

CHAPTER 1

HISTORY OF SCIENCE/TECHNOLOGY/SOCIETY AS REFORM IN THE UNITED STATES¹

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SCIENCE IN THE SCHOOL CURRICULUM

Science has been an integral part of the school curriculum for our entire history in the United States. Basically, science has been a collection of courses in high school that reflect the major disciplines of science, that is, astronomy, botany, chemistry, geology (physical geography), physics, physiology, and zoology. Although science has enjoyed status as a core “subject” in the secondary school curriculum, along with language arts, mathematics, social studies, and foreign languages, it has never been considered as basic as language arts and mathematics, presumably because of the special skills characterizing these two curricular areas (quantification, measuring, reading, writing, and speaking). Nonetheless, science has been considered an important and at times a vital part of the kindergarten through twelfth-grade curriculum, especially during the past fifty years.

Unfortunately, high school science is invariably associated with preparation for college. And the courses prior to high school are thought to be preparatory for the next science course for the next academic year. Although there have been many reform efforts for school science over our 200+ year history, few have resulted in significant changes. Most courses have been organized around basic concepts—those identified as important in a state framework or those recognized as basic by various professional groups. The major determiner for science content has been standard science textbooks, where there has been found to be less than a 10 percent variation among those available for a given grade level (Harms and Yager, 1981).

THE STS MEGATREND

Science/Technology/Society has been called the current megatrend in science education (Roy, 1984). Others have described it as a paradigm shift for

the field of science education (Hart and Robottom, 1990). In 1980 the National Science Teachers Association called STS the central goal for science education in its official Position Statement for the 1980s:

The goal of science education during the 1980s is to develop scientifically literate individuals who understand how science, technology, and society influence one another and who are able to use their knowledge in their everyday decision-making. The scientifically literate person has a substantial knowledge base of facts, concepts, conceptual networks, and process skills which enable the individual to learn logically. This individual both appreciates the value of science and technology in society and understands their limitations. (NSTA, 1982, p. 1)

During the decade that followed, STS became the focus for two year-books for NSTA (Bybee, 1985; Bybee, Carlson, and McCormack, 1984) and one for the Association for the Education of Teachers of Science (James, 1986). STS sessions have become a program category for NSTA conventions. A new national organization has been formed—the National Association for Science, Technology, and Society (NASTS); it has a growing membership. There have been several major NSF grants awarded to foster STS approaches to school science and related curriculum fields. Two of the largest grants have been awarded to the Pennsylvania State University which boasts of establishing one of the first STS programs in a major U.S. university.

Rustum Roy of Penn State was the Principal Investigator of a major NSF grant in 1985, a project called Science through STS. The effort involved surveying all STS initiatives, kindergarten through college, throughout the United States and other nations. Materials were collected, a newsletter was initiated, and new instructional materials were developed. It was from these initiatives that NASTS was launched. A second grant established a network for promoting STS among science and social studies leaders in all fifty states; this network continues to provide a communication link among STS reformers.

Nearly every textbook publisher has embarked on actions to add STS materials in response to state mandates and local curriculum developments. Often industrial and private foundations have added support for specific STS projects. All indicators seem to suggest that STS indeed is a megatrend. How did it arise? How has it evolved? What is the rationale for the movement?

ORIGIN

STS efforts were underway in several European countries before STS became a major focus in the United States. Two national programs have existed

in the United Kingdom for several years; both are active and sponsored by the Association for Science Education in the United Kingdom. The first of these was *Science in Society* (Lewis, 1981) and the second is called *Science in a Social Context* (SISCON) (Solomon, 1983). *Projekt Leerpakketontwikkeling Natuurkunde* (PLON) is a well-established STS program in the Netherlands (Eijkelfhof, Boeker, Raat, and Wijnbeek, 1981). *SciencePlus* is a curriculum development in Canada that enjoys widespread use in most provinces in the middle school years (ASCP, 1986, 1987, 1988).

STS as a term was coined by John Ziman in his book *Teaching and Learning About Science and Society* (1980). Ziman identified several courses and titles and special projects that had many common features. All were concerned with a view of science in a societal context—a kind of curriculum approach designed to make traditional concepts and processes found in typical science and social studies programs more appropriate and relevant to the lives of students.

STS IN THE UNITED STATES

There have been many attempts in the United States to initiate STS programs in secondary schools. One such attempt centered at the University of Iowa in the Laboratory School in the early 1960s. Faculty from social studies and science conceived a course called *Science and Culture*, which met graduation requirements in science or in social studies. The course, in operation until the school closed in 1972, was funded by a grant from the Department of Education and was the subject of a PhD dissertation (Cossman, 1967) and some resulting publications (Yager and Casteel, 1966, 1968). The research indicated that students were able to attain and to retain many skills and competencies defined as science literacy. Such skills and competencies were not developed as a result of study in standard social studies or science courses.

Although the many efforts and their results were encouraging, STS did not get underway in the United States until 1981 with the report of Norris Harms's *Project Synthesis* study (1977). Harms included STS as one of five areas of concern as school science programs were studied in terms of how they met criteria for excellence established by expert task forces. *Project Synthesis* was organized around four goal clusters that served as one basis for a variety of analyses. These goal areas offered justifications for the inclusion of science in schools and for requiring it each year for ten to thirteen years. These four goal clusters were:

1. *Science for meeting personal needs.* Science education should prepare individuals to use science for improving their own lives and for coping with an increasingly technological world.

2. *Science for resolving current societal issues.* Science education should produce informed citizens prepared to deal responsibly with science-related societal issues.
3. *Science for assisting with career choices.* Science education should give all students an awareness of the nature and scope of a wide variety of science and technology-related careers open to students of varying aptitudes and interests.
4. *Science for preparing for further study.* Science education should allow students who are likely to pursue science academically as well as professionally to acquire the academic knowledge appropriate for their needs.

An analysis of the three National Science Foundation (NSF) status studies (Helgeson, Blosser, and Howe, 1977; Stake and Easley, 1978; Weiss, 1978) and the *Third Assessment of Science* by the National Assessment of Educational Progress (NAEP, 1978) were also basic parts of Harms's Project Synthesis. Several findings concerning the actual state of science teaching combined to encourage more attention to STS approaches. These included:

1. Ninety percent of all science teachers used textbooks for science instruction in excess of 90 percent of the time.
2. Textbooks were devoid of any considerations of the first three goal areas (material dealing with personal needs, societal issues, and/or career awareness).
3. Instruction focused on textbook readings, teacher lectures, question and answer techniques, and verification-type "laboratories."
4. Over 90 percent of the evaluation in science classes was based on the recall of information.
5. Teachers viewed themselves as the determiners of information to be covered and the evaluators for discovering the degree such information was acquired by each student.
6. The only goal area of concern to teachers and in evidence in schools was the fourth one, that is, preparing students for the further study of science.

Harms concluded his analysis of Project Synthesis report:

... a new challenge for science education emerges. The question is this: "Can we shift our goals, programs, and practices from the current overwhelming emphasis on academic preparation for science careers for a few students to an emphasis on preparing all students to grapple successfully with science and technology in their own, everyday lives, as well as to participate knowledgeably in the important science-related decisions our country will have to make in the future?" (Harms and Yager, 1981, p. 119)

In one sense STS efforts are seen as responses to the first three goal clusters of Project Synthesis. STS means focusing on personal needs of students, that is, science concepts and process skills that are useful in the daily living of students. It focuses on societal issues, that is, issues and problems in homes, schools, and communities as well as the more global problems that should concern all humankind. STS also means focusing on the occupations and careers that are known today; it means using human resources in identifying and resolving local issues.

Evidence is mounting that concentrating on the first three goal clusters (STS foci) allows one to ignore goal area four. Students who are actively involved in studies that meet their personal needs, assist them to deal with current societal issues, and be aware of occupational-career possibilities, also find that science information is required—the same information that is widely accepted as needed preparation for further study in particular science disciplines. Students who experience their science in an STS format are well equipped to study and learn on their own, whether in college or in living outside of an educational institution.

For many, a focus on personal needs is an especially important concept for science in the elementary school. A focus on social issues and career awareness is often reserved for the middle and high school levels. However, when STS is viewed primarily as an approach to teaching and a meaningful view of science in people's lives, differences among the levels of teaching (i.e., kindergarten through college) become less significant than if STS is viewed primarily as a curriculum change.

STS is seen as a response to many of the perceived problems of traditional science teaching. The most critical problems with traditional science teaching are:

1. Students generally cannot use the science (either concepts or processes) that they learn. The number of misconceptions that typical high school students have is large. Misconceptions that the most successful students have are shocking. For example, recent reports indicate that 80 percent of university physics majors have misconceptions about nature even though they recite correct factual information and can perform exercises in the laboratory that contradict their own views of the world (Champagne and Klopfer, 1984). As many as 90 percent of engineering majors cannot relate their preparation to the real-world (Mestre and Lochhead, 1990).
2. Well over 90 percent of all high school graduates do not attain scientific literacy—even though they pass courses and generally perform well (Miller, 1989; Miller, Suchner, and Voelker, 1980). Science instruction does not seem to produce persons with traits of scientific literacy that are deemed important—perhaps the fundamental goal of instruction (see quote from 1982 NSTA Position Statement in the opening paragraph).

3. Interest in science and initiation of further study of science declines across the K–12 years. In fact, positive attitudes about science, science classes, science teachers, and the usefulness of science to living decline the more science is studied in school (ETS, 1988; Hueftle, Rakow, and Welch, 1983; NAEP, 1978; Yager and Penick, 1986).
4. Creativity is central to basic science, including the questions asked of nature, the explanations offered, and the tests devised to determine the validity of such explanations. And yet the study of typical science results in a diminution of the creativity skills originally possessed. Typical science instruction causes students to be less curious, less prone to offer explanations, less able to devise tests, less able to predict causes and consequences of certain actions (ETS, 1988; Hueftle, Rakow, and Welch, 1983; NAEP, 1978; Yager and Penick, 1986).
5. There is no evidence that traditional science teaching results in persons who possess the traits which characterize a scientifically literate person. NSTA adopted a listing of the characteristics of a person who is scientifically literate. Such a person:
 - a. uses concepts of science and of technology and ethical values in solving everyday problems and making responsible everyday decisions in everyday life, including work and leisure;
 - b. engages in responsible personal and civic actions after weighing the possible consequences of alternative options;
 - c. defends decisions and actions using rational arguments based on evidence;
 - d. engages in science and technology for the excitement and the explanations they provide;
 - e. displays curiosity about and appreciation of the natural and human-made world;
 - f. applies skepticism, careful methods, logical reasoning, and creativity in investigating the observable universe;
 - g. values scientific research and technological problem solving;
 - h. locates, collects, analyzes, and evaluates sources of scientific and technological information and uses these sources in solving problems, making decisions, and taking actions;
 - i. distinguishes between scientific-technological evidence and personal opinion and between reliable and unreliable information;
 - j. remains open to new evidence and the tentativeness of scientific-technological knowledge;
 - k. recognizes that science and technology are human endeavors;
 - l. weighs the benefits and burdens of scientific and technological development;
 - m. recognizes the strengths and limitations of science and technology for advancing human welfare;

- n. analyzes interactions among science, technology, and society;
- o. connects science and technology to other human endeavors, for example, history, mathematics, the arts, and the humanities;
- p. considers the political, economic, moral, and ethical aspects of science and technology as they related to personal and global issues; and
- q. offers explanations of natural phenomena that may be tested for their validity (NSTA, 1990).

STS means viewing science in a way quite different from the post-Sputnik period where the emphasis was on the identification of the central concepts, the unifying themes, and/or the major theories that characterize the various science disciplines if not science itself. The prevailing view is that science could be made meaningful, exciting, and appropriate for all if it were presented in a way known to scientists. Science educators were anxious to see, learn, and transmit this view of science to students. There was no chance for student ownership, student questions, or student views of the world in which they lived. Rather, the attempt was to get students into the world seen, known, and experienced by scientists; that was identified as the major task of the science teacher.

During the 1960s every effort was made to distinguish between science and technology. Basic science was a focus and technology was stricken from courses labeled "science"! STS means using technology as a connector between science and society. The applications of science are seen as closer to the lives of students, including advances and issues concerning food, clothing, shelter, transportation, communication, and careers.

Certainly STS is viewing school science in broader terms than merely the science concepts accepted by practicing scientists and the process skills they use to discover new concepts and/or to test old ones. STS assumes that equating science only to specific concepts and processes and then assessing the degree each has been acquired is not an adequate indicator of real learning. Such practices provide no information concerning how the concepts and processes can be used in the lives of students and for future problem resolution.

STS AS A MEANS FOR MEETING EDUCATIONAL GOALS

If STS is proclaimed a megatrend in science education, it must focus on educational goals and unifying themes that tie most disciplines together to meet common goals. The strength of STS is the use of personal, societal, and career imperatives as organizers for curriculum. Such organizers bring relevance to study and build on past and continuing experiences of stu-

dents. STS, when considered broadly, is free of specific topics, its own concepts, special processes, and unique teaching strategies. In final analysis STS is focusing on real issues of today with the belief that working on them will require the concepts and processes so many consider basic. In traditional schools and curriculum outlines, the concepts and processes of a given discipline are central. Time and effort are expended to figure out better ways to *present* this information and these skills to students. STS means starting with a situation—a question, problem, or issue—where a creative teacher can help students see the power and utility of basic concepts and processes. STS means starting with students and their questions, using all resources available to work for problem resolution, and, whenever possible, advancing to the stage of taking actual actions individually and in groups to resolve actual issues. STS makes science instruction current and a part of the real world. STS provides a context for learning basic concepts and process skills.

STS means dealing with students in their own environments and with their own frames of reference. It means moving into the world of applications, the world of technology, the world where the student makes his or her own connections to living and to the traditional disciplines.

Dealing with the real-world and problems in it tends to improve student attitudes and to use and sharpen creativity skills. These are called the enabling domains. They provide access to the concepts and processes as seen, advanced, and practiced by the professionals in a given discipline. When one starts with these concepts and processes (as in the case in traditional discipline-bound programs), most students are lost before they can apply anything to their own lives. Attitude worsens and creativity skills decline as one considers concepts and processes for their own merit and centrality. Those who maintain that scientific literacy is a nongoal usually assume that such literacy is dependent on the mastery of such standard concepts and processes. They insist that it is impossible to make all students knowledgeable of all basic/central concepts and processes that characterize a discipline. And this is so—if one accepts a definition of science/technological literacy and focuses only on a recitation of “basic” concepts and process skills.

Concept mastery is a goal. But for mastery to exemplify real learning, information and process skills must be demonstrated as useful. Such a situation seldom occurs as a result of typical instruction. STS means that concepts and processes are useful because they are encountered when the student needs them to deal with problems he or she identifies. This occurs because of high motivation and interest and because the student has formulated questions, has offered explanations, and is interested in the validity of these explanations. This is science and these are basic ingredients of creativity.

REQUIREMENTS FOR IMPLEMENTING STS

STS teaching requires new models for pre- and inservice teacher education. One of the greatest problems associated with shifts to STS teaching is the failure of most teachers, even those newly certified, to have ever experienced science study and learning themselves as STS, that is, learning in the context of human experience. The current focus upon the Constructivist Learning Model (Yager, 1991; Yeany, 1990) indicates the importance of learning (including learning to teach differently) by direct personal experience.

A rationale/framework for STS can be discerned from a set of contrasts dealing with concepts, processes, attitudes, creativity skills, and applications. Tables 1.1–1.5 provide lists of these contrasts.

TABLE 1.1 Contrasts of Student Mastery of Concepts Emerging from Traditional and STS Classes

<i>Traditional</i>	<i>STS</i>
1. Concepts are really bits of information mastered for a teacher test	1. Students see concepts as personally useful
2. Concepts are seen as outcome themselves	2. Concepts are seen as a needed commodity for dealing with the problems
3. "Learning" is principally for testing	3. Learning occurs because of activity; it is an important happening but not a focus in and of itself
4. Retention is very short lived	4. Students who learn by experience retain it and can often relate it to new situations.

TABLE 1.2 Contrasts of Student Process Skills Emerging from Traditional and STS Classes

<i>Traditional</i>	<i>STS</i>
1. Students see science processes as skills scientists possess	1. Students see science processes as skills they can use
2. Students see processes as something to practice as a course requirement	2. Students see processes as skills they need to refine and develop more fully for themselves
3. Teacher concerns for process are not understood by students, especially since they rarely affect course grades	3. Students readily see the relationship of science processes to their own actions
4. Students see science processes as abstract, glorified, unattainable skills unrelated to their lives	4. Students see processes as vital parts of what they do in science classes

TABLE 1.3 Contrasts of Student Attitudes Emerging from Traditional and STS Classes

<i>Traditional</i>	<i>STS</i>
1. Student interest declines at a particular grade level and across grade levels	1. Student interest increases in specific courses and from grade to grade
2. Science seems to decrease curiosity about the natural world	2. Students become more curious about the natural world
3. Students see teacher as a purveyor of information	3. Students see teacher as a facilitator/guide
4. Students see science as information to learn	4. Students see science as a way of dealing with problems

TABLE 1.4 Contrasts of Student Creativity Skills Emerging from Traditional and STS Classes

<i>Traditional</i>	<i>STS</i>
1. Students decline in their ability to question; the questions they do raise are often ignored because they do not fit into the course outline	1. Students ask more questions; such questions are used to plan activities and use materials
2. Students rarely ask unique questions	2. Students frequently ask unique questions that excite their own interests, that of other students, and that of the teacher
3. Students are ineffective in identifying possible causes and possible effects of specific situations	3. Students have skills needed to suggest possible causes and effects of certain observations and actions
4. Students have few original ideas	4. Students seem to effervesce with ideas

TABLE 1.5 Contrasts of Application of Science Concepts Emerging from Traditional and STS Classes

<i>Traditional</i>	<i>STS</i>
1. Students see no value and/or use of their science study to their living	1. Students can relate their science study to their daily living
2. Students see no value in their science study for resolving current societal problems	2. Students become involved in resolving social issues; they see the relativity of science study to fulfilling citizenship responsibilities
3. Students can recite information/concepts studied	3. Students seek out information to use in dealing with questions
4. Students cannot relate the science they study to any current technology	4. Students are engrossed in current technological developments and use them to see the importance and relevance of science concepts

STS as a movement is less than ten years old in the United States. In that short time it has grown from a seemingly new idea to a major effort in every state. There remain conflicts as to what it is and what it is not. Many cannot deal with a movement like STS, which is not curriculum based. Instead of a curriculum it is a context for a curriculum. Many want to reserve judgment on STS until they see a curriculum and some goals and assessment instruments focused on basic concepts. Others are moving from STS to integrated science themes thereby retaining a more common concept of science courses and topics in them. Many in the STS movement are resisting the temptations of preparing a curriculum outline, of adding STS strands to existing courses and textbooks, of identifying new lists of concepts and processes, or preparing new examinations to assess the degree of recall of the new concepts and process skills. They even resist the temptation to move to identifying the effort as one of integrating science concepts from a variety of disciplines. To provide this framework can mean the end of Roy's Megatrend and/or Hart and Robotom's suggestion that STS represents a Paradigm Shift.

NOTE

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