the academic disciplines. "Integrative threads" can be used to provide common learning experiences within and between distinct courses in the social studies and the sciences. "Integrative threads" are themes, concepts, principles, or methods of thinking that can link learning experiences within or between separate fields of knowledge.

4. <u>Decision making can be a powerful integrative thread for linking social studies and science instruction</u>.

The essential elements of decision making comprise a generalizable problem-solving routine that can be applied to a wide range of science/technology/society issues at both the personal and public policy level. Appropriate study of decision making can occur in both science and social studies courses at various levels of complexity with students of different ages. A variety of promising instructional practices, such as decision trees, are available to put instruction focused on decision making into widespread practice.

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Most, but not all, ERIC documents are available for viewing in microfiche (MF) at libraries that subscribe to the ERIC collection. Microfiche and/or paper copies of these documents can also be purchased from the ERIC Document Reproduction Service (EDRS), Box 190, Arlington, VA 22210. For price information, consult a current issue of RIE or CIJE or write EDRS.

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