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ABSTRACT

This paper proposes a teaching model for the implementation of a Science-Technology-Society (STS) curriculum. The topics of technologic literacy, STS goals, and STS instruction are included. The historical and contemporary perspective of technology is addressed. The Graham model of STS instruction is compared with the Oregon instructional model. The eight parts of the Oregon model are described by the following: (1) "Issues in Application of Technology"; (2) "Diagnosis of Understanding"; (3) "Technological Processes"; (4) "Instructional Method and Technology"; (5) "Science Content"; (6) "Essential Learning Skills"; (7) "Problem Solving and Decision Making"; and (8) "Responsible Action". (KR)

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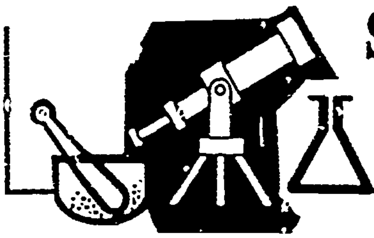

Science, Technology and Society

Science Curriculum Concept Paper #3

"From the moment humans first picked up a stone or a branch to use as a tool, they altered irrevocably the balance between them and their environment. From this point on, the way in which the world around them changed was different. It was no longer regular or predictable. New objects appeared that were not recognizable as a mutation of something that had existed before, and as each one emerged it altered the environment not for a season, but forever. While the number of these tools remained small, their effect took a long time to spread and to cause change. But as they increased, so did their effects; the more the tools, the faster the rate of change."

Adapted from an article by James Burke in *Connections*

Introduction

Recent years have seen the expression of a variety of concerns related to science education and its role in the public schools. These concerns range from decline in enrollment at the secondary school and neglect of science education at the elementary school to failure to meet national demands for continuing supremacy in science and technology. These changes show in declining test scores and low achievement in comparison with students in other technologically developed nations (Hurd, 1984; Penick and Yager, 1986; Trowbridge and Bybee, 1986, International Association for the Evaluation of Education Achievement, 1988).

Responding to the perceived needs of science education, the National Commission on Excellence in Education, itself a primary critic, called for a broadening of the curriculum to include not only the concepts, laws and processes of science, and the methods of scientific inquiry and reasoning but also the application of scientific knowledge to everyday life, and the social and environmental implications of scientific and technological development (*Nation at Risk*, 1983). The National Science Board on Precollege Education echoed this direction by stating that science and technology education should be considered a 'basic' and recommending that science curriculum *"should be organized around problem-solving skills, real-life issues, and personal and community decision making."* This recommendation took form in a series of goals which included development of the *"scientific and technical knowledge needed to fulfill civic responsibilities, improve the student's own health and life, and ability to cope with an increasingly technological world"* (*Educating Americans for the Twenty-First Century*, 1983).

Preceding the National Commission on Excellence in Education and National Science Board Reports but responding to the same concerns, the National Science Teachers Association, in its 1982 Position Paper, 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."* In the position paper the scientifically literate person is defined as one who "has a substantial knowledge base of facts, concepts, conceptual networks, and process skills which enables the individual to continue to learn and think logically" and who "appreciates the value of science and technology in society and understands their limitations."

Technologic Literacy

Because the influence of science on society is through technology, it is instructive to define technology and consider its particular relationship to social behavior.

- Selby (1986) defines technology as *"both the process and the product of human endeavors to develop tools and systems to enhance human capacity to do, to feel, to smell, to think."*

- As a discipline, technology is defined by DeVore (1986) as *"the study of the creation and use of technical means—tools, machines, techniques, technical systems—and the behavior of technological systems in relations to people, their societies, the environment and the civilization process."*

- Kline (1986) characterizes technology as consisting of artifacts (non-natural objects manufactured by humans (e.g., an automobile); socio-technical systems of production (all elements needed to manufacture a particular kind of hardware; e.g., an assembly line); techniques (information, skills, processes, and procedures for accomplishing tasks; e.g., automation); and socio-technical systems of use (combinations of hardware and manpower to accomplish particular tasks; e.g., a transportation system).

Technological literacy is the ability to communicate effectively about technology and its influence on individuals, including ourselves, and groups living in a highly technological society (Roy, 1985). Piel (1985) describes the technologically literate person as one who has some understanding of the specific capabilities and limitations of specific technologies. This person understands that technology is purposeful and has the confidence to learn about technology *"even without a technological background."* Miller (1986) adds to this an understanding of terminology necessary to communicate about technological issues and recognition of the interaction between people and the technologies they use.

> *"The technologically literate person should understand that in democratic societies, citizens can have some say in which technologies are advanced and which are restrained."* Miller 1986

In the above descriptions two elements of technological literacy are clear. The first is an understanding of technology and the processes associated with its development. The second reflects socio-technical considerations of application and their relationship to the individual.

Focusing particularly on the socio-technical dimension, Snow (1988) has created the following list of statements which place technology in historical and contemporary perspective.

From a *historical* perspective:

- Human beings are technology users—that is how we have always made our way as a species.

- The social and environmental problems of the modern world are similar to those which have always faced human societies. The uniqueness of the contemporary situation lies in the power, rapidity of development, and the wide scale of application of modern science-based industrial technology.

- Significant decisions about technology always involve questions of social equity and environmental quality because they allocate resources and the opportunities of individuals and/or groups to use those resources.

- Changes in the technical systems usually confer both benefits and burdens upon individuals and communities. Often the benefits go mainly to one group while the burdens are born by others.

- Technological changes are always implemented and supported by particular individuals, groups or organizations to achieve their particular goals.

- Significant technological changes always have unintended and unforeseen environmental and social consequences.

From a *contemporary* perspective:

- Decision making about complex technological issues usually involves trade-offs among alternative courses of action. Often the trade-offs involve weighing the benefits and burdens for people and the environment.

- The specialized training and experience of technical experts encourages the development of a characteristic tunnel vision which makes it difficult for them to recognize the importance of the science-technology-society web and to take account of the science-technology-society connections.

- People share a persistent tendency to assume that the development of more powerful technologies will inevitably lead to social progress.

- Technological decisions are always made within a context of uncertainty.

Technology is a fundamental force in our modern society. Its importance to the school curriculum has been underscored by the reports and recommendations of the national panels and commissions which recognize that, while science and technology are not synonymous, they are closely related and interdependent, and that, while knowledge in science is not sufficient to the development of technological literacy, it is a necessary component.

> A common recommendation has been that considerations of technology as a socio-technical system be incorporated into the goals and curriculum of school science.

Science-Technology-Society (STS) Goals

While many efforts at responding to the perceived crisis in science education have been external (e.g., additional required coursework, increased graduation requirements, increased teacher certification standards, standardized achievement testing), other efforts have focused on curriculum and have led to re-examination of the goals and structure of the science curriculum. For example, the National Science Through Science-Technology-Society (S-STS) Project at Pennsylvania State University has framed the following goals for science instruction which emphasize the interrelationship of science, technology and society:

- Show the relationship of technological and scientific developments to socially relevant issues.

- Show the influences of technology, science, and society on each other.

- Develop the learners' understanding of (a) themselves as interdependent members of society, (b) the effects of society upon the eco-system of nature and of nature upon society.

- Examine differing viewpoints about STS issues and options.

- Explore broad considerations of science, technology, and society including personal and societal values and ethics.

- Develop problem-solving and decision-making skills, and apply these skills to everyday social issues involving science and technology.

- Encourage learners to become involved in a personal course of action after weighing the advantages and disadvantages of the different options in STS areas.

- Foster learners' confidence in using and understanding quantified, scientific, and technological information in at least one limited area as a basis for making judgements about STS issues (*S-STS Reporter,* 1986).

In Oregon, the relationship between science technology, and society is addressed in Goal 6 (Interactions) of the Common Curriculum Goals for science education.

Implementation of STS goals occur through insertion of single lessons or short topics at appropriate sections of the regular science curriculum, discrete units, short or regular courses offered as electives, interdisciplinary courses encompassing several subject areas, or single or multi-grade curricula focusing on STS (Jarcho, 1985). Regardless of the strategy employed, the content, as envisioned by the STS Project (*S-STS Reporter,* 1986), should address:

- the characteristics of science, technology, and society and elicit perspectives on science, technology, and society through historical, philosophical, religious, ethical, sociological, economic, political, aesthetic, practical, personal, and ecological consideration;
- the relationships of science, technology and society;
- individual, family, local, national, global responses to STS by asking questions, seeking solutions, and framing and addressing relevant issues.

In reviewing ten exemplary STS programs described in the National Science Teachers Association monograph ***Focus on Excellence: Science/Technology/Society*** (Penick and Meinhard-Pellens, 1984), Rubba (1987) identifies two common characteristics that define effective STS education as issue investigation and action. He further identifies the development of skill in the endeavors of issue investigation and responsible action as the core of STS instruction. The former, he characterizes as encompassing problem investigation skills such as problem identification, exploration of alternative approaches, and devising and acting upon a plan. The latter, action skills instruction addresses the rationale and means for taking action (e.g., civil, consumer, legal, persuasion, physical, political). He then translates this instruction into curriculum in terms of four levels of competencies.

- The STS Foundation Level (I) should provide learners with sufficient background knowledge:

  (a) of concepts in the natural and social sciences,

  (b) on the nature of science and technology, and

  (c) in the characteristic interactions among science, technology, and society

  to enable them to make informed decisions on STS issues.

- The STS Issue Awareness Level (II) should help learners become cognizant of how the interrelationships between science, technology, and society sometimes result in issues that must be resolved by examining:

  (a) all sides of the issue,

  (b) human beliefs and values,

  (c) alternative solutions for resolving issues, and

  then by taking action.

- The STS Issue Investigation Level (III) should develop in learners the knowledge and skills to:

  (a) investigate STS issues, and

  (b) judge the efficacy of possible solutions against various value positions.

This level would encompass training with problem investigation skills and the second opportunity for learners to apply these skills in the investigation of STS issues.

- STS Action Skills Development (IV) should develop learners' skills which could be used individually or in groups to take action on STS issues. Instructional activities would be designed to:

  (a) develop an understanding of actions that fall into one of five categories (consumerism, legal action, persuasion, physical action, and political action), and

  (b) offer opportunities to apply these actions and evaluate their effectiveness in resolving STS issues.

Science-Technology-Society (STS) Instruction

The S-STS Project prescribed the following as techniques appropriate to instruction in STS:

- Organize topics, lessons, units, or courses around topics which illustrate the integration of science and technology in a societal context.
- Include issues which meet the interests and aptitudes of students and teachers that (a) relate to the lives of the students, their families, and communities, and (b) emphasize connections to themes of broader regional, national, and global significance.
- Focus on the practices and procedures by which knowledge of STS is gained by asking "How do we know?," "Why should we care?," and "What can we do? "
- Gather information from diverse sources and communicate it in a variety of ways.
- Encourage students to explore their emotions and values in relation to specific issues.
- Practice decision-making strategies leading to action on real problems.
- Give interdisciplinary perspectives by bringing together perspectives from the arts, social science, and natural sciences.
- Draw on sources available locally (e.g., industry, government, the press, religious organizations, public interest groups).
- Use student projects, case studies, debates, field trips, role-playing, simulations, games, and community based experiences.
- Use a variety of instructional techniques (*STS Network,* 1986).

Graham (1986) identifies four instructional components (societal problems and issues, technological processes and devices, scientific concepts and principles, and problem solving and decision making) and offers three instruction strategies or patterns for their discussion. Instruction may begin with societal problems and issues, technological processes and devices, or with basic science, but in each case concludes with problem solving and decision making (Figure 1).

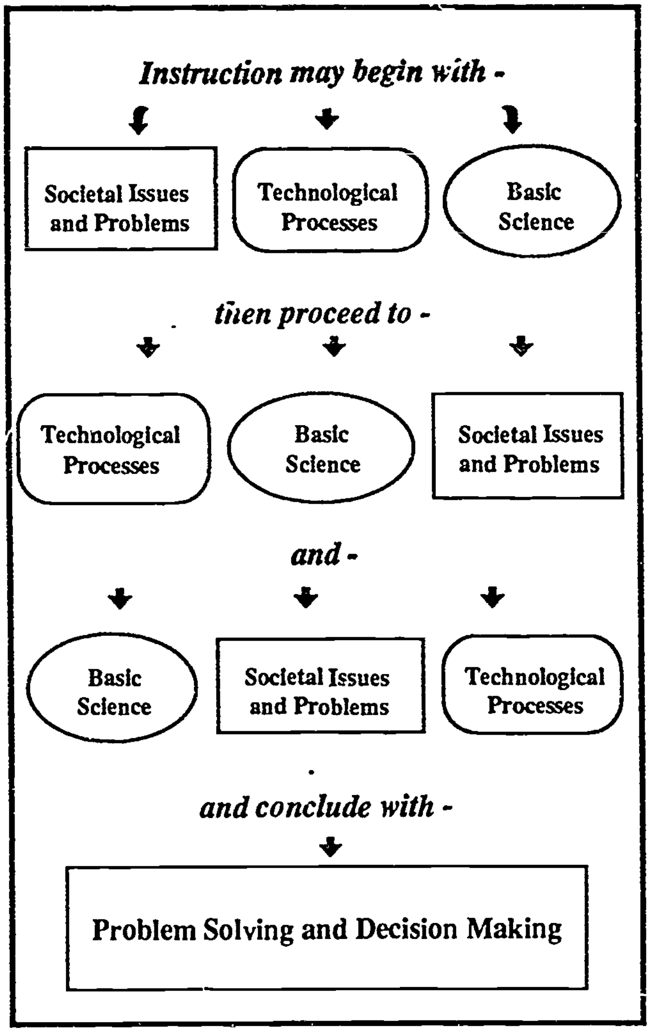

Figure 1. STS Instructional Model (Graham, 1986)

The Oregon model of science instruction is presented in Figure 2 (page 6). As with Graham, instruction may be initiated at any point in the issue investigation step of the model but must conclude with decision-making and responsible action. This progression is consistent with studies in environmental education which suggest that knowledge and skill in the use of action strategies are essential to continuing involvement with environmental issues (Sia, 1986; Hines, Hungerford, and Tomera, 1987).

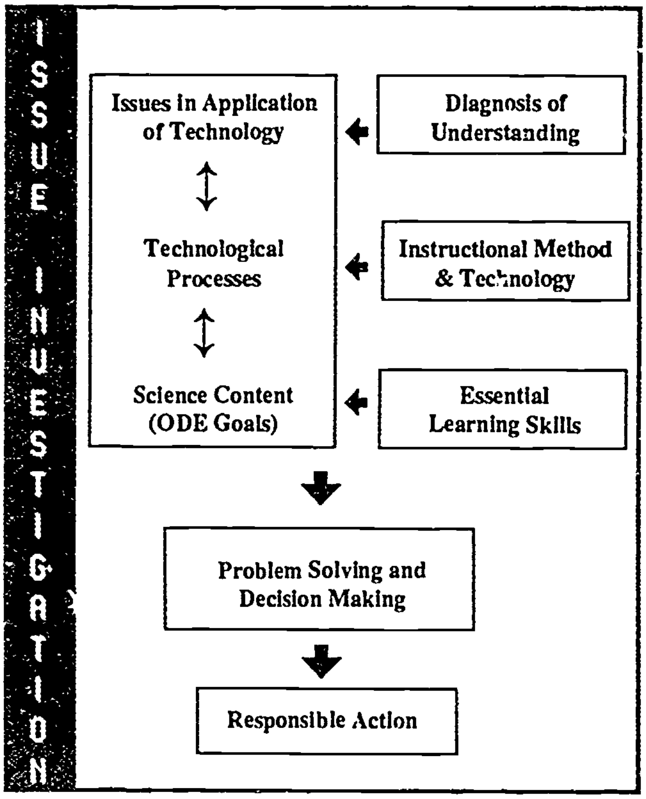

Figure 2. Instructional Model for STS Instruction

The following is a brief description of each of the elements of the above model:

Issues in Application of Technology. The most appropriate issues for the STS classroom are those of relevance and interest to the students in that classroom. These issues, often of a local and restricted nature, are important because they are most likely to motivate students and to provide the opportunity to gain real experience in decision making and responsible action. Many of these issues will be subsumed under pressing national and global issues and may form a bridge to their considerations, but the opportunity for students to practice issue investigation and responsible action skills in a context in which they may see the benefit of their effort requires, at least initially, a local orientation.

Diagnosis of Understanding. Findings from recent research on student misunderstanding of science concepts suggest that students' comprehension is strongly influenced by the experience and knowledge they bring to the learning task (Champagne and Klopfer, 1984). Children do not live in a vacuum prior to or during their formal school experience. They observe their natural environment and construct "theories" (albeit naïve) that persist and influence later learning.

It becomes important to understand the child's 'science' in order to challenge naïve theory with more accurate, serviceable knowledge.

Technological Processes. Technology is more common in the experience of students than science and is often of greater interest to them. By relating science to technology their interdependence and social significance are emphasized in a manner that has meaning in the daily lives of students. The concept of 'cycle' may be abstract but the role of technology in enhancing or interfering with natural cycles may have some significance; 'probability' as an independent concept may not have immediate utility but risk-benefit analysis as a technique of decision-making might. Science impacts society through technology, and it is appropriate to emphasize that relationship through science instruction.

Instructional Method and Technology: Although science as a discipline is envisioned as active and participatory, school science is often didactic. Strategies for the teaching of science with a technological orientation should be to the greatest extent possible student centered and activity-based.

Students need not only learn and practice process skills traditionally associated with the conduct of science but also issue investigation and action skills pertinent to participation in a technological society.

Further, since technology impacts our lives daily in the form of information management and dissemination systems, these should be integrated into instruction whenever possible.

Science Content. The seven science goals prescribed in the *Oregon Comprehensive Curriculum Goals: Science Education* (1989) form an operational definition of scientific literacy. Since scientific literacy is necessary to the development of technological literacy, the goals provide a structure appropriate to a model of instruction which seeks to focus on the interdependence of science and technology and on the relationship of both to society.

Essential Learning Skills. Identified by the Oregon Department of Education as those skills necessary to gain knowledge, to communicate effectively, to think logically, and to solve problems, the Essential Learning Skills are directly addressed in STS learning activities. Skills in the use and communication of quantitative data, problem definition, obtaining information, reasoning, problem solving, and using resources are directly applied in the processes of investigating, decision making, and initiating responsible action through an STS curriculum.

Problem Solving and Decision Making. Answers deriving from applications of science and technology are often political, 'best' answers are contextually defined.

> STS addresses how science and technology create the need for action in an environment in which there may be no "right answer" only the "least wrong response," and in which action must be based on moral and ethical considerations as well as on the interpretation and analysis of scientific data.

There are a number of decision-making strategies and techniques that might be employed in the development of plans of responsible action. Hickman (1985) suggests a generalized process of:

(a) problem recognition,
(b) generation of alternative courses of action,
(c) description of the consequences of the alternative course(s) of action,
(d) analysis of the consequences in terms of well-articulated value positions,
(e) selection of preferred alternative, and
(f) evaluation of the alternative in terms of previously established criteria.

She further suggests the application of techniques such as 'weighted options' (Oxenfelt, 1979) and 'fault-free analysis' (Fischhoff, Slovic, and Lichenstein, 1978) as examples of appropriate techniques for use in identification and analysis of consequences.

Responsible Action. Responsible action in relation to a specific issue is a critical element in the STS instructional model. This action might represent a group decision or an expression of individual concern or commitment. In either case students need to learn appropriate techniques of positive action which are directed toward influencing, within a particular context, the way in which science, technology, and society interact. Actions might be political (e.g., letters to congressmen, participation in public hearings), economic (e.g., participation in a consumer boycott), social (e.g., initiating a school recycling program), or personal (e.g., an individual commitment to a course of action) but should always follow a careful analysis of alternatives and the effects of the action as well as the technology toward which it is directed.

Conclusion

Although the concept of STS education within the context of the science curriculum has been addressed, it should be noted that STS education is a theme that carries across much of the remaining curriculum as well. Certainly, all forms of technical education are closely allied. But perhaps more importantly, appropriate response to technology as we experience it in our everyday lives requires knowledge of social, cultural, economic, and political issues as well as exploration of personal and social values and ethics. STS education is an interdisciplinary endeavor which can be viewed as a bridge across the curriculum, drawing together diverse subject matter in a manner reflective of the true integration of knowledge.

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