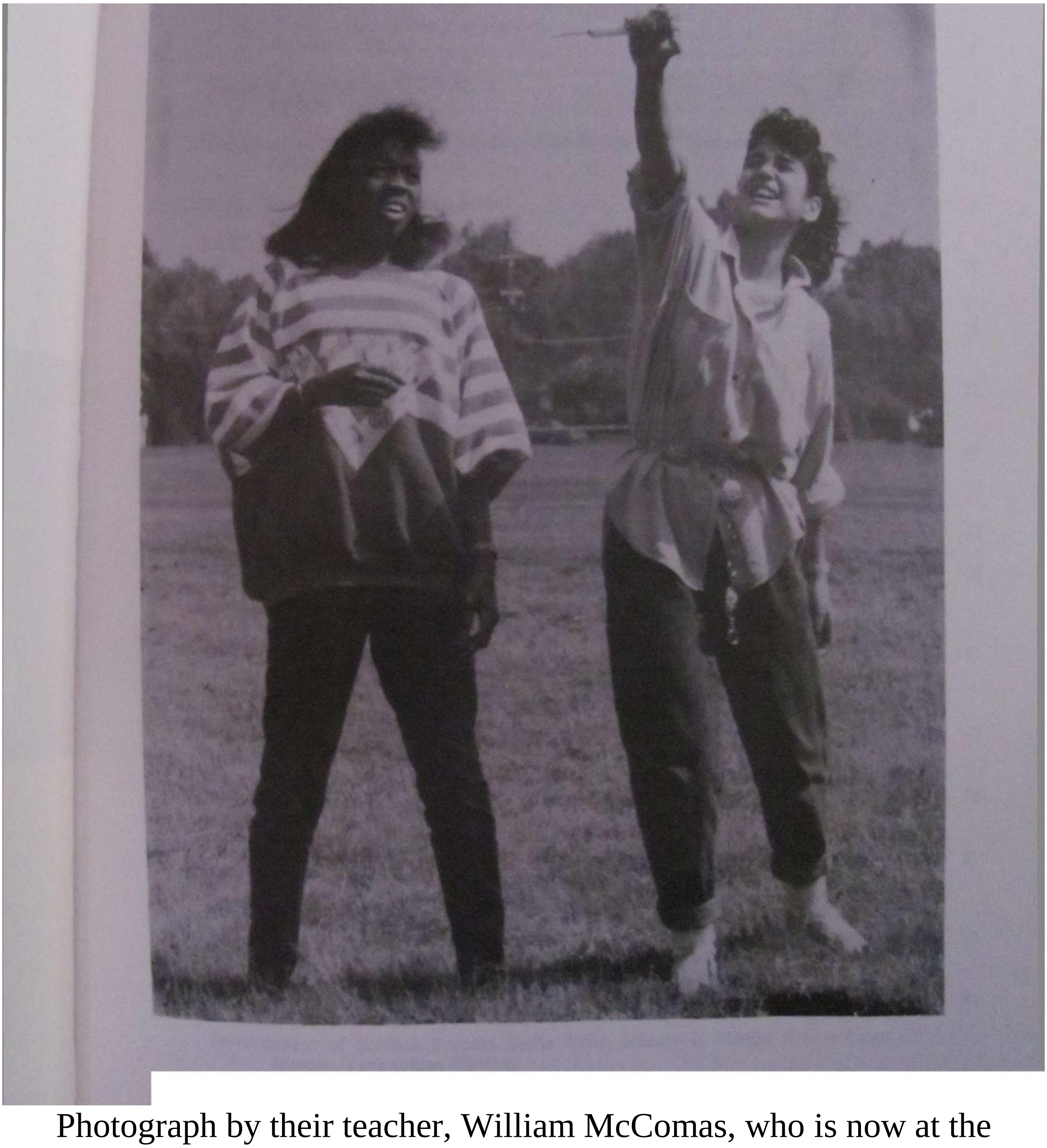
INTERNATIONAL COUNCIL OF ASSOCLATIONS
FOR SCIENCE EDUCATION

ICASE YEARBOOK 1992

The Status of Science - Technology - Society Reform Efforts around the World

Edited By Robert E.Yager

Students at Eisenhower Middle School in East Norristown, Pcnnsylvanla take an active interest in science as they «experiment with watcr rockets



Photograph by their teacher, William McComas, who is now at the University of lowa Science Education Center

Table of Contents

SECTION II - Examples of STS Initiatives…………………………………………….18

SATIS 16-19 on Trial in the UK
Andrew Hunt and Graham Lenton 19
The Jurisprudential Model of Study For STS Issues
Jon E. Pedersen …………………………………………………………26
Environmental Education; Sustainable Development and Decision-Making
Koos Kortland……………………………………………………………32
STS in the Preparation of Elementary Science Teachers
Dar-Sun Huang .... ……………………………….40
Experiences with Research and Development to Improve STS-Education on Radioactivity and lonizing Radiation
Harrie Eijkelhof and Piet Lijnse…………………………………………… 47

FOREWORD

Science-Technology-Society attracts even more attention than it did ten years ago when it became **a ne** w focus for reform in a few nations İlke the United ICingdom, The Netherlands, and, to a lesser extent, the United States. Currently it is a focus in nations on every continent. For many it represents the most significant change seen in classrooms during this century. For some the reform seems slow--not to be realized to any degree before the year 2000.

This Yearbook has been prepared as a means of updating science educators and ICASE member societies around the world. Hopefully it wİU help coalesce the concept in ali nations and provide support for emerging projects in other nations. The reports are offered in the spirit of providing a statü s statement. Alsot information is included that can be used as evidence for STS as real reform. Hopefully such evidence will be useful for schools and the most innovative and creative teachers in science societies who are struggling with STS in their own situations. The Yearbook is organized as STS definitions and ratioııales, exampies of STS initiatives, evaluation of STS efforts, and reports of STS moves in various nations. The authors ali hope their contributions provide useful information and suggestions. They ali hope that the Yearbook provides a needed record of where we are while also being controversial enough to promote debate and dialogue.

Robert E. Yager, Editör
Jack B Holbrook, ICASE
Executive Secretary

A companion volume focuses upon the research concerning STS--with a focus on results of efforts in the U.S. This volume, prepared by a National Science Teachers Association (NSTA) Task Force, is also edited by Robert Yager. It will provide much additional information concerning emerging assessment and evaluation data of value and interest to the international STS movement. The publication is entitled: ***W hat Research Says to the Science Teacher About STS.***

It is available by contacting:

Special Publications National Science Teachers Association 3140 North Washington Boulevard Arlington, Virginia 22201 703-243-7100
FAX: 703-243-7177.

SECTION I - STS Definition and Rationale

This section offers meaning to the STS concept and/or teaching approach and provides a philosophy for STS efforts. The broad definition of the National Science Teachers Association in the U.S. is advanced as the most useful and inclusive of the definitions generally used. This definition focuses upon the context for teaching and learning. It assumes the accuracy and usefulness of the Constructivist Learning Model as reform calls for a greater success with science education in schools are more frequent and intense. The modej. emphasizes the importance of human experiences and personal involvement for real learning to occur.

Science-Technology-Society as Reform

Robert E. Yager
The University of Iowa, USA

Science-Technology-Society (STS) is recognized as reform in science education across the world. Curriculum developers and textbook publishers are anxious to include STS themes. Unesco has shifted its emphasis from integrated science to STS, presumably because it provides a context for science study and thereby becomes more appropriate for all learners. Science for the sake of science, science as an expression of the structures produced and valued by scientists, science because we live in a science/technological age can be science that most students see as unimportant to them. To put science in a human context makes science relevant to the lives of all.

Many STS enthusiasts are content to define STS in a curricular sense. They identify strands, lessons, topics, and special themes which they label STS. Such a curriculum emphasis means that course structures, textbooks, .and curriculum frameworks are based upon different concepts of science and technology than typically found in schools around the world.

The National Science Teachers Association (NSTA) in the US has developed a Position Statement on STS--because of the growing importance of STS in US schools (NSTA, 1990-1991. STS has been identified as a new trend in most state frameworks; it has become a theme area for most professional meetings of science teachers. The popularity of STS and variations of its meaning prompted the NSTA action. Because of the size and prestige of NSTA, many are adopting its definition of STS and the associated descriptions of the basic features of STS as reform.

NSTA has defined STS as the teaching and learning of science in the context of human experience. It emphasizes the importance of technology <u>and</u> science, noting that technology is understood better and accepted more readily as curriculum and course topics appropriate for <u>all</u> students even though it has not been a focus previously. Student interest in and knowledge of technology seems strange to many active in the post-Sputnik era when technology was consciously stricken from K-12 science courses. "Science" was to include only pure science and the basic concepts of the disciplines were routinely used to define courses. Most science educators now see the folly of this. Now many advocate the inclusion of technology concepts in science courses. However, the curriculum continues to be organized around concepts. The curriculum is an expression of the espoused goals and instruction is relegated to a position of "considering" the curriculum.

STS as reform provides a focus on instruction. STS advocates argue that what a teacher does and how a teacher teaches is more important in stimulating student learning than a curriculum framework. Such thinking is in keeping with the Constructivist Learning Model which indicates that real learning results when individuals construct meaning of objects and events they encounter on their own. Typical science instruction, on the other hand, assumes that science (and technology) can be identified by the teacher (and/or the textbook and the course) and "given to" students. Such is not the case for STS classrooms.

NSTA has identified eleven features of STS programs. These features indicate the importance of instruction over curriculum and indicate how the "context of human experience" is attained. STS programs are those which include:

* student identification of problems with local interest and impact;
* the use of local resources (human and material) to locate information that can be used in
  problem resolution;

* the active involvement of students in seeking information that can be applied to solve real-life problems;
* the extension of learning beyond the class period, the classroom, the school;
* a focus upon the impact of science and technology on individual students;

a view that science content is more than concepts which exist for students to master on tests;
an emphasis upon process skills which students can use in their own problem resolution;
an emphasis upon career awareness—especially careers related to science and technology;
opportunities for students to act in their communities as they attempt to resolve issues they have identified;
identification of ways that science and technology are likely to impact the future;
some autonomy in the learning process (as individual issues are identified and considered).

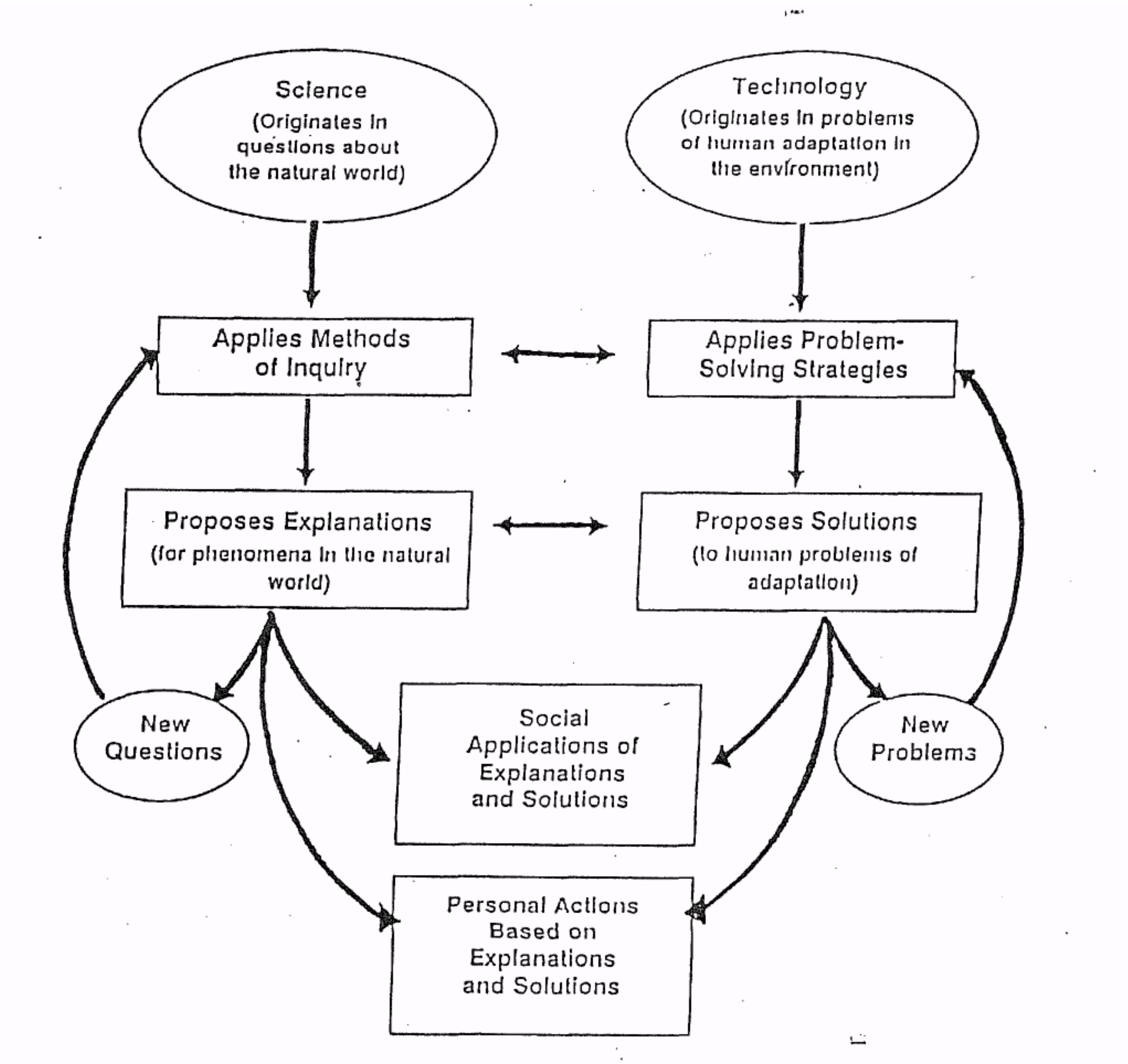
Basic to STS efforts is the production of an informed citizenry capable of making crucial decisions about current problems and issues and taking personal actions as a result of these decisions. STS means focusing upon current issues and attempts at their resolution as the best way of preparing students for current and future citizenship roles. This means identifying local, regional, national, and international problems with students, planning for individual and group activities which address them, and moving to actions designed to resolve the issues investigated. The emphasis is on responsible decision* making in the real world of the student. STS provides direction for achieving scientific and technological literacy for all. The emphasis is on responsible decision making in the real world of the student where science and technology are components. Curricular and instructional processes typically consider the following:

* Is it a problem or issue?
* How did it become a problem or issue?
* What are some alternative approaches to its solution?
* What are the potential effects of applying the alternatives on individuals and/or society?

There are no concepts and/or processes unique to STS; instead STS provides a setting and a reason for considering basic science and technology concepts and processes. STS means determining and experiencing ways that these basic ideas and skills can be observed in society. STS means focusing on real-world problems which have science and technology components from the students' perspectives, instead of starting with basic concepts and processes. This allows students to identify, analyze, and apply concepts and processes that can be used in real life situations. A good program will have built-in opportunities for the students to extend beyond the classroom to their local communities. These activities should be appropriate for the age of the students and be learner centered. STS should help lay the basis for empowering students so that as future citizens they realize they have the power to make changes and the responsibility to do so.

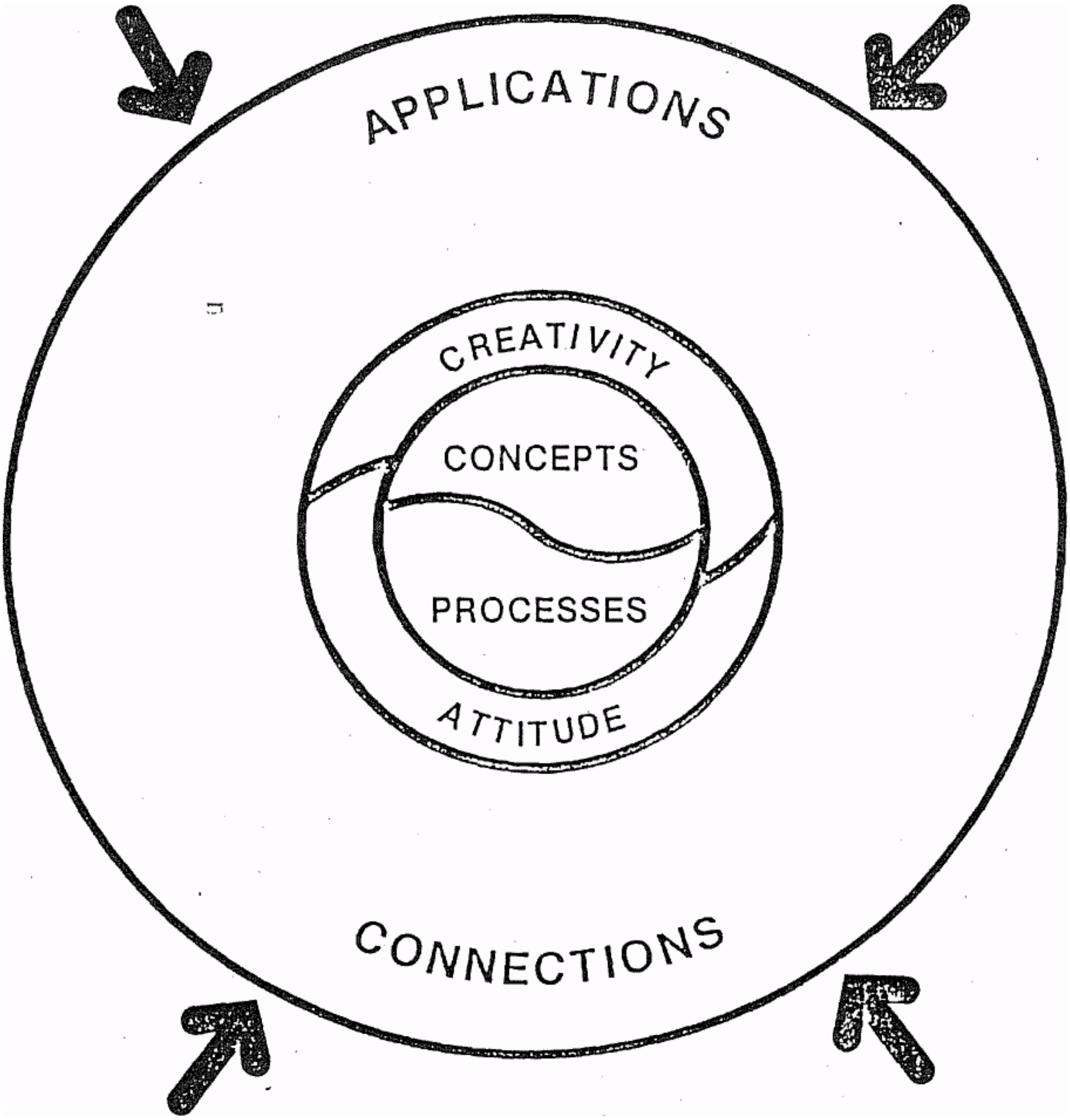
Although "Society" (the second S) may be more of an emphasis in an STS course in the social studies, certainly both Science and Technology are given emphasis in an STS approach in school science. Bybee, et al. (1989) have prepared a figure that illustrates similarities and differences between these two human enterprises that were so separate during curriculum efforts of the 60s. Figure 1 shows this relationship

Figure 1: The Relationships Between Science and Technology and Their Connections to Educational Goals



Yager and McCormack have broadened the view of appropriate science for all learners (1989). They have identified five domains that are important as science for all is discussed and defined. These domains represent areas and provide a basis for determining goals, curriculum strands, instruction, and assessment for many STS advocates. Figure 2 is an attempt to illustrate this relationship.

Figure 2: STS Domains for Teaching and Assessment THE WHOLE OF SOCIETY



STUDENTS

Some elaboration of the Yager-McCormack domains may be helpful as other ways of conceptualizing the domains are considered. Certainly additional domains may be added to the model as well. A brief elaboration follows.

Concept Domain. Science aims to categorize the observable universe into manageable units for study, and to describe physical and biological relationships. Ultimately, science aims to provide reasonable explanations for observed relationships. The Concept Domain includes: facts, concepts, laws (principles), and existing hypotheses and theories being used by scientists. All of this vast amount of information isjisually classified into such manageable topics as: matter, energy, motion, animal behavior, plant development.

Process Domain. Scientists use certain processes (skills). Being familiar with these processes concerning how scientists think and work is an important part of learning science. Some processes of science are: observing and describing, classifying and organizing, measuring and charting, communicating and understanding communication with others, predicting and inferring, hypothesizing, hypothesis testing, identifying and controlling variables, interpreting data, and constructing instruments, simple devices, and physical models.

Creativity Domain. Most science programs view a science program as something to be done to students to help them learn a given body of information. Little formal attention has been given in science programs to development of students' imagination and creative thinking. Some of the specific human abilities important in this domain: visualizing - producing mental images, combining objects and ideas in new ways, offering explanations for objects and events encountered, questioning, producing alternate or unusual uses for objects, solving problems and puzzles, designing devices and machines, producing unusual ideas, and devising tests for explanations created.

Attitudinal Domain. Human feelings, values, and decision-making skills need to be addressed. This domain includes: developing positive attitudes toward science in general, science in school, and science teachers; developing positive attitudes toward oneself (an "I can do it" attitude); exploring human emotions; developing sensitivity to, and respect for, the feelings of other people; expressing personal feelings in a constructive way; making decisions about personal values; and making decisions about social and environmental issues.

Applications and Connections Domain. It seems inappropriate to divorce "pure" or "academic" science from technology. Students need to become sensitized to those experiences they encounter which reflect ideas they have learned in school science. Some dimensions of this domain include: seeing instances of scientific concepts in everyday life experiences; applying learned science concepts and skills to everyday technological problems; understanding scientific and technological principles involved in household technological devices; using scientific processes in solving problems that occur in everyday life; understanding and evaluating mass media reports of scientific developments; making decisions related to personal health, nutrition, and life style based on knowledge of scientific concepts rather on "hear-say" or emotions; and integrating science with other subjects.

STS programs begin at the application/connections domain. Everything considered (i.e., information sought, evidence gathered, alternatives considered, actions taken) is student centered and seen as useful to by students. They apply and connect concepts and processes to real world problems. The applications/connections domain seems to be a desired starting point if one is concerned with providing an appropriate and meaningful experience with science for all. It is related to the society from whence "all" come.

Rather than to assume that one may be able to reach the applications/connections domain after experiences with organized knowledge and some processes (skills used by scientists), STS teachers start with applications, real issues, relevant questions, ideas that provide linkages and connections for students. Such a starting point offers "higher-order thinking skills" in a context of a problem rather than as a separate entity in the school program, i.e., something to work toward. Such a starting point also emphasizes the real world where science is as opposed to something people do in science classes or laboratories. Science is seen related to everything, especially curricular areas such as mathematics, social science, vocational subjects, and the humanities.

Apparently it is not necessary to study new knowledge and to experience new process skills out of any real life context before becoming involved with a problem/issue that provides for applications and connections for learners. Traditional teachers begin in the Center of the diagram (Figure 2), i.e, with presenting basic concepts and processes. The STS teachers wait until the situation demands/needs these concepts and processes. Of course, such teachers continue to create situations and questions that encourage students to see the need and value of basic concepts and processes.

Dealing with the real world and problems in it tends to improve student attitudes and to sharpen creativity skills through use. 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 is the case in traditional discipline-bound programs), most students are lost before they can apply anything to their own lives. And, attitude worsens and creativity skills decline the more one considers the concepts and processes for their own merit and centrality. Those who maintain that scientific literacy is a non-goal usually assume that such literacy is dependent upon 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 such a definition of science/ technological literacy.

Knowledge is a goal. But this means that information and process skills are useful. STS means that they are useful because they are encountered only when the student needs them to deal with his/her problems. And, this occurs because of high motivation and interest and because he/she has questions, has offered explanations, and is interested in the validity of these explanations. This is science and these are basic ingredients of creativity.

The emerging research is clear in illustrating that learning science in an STS context results in students with more sophisticated concept mastery and ability to use process skills. Students improve in terms of creativity skills, developing more positive attitude toward science, ability to use science concepts and processes in their daily living and in responsible personal decision-making.

To some STS as reform is a mechanism for achieving the Desired State envisioned by the Project Synthesis research team (Harms & Yager, 1981). Table 1 provides a summary of the differences between the goals, curriculum, instruction, assessment, and teachers which typically exist and those identified as desirable by the Project Synthesis research team.

Table 1

Desirable State	Actual State
Goals:	
1. Human adaptation and alternative futures emphasized.	1. Minimal consideration given to human adaptive capacities.
2. Dealing with societal problems and issues as goals which creates a need for learning science concepts.	2. Marginal emphasis on current societal problems and issues--and then only as an after thought (i.e., if there is any extra time at the end of a unit).
3. Inquiry processes unique to each problem.	3. Inquiry skills, if present, characteristic of a generalized model of science (often follow the direction-type activity).
4. Decision-making using scientific knowledge in social contexts.	4. Uncovering a correct answer to discipline-bound problems.
5. Career awareness an integral part of learning.	5. Minimal attention to careers; only historical personages highlighted.
6. Value, ethical, and moral dimensions of problems and issues considered.	6. Value-free interpretations of discipline- bound problems.
Curriculum:	
7. Curriculum is problem-centered, flexible, and culturally as well as scientifically valid.	7. Curriculum is textbook-centered, inflexible; only scientific validity is considered.
8. Humankind central.	8. Humankind incidental.
9. Multifaceted, including local and community relevance.	9. Textbook controlled; local relevance fortuitous.
10. Use of the natural environment, community resources, and the students themselves as foci of study.	10 Contrived materials, kits, and classroom-bound resources; use of hands-on materials — often only for the sake of keeping students involved.

11. Information is in the context of the student as a person in a cultural/social environment.	11. Information is in the context of the logic and structure of the discipline.
12. Portrays a more accurate view of the nature of science by explicitly making connections between science and society (externalism) as well as the isolated workings of science (internalism).	12. Distorts-the nature of science by portraying science solely from an internalist position.

Instruction:

13. Student-centered.	19. Group instruction geared for the average student and directed by the organization of the textbook.
14. Individualized and personalized, recognizing student diversity.	
15. Cooperative work on problems and issues.	15. Some group work, primarily in laboratory.
16. Students are considered important ingredients in instruction, i.e., active partners.	16. Students seen as recipients of instruction.
17. Methodology based on current information and research in developmental psychology involving cognitive, affective, experiential, and maturational studies.	17. Weak psychological basis for instruction in the sciences; behavioristic orientation.
18. Teachers build on student experiences, assuming that students learn only from their own experiences.	18. Teachers ignore students in terms of what they might bring to the instructional process; use of information assumed to follow rote learning.

STS means involving learners in experiences, questions, and issues which are related to their lives. Situations are sought which will engage the students. STS teachers try to create situations where students will need the basic concepts and process skills so many wish to force on to their students "because they will need them in the future." STS empowers students with skills which allow them to become active, responsible citizens by responding to issues which impact their lives. Experience with science in the STS format creates the scientifically literate citizenry for the 21st century for which most yearn.

References

Bybee, R. W., Buchwald, C. E., Crissman, S., Heil, D. R., Kuerbis, P. H., Matsumoto, C., & Mclnerney, J. D. (1989). Science and technology education for the elementary years: Frameworks for curriculum and instruction. Andover, MA: The National Center for Improving Science Education.

Harms, N. C., & Yager, R. E. (Eds.). (1981). What research savs to the science teacher (Vol. 3). Washington, DC: National Science Teachers Association.

National Science Teachers Association. (1990-1991). Science/technology/society: A new effort for providing appropriate science for all (Position Statement). In NSTA Handbook (pp. 47-48). Washington, DC: Author.

Yager, R. E., & McCormack, A. J. (1989). Assessing teaching/learning successes in multiple domains of science and science education. Science Education. 73(1). 45-58.

Teaching Science the STS Way

Jack B. Hoi brook University of Hong Kong, Hong Kong

Changes have begun to occur in the way science is being taught. Projects such as ChemCom by the American Chemical Society and the Salter's Chemistry project from the U.K. have taken a fresh look at what constitutes a science course in the secondary school. These courses are starting to have an impact: worldwide.

The Present Scene

Previous science programs had Md emphasis on the teaching of science as a body of knowledge, Yager (1991) put it this way—the important view of a discipline was what persons in the discipline do—science for the scientist These developments in the teaching of science subjects CiiSt from curriculum projects following the Sputnik and emphasized conceptual understanding of unifying themes and/or major theories and learning form both experimentation and model making. ChemStudy in the U.S. and the Nuffield programs in the U.K. are good examples of projects developed in this manner during the late 1950's and early 1960's. These innovative programs certainly made an impact and gave some students an in-depth view of science rather than a mere coilsciia® of facts. This was amplified by sub-divisions of cognitive skills, an emphasis on inquiry skills, and a recognition of a hierarchy based on Bloom's taxonomy. Such courses greatly influenced the teaching of science worldwide from later in the 1960's until now.

But It made subjects such as science difficult in the eyes of students compared with other subjects. Science subjects demanded intellectual thinking and were geared to the more able students. And subjects such as science promoted fundamental ideas necessary for the understanding of science concepts as a first requirement Science was divorced from technology. Science was considered a pure rather than an applied subject.

The experiments could be fun, the observations easy, but the interpretation of the experiments related to a unique observation (there was only one answer) and often the interpretation demanded insights at a higher level beyond the comprehension of the students such that interpretations were highly directed by the teacher. Traditional teaching methods in which teachers supplied the answers were apt to prevail and were perhaps dominant for the average student.

The Change of Direction

But a change in objectives is slowly emerging in science teaching. Objectives are being encouraged that favour looking at the science around us and in so doing trying to understand from a societal viewpoint rather than from that of a scientist. An emphasis is emerging on responsible decision-making in the real world of the student whereby the student considers: Is It a problem? How did it become a problem? What are some alternative approaches to its solution? What are the potential effects of applying the alternatives on individuals and/or society?

Partly this has come about by the everlasting increase in scientific knowledge, but more so from a concern about the role science is playing in the environment and the need to combat the very negative image the mass media gives to science highlighting as it does on pollution, social concerns, and fears.

Today there is the recognition that the man-made world around us is based on technology. The science is less visible and yet to obtain a more technologically literate society, there is a need for people to receive a nrdre relevant grounding in science. This grounding involves the technology that surrounds them and. .in addition the issues and conflicts that are related to the use of that technology in society. This leads to an understanding of the science related to that technology and to an informed opinion on the likely advantages and disadvantages of promoting various technologies.

It leads to a recognition of problems, of considerations of how to solve problems, and an ability to make decisions based on sound judgment. All this is in addition* to the cognitive skills acquired through laboratory science teaching. Thus the goal of a scientifically literate person could be seen as encompassing abilities to:

1. use concepts from science and technology and ethical values in solving everyday problems and making responsible decisions in everyday life, including work and leisure;
2. engage in responsible personal and civic actions after weighing the possible consequences of alternative options;
3. distinguish between scientific evidence and personal opinion and between reliable and unreliable information;
4. defend decisions and actions using rational arguments based on evidence;
5. remain open to new evidence and the tentativeness of scientific knowledge;
6. value scientific research and technology problem solving;
7. offer explanations of natural phenomena which may be tested for their validity;
8. locate, collect, analyze and evaluate sources of scientific and technological information and use these sources in solving problems, making decisions, and taking actions.

The Curriculum

A constant dilemma in science teaching is what to leave out. Teaching time is rarely sufficient and any discussion among curriculum developers to eliminate sections from a course that is based on science fundamentals leads to constant disagreement as there are demands- for all foundation concepts to be covered to provide a framework for later study.

An alternative curriculum approach is to take the technology around us as the barometer and then to look at the scientific issues related to this. The depth of treatment is geared to providing an informed opinion related to the issue as indicated in the goals for scientifically literate persons stated earlier. All possible conceptual developments are no longer considered appropriate. Whilst the linking together of various topics may not be scientifically logical in so far as the approach differs from introducing a fundamental concept acquisition first, leading later to a consideration of uses, the curriculum can still be inherently logical to the student as it relates to various technologies in the local environment. This has come to be known as the STS (Science-Technology-Society approach). STS is a term applied to the latest effort to provide a real world context for the study of science and for the pursuit of science itself. STS includes the whole spectrum of critical incidents in the education process including goals, curriculum, instructional strategies, evaluation, and teacher preparation/performance (Yager, 1989).

STS teaching also attempts to meet the goals stipulated by Project Synthesis in the U.S. (Harms, 1977) vis

1. Science for Meeting Personal Needs. Science education should prepare individuals to utilize 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 (Harms and Yager, 1981).

I suggest the new direction for science is very supportive of these statements. The first relates to technology skills such as creativity, problem solving and other process skills. The second is geared to civic awareness and the development of social skills such as debating, making judgments, and separating fact from fiction. The third is a much neglected area and one that makes science teaching relevant to the society in which it is taught. The last involves developing higher ability skills and in exploring something of the foundations and philosophies of science and technology. Perhaps this last goal would be better expressed if it mentioned acquiring knowledge and concepts.

A Comparison

In the earlier fundamental approach, the emphasis in science is on a systematic study at the microscopic level. Atoms and molecules are followed by protons, neutrons, and electrons leading to atomic structure and bonding. Based on this, formulae and equations can be written and processes such as electrolysis and rusting explained. It is all very logical, very systematic, but much study for little relationship with the world around us.

The alternative recognizes the technology in society around us. It recognizes the concerns of society, the skills required to deal with scientific issues in society, and the depth of understanding needed to gain somercomprehension for problem solving. It begins with societal technology and in particular the concerns we have related to areas such as resources, health, food, the environment, energy problems, the need for industry and how we can communicate.

The implication for the curriculum is that:

1. Teaching the STS way does not mean a syllabus driven by fundamental concepts;
2. Syllabi units should have societal titles, not academic titles;
3. Sequencing within units should be from the society to concepts;
4. A societal consideration could be an issue or a technological process;
5. Room should be included for economic, ethical, political relations with science topics;
6. More attention should be given to communication skills related to discussing, debating, role playing;
7. More attention should be given to problem-solving and planning skills;
8. Science should be given a positive rather then a negative image;
9. Skills within the laboratory should be relevant outside the school, e.g., removal of glassware related skills where possible in favour of plastic/metal handling skills;
10. A greater link between school science and the persons outside the school utilizing/carrying out science, visits to factories, visits from persons involved in chemical process to the school are examples;
11. A greater link between school science and chemical processes in the society; and
12. A greater link between science and other subject areas particularly the social sciences.

An Illustration

To illustrate the difference between a syllabus driven by fundamental concepts and an STS syllabus, an example is given related to the teaching of chlorine. .Note that the former begins with the science and any uses, e.g., technological or societal considerations, that are to be included follow. Holman (1985) describes this as the "science first" approach. The latter illustrates an approach from issues, concerns, and application problems and then branches out into the science needed to comprehend the issue or problem involved. Holman describes this as the "applications or issues first" approach.

Part of a Syllabus That is Fundamentally or Academically Driven

The Halogens (suggested time allocation: 8 periods)

<u>5.1 The halogens.</u>

Trends in physical properties of the halogens as a family of elements.
Family trends should be emphasized where appropriate, e.g. physical states, methods of preparation of the halogens.
Preparation of chlorine by oxidation of HC1 or NaCl.
Chemical properties of chlorine.
Manufacture and uses of chlorine. (The manufacture of bleaching powder is not required).
Chemical properties of other halogens should be related to the family trend.

5.2 Halides.

Tests for the halide ions (excluding fluorine). r.

Relative ease of oxidation of hydrogen halides. (Halides of nitrogen, oxygen, and sulphur not required).

Experiments Expected to be Included in the Teaching

5.1 Prepare chlorine from concentrated HC1 or NaCl.

Reactions of chlorine with: 1) water; 2) metals (e.g., sodium, magnesium, zinc, iron, and copper); 3) non-metals (e.g., phosphorus); 4) dilute alkali solutions; 5) hydrocarbons (e.g., turpentine); 6) solutions of other halides (e.g., Br~, I" (displacement reactions); 7) reducing agents (e.g., SO_3^{2}~(aq) and $Fe^{2"l"}$(aq); and 8) dyes and pigments i.e., bleaching action.

Reaction of bromine water with iodides.

5.2 Action of acidified silver nitrate solution on solutions containing chloride, bromide, and iodide ions.

Actions of concentrated H_2SO_4 on solid sodium chloride, sodium bromide and sodium iodide.

A Similar Part of a Syllabus STS Driven Some chemicals for

health and for use in the home (suggested teaching allocation 12 periods)

Cl. Bleach - Why is it available on supermarket shelves?

An investigation of bleach as a decolorizer of dyes and killer of germs.

A consideration of how much to use and the dangers of fumes from excess.

An introduction to chlorine—a dangerous gas.

The strength of a bleach measured by amount of 'available chlorine' liberated on adding acid.

C2. Making Bleach - understanding the electrolysis process

Electrolysis of a chloride solution (e.g., aq. sodium chloride)

A consideration of the chlor-alkali industry, its main products, and the relative importance of bleach. Role-playing exercise geared to siting of the industry and balancing the demand for the various products.

C3. How Bleach Functions - an introduction to oxidation and reduction

Explanation of bleaching action of OCl"(aq) and the instability of HOCl(aq). An introduction to oxidation numbers to show bleaching is an oxidation process. Explanation of germ killing action by oxidation. Chlorine purifying drinking water. A look at the water treatment industry. Bleaching by reduction--the SO_2 story

C4. Swimming Pools - Are they healthy? ^

Purification of swimming pool water by chlorine, but under controlled pH conditions. Convenient chlorine supplies for swimming pools.

Determination of the chlorine concentration--a comparison of the reactivity of chlorine, bromine and iodide, and their salts.

C5. Fluorides, chlorides, bromides and iodides for our health. Fluoridation of water and toothpaste. Why?

Fluoridation of drinking water—is it necessary? Should we have the right to choose? lodination of table salt. Why? Should this be debated also? Effects of sunlight on halogen compounds e.g. silver chloride. Tests for halogens in the laboratory. What are X-ray plates/photographic papers?

C6. Halogen compounds in general - Are they friend or foe?
A debate.
The good—nonflammable, compounds relatively stable, compounds of low molecular mass are volatile, high relative density in relation to number of carbon atoms in the molecule, (as liquids) form good solvents for greases, poisons as in herbicides and pesticides, antiseptic qualities.
The bad--liable to form free radicals and thus a carcinogen, destroyer of ozone, not decomposed in soils leading to build up of residues.
Examples for consideration—non-stick saucepans, aerosol sprays, pesticides, solvents, nonflammable polymers, medicines.

Science Concepts Included

Cl and C2: Preparation of chlorine
Cl: Property of chlorine pleach)
C3: Property of chlorine (oxidizing agent)
C4: Displacement of bromine and iodine by $C1_2$
C5: Test for the chloride ion
C6: Relative density and physical state
C7: Free radicals

Experiments Suggested for Inclusion

Cl. Strength of bleach compared by measuring volume of chlorine liberated on reaction with a dilute acid.
C2. Electrolysis of aq. sodium chloride with carbon electrodes. C3. Using SO_2 water as a bleach - comparison with Cl_2(aq). C4. Reaction of aq. halogens with various halide ions. C5. Silver nitrate test for the halide ions.

References

Harms, N. C. (1977). Project Synthesis: An interpretative consolidation of research identifying needs in natural science education. (A proposal prepared for the National Science Foundation.) Boulder, CO: University of Colorado.

Harms, N. C., & Yager, R. E. (Eds.). (1981). What research savs to the science teacher (Vol. 3). Washington, DC: National Science Teachers Association.

Holman, J. S. (1986). Contrasting approaches to the introduction of industry and technology into the secondary science curriculum. In D.J. Waddington (Ed.), Education. Industry and Technology. ICSU Press.

Yager, R. E. (1991). New goals needed for students. Education. 111(3). 418-435.

The Constructivist Learning Model: A Must for STS Classrooms "

Robert E. Yager The
University of Iowa, USA

The Constructivist Learning Model is attracting much attention today because it suggests ways that learning can be enhanced and the changes in teaching that are essential for it to occur. The emerging research regarding constructivism is convincing and has prompted many to identify it as a break-through that will enable President Bush's Education Goals and the vision of America 2000 to be realized in the U.S. Learners who are enthused and who can use the concepts and skills stressed in classrooms in their world outside the school result more readily and more often when Constructivist practices are used. At the same time the Constructivist Model offers assurance to thousands of excellent teachers who use many of the procedures instinctively without having heard of Constructivism. Perhaps the model can help bring science and other teachers together to the benefit of the whole educational enterprise. Yeany (1991) suggests that constructivism has the potential to connect most current thinking and research in science education.

Meaning of Constructivism

Constructivism indicates that each human being (learner) must put together ideas and structures that have personal meaning if he/she is to learn. The model suggests that knowing means being able to do or to construct something. Research concerning the Constructivist Model continues today at an ever quicker rate as educators attempt to apply what we know about learning to instructional strategies and curriculum materials in attempts to meet goals better.

The Constructivist Model explains that knowledge can never be observer-independent. In fact knowledge must be attained in a personal sense; it can not be transferred from one person to another like filling a vessel. It is not like other physiological processes which can be described chemically. Instead, it requires a personal commitment to question, to explain, to test explanations for validity.

Although the model indicates that each learner constructs meaning for him/herself, it does not always mean in isolation. Nonetheless, it often occurs without teachers, textbooks, and schools. The classroom must become a place where students offer their personal constructions. They can then be used to apply them to new situations where they are useful, adequate, and/or altered. Teachers, other adults, and, even more often, peers can enhance learning by challenging conceptions of a given learner.

Constructivist Practices *

The effective use of the Constructivist Model demands the use of .teaching practices which are not unlike those most exemplary teachers use. Some of these specific procedures include:

Planning Activities

1. Seeking out and using student questions and ideas to guide lessons and whole instructional units;
2. Accepting and encouraging student initiation of ideas; and
3. Promoting student leadership, collaboration, location of information, and taking actions as a result of the learning process.

Classroom Strategies

1. Using student thinking, experience, and interest to drive lessons (this means frequently altering teachers' plans);

2. Encouraging the use of alternative sources for information both from written materials and live "experts"; and

3. Using open-ended questions.

4. <u>Student activities</u>

5. 1.Encouraging students to elaborate on their questions and their responses;
6. 2.Encouraging students" to suggest causes for events and situations;
7. 3.Encouraging students to predict consequences; and
8. 4.Encouraging students to test their own ideas, e.g., answering their questions, making guesses as to causes, and predicting of certain consequences.

9. <u>Teaching Techniques</u>
10. 1.Seeking out student ideas before presenting teacher ideas or before studying ideas from . textbooks or other sources;
11. 2.Encouraging students to challenge each other's conceptualizations and ideas;
12. 3.Utilizing cooperative learning strategies which emphasize collaboration, respect individuality and use division of labor tactics
13. 4. Encouraging adequate time for reflection and analysis;
14. 5. Respecting and using all ideas that students generate; and
15. 6.Encouraging self-analysis, collection of real evidence to support ideas, reformulation of ideas in light of new experiences and evidence.

16. Constructivist Strategies

17. Constructivist strategies are organized into four categories, namely invitation, exploration, proposing explanations and solutions, and taking actions. Following is a list of strategies commonly if used by Constructivist teachers in each category:

Invitation:	Observe one's surroundings for points of curiosity Ask questionsConsider possible responses to questions Note unexpected phenomena Identify situations where students perceptions vary
Exploration:	Engage in focused play Brainstorm possible alternatives Look for information Experiment with materials Observe specific phenomena Design a model Collect and organize data Employ problem-solving strategies Select appropriate resources Discuss solutions with others Design and conduct experiments Evaluate choices Engage in debate Identify risks and consequences Define parameters of an investigation Analyze data
Proposing Explanations and Solutions:	Communicate information and ideas Construct and explain a model Construct a new explanation Review and critique solutions Utilize peer evaluation Assemble multiple answers/solutions Determine appropriate closure Integrate a solution with existing knowledge and experiences

Taking **Action:** Make decisions –
Apply knowledge and skills
Transfer knowledge and skills
Share information and ideas Ask
new questions Develop products
and promote ideas
Use models and ideas to illicit discussion and acceptance by others
Approach decision makers in society urging them to act in specifici ways

Moving to Constructivist Practices

Constructivist practices result in students who attain more of the goals typically cited by teachers. Among these are demonstrated mastery of basic concepts (in ways other than repeating or recognizing standard definitions); use of basic process skills (again, in new situations); ability to apply, interpret, and synthesize information; enhancement of creativity skills (questioning, proposing causes, predicting consequences); and improved attitudes toward science study, schools, classes, teachers, and careers.

Constructivist practices require teachers to place students in more central positions in the whole instructional program. They must question more and their questions must be used as the basis for discussions, investigations, and actions in the classroom/laboratory. They must propose solutions and offer explanations and these proposals must be used in the classroom and form the basis for seeking and using information and for testing the validity of all the explanations offered. This suggests a progression of involvement which starts with the student, moves to pairs and/or small groups of students for more questions and eventually consensus, then to the whole class for similar processing, and finally to what the professional (scientific) community views are. This progression is just the opposite of what typically happens. In traditional classrooms where traditional strategies are used, the textbook, teacher, or professionals (scientists) define what students should know. Typically they are expected to read, to listen, and to repeat the desired information. If students read, listen, and repeat, they are said to have learned. However, this definition of learning is simply not adequate.

Cognitive scientists report that most undergraduate science majors (the most successful K-12 and college students in a discipline) can not use the concepts and skills they seem to have mastered in solving real world problems given to them. As many as 90% of the engineering students studied can not relate what they seem to know to problems in real world situations (Miller, 1989; Miller, Suchner & Voelker, 1980, Mestre & Lochhead, 1990). Such "learning" in typical situations did not result from "Constructivist" practices; this suggests the reason for real learning not to have occurred. Measures of successful learning too often consider only recall of concepts and definitions and performance of basic skills out of any real world context.

All of the features of the Constructivist Teaching Model characterize STS teaching. When STS is viewed primarily as an approach to science teaching, the^teaching utilizes Constructivist procedures by definition. For many, the major aspect of STS is instruction (i.e., what a teacher does). Effective STS teaching requires teachers to utilize Constructivist procedures. STS that focuses on curriculum dimensions can result in learning that is no more impressive than that which occurs in traditional science concept-bound courses. In some ways learning is restricted to students reporting different information. Such information often focusses upon societal issues, e.g., environmental degradation, and provides students with information (for their mastery) that will lead to problem resolution.

The NSTA definition for STS surely focuses upon instructional features at the expense of curricular ones. When this occurs, the descriptions of STS teaching are synonymous with Constructivist features.

References

Miller, J. (1989, April). Scientific literacy. Paper presented at the meeting of the American Association for the Advancement of Science, San Francisco, California.

Miller, J. D., Suchner, R. W., & Voelker, A. M. (1980). Citizenship in an age of science: Changing attitudes among young adults. New York, NY: Permagon Press.

Mestre, J. P., & Lochhead, J. (1990). Academic preparation in science: Teaching for transition from high school to college. New York, NY: College Entrance Examination Board.

Yeany, R. H. (1991). A unifying theme in science education? NARST NEWS. 21(2), 1, 3.

SECTION II – Examples of STS Initiatives

Definition and rationale are fine. However, real meaning often awaits examples and experience with the idea/concept in life. This section includes reports of some of the most innovative and exciting experiences with STS courses and STS teaching. We expect such examples will bring life to STS as basic reform. They will also offer models for others wishing to try similar materials and approaches—or to those needing examples before trying something totally new on their own.

SATIS 16-19 on Trial in the UK

Andrew Hunt SATIS 16-
19 Project Director

Graham Lenton University of
Oxford, United Kingdom

The SATIS 16-19 project was set up by the Association for Science Education (ASE) to build on the success of the Science and Technology in Society (SATIS) project which, by 1988, published 100 units for 14-16 year-old students (updated and extended to 120 units in 1991).

The projecr'team has devised and published a low-cost and flexible bank of resources intended for students in the sixteen to nineteen age-range: 1) to enhance their general education. and 2) to enrich specialist science courses in academic and vocational programs. There is no sharp division intended between these types of materials and teachers have found that many units can be used successfully in both contexts.

The Quest for Originality and Authenticity

The SATIS 16-19 project developed a strategy for helping teachers to share good ideas and effective classroom practices. All the writers were volunteers free to choose their topics and to present them in a form to engage students. As a result the units are very diverse, reflecting the varied interests of the contributors.

Early in the project the director set up 17 informal development groups across the UK in places where an enthusiast had the time and resources to arrange meetings. Teachers came to the meetings to discuss their ideas for writing, to review draft units, and to get involved in trials. At the same time it was possible for individual authors to contact one of the editors directly to make a contribution.

Many novel units arose by collaboration between teachers and their local contacts in professional institutions, universities, industry, medical services, and other organizations. The advisers brought to the project new examples, fresh stories, and up-to-date views on topical issues. The teachers then used their expertise to develop the topic into a form which could be readily adopted into schools and which was likely to appeal to students.

The editors were very concerned that all units should be both accurate and authentic. They were determined to avoid contrived tasks devised purely as teaching exercises. Working closely with expert advisers not only helped to ensure accuracy, it also contributed to authenticity. Very often the advisers were able to suggest activities which reflected, albeit in a simplified way, typical tasks which they might have to undertake in their normal work.

The draft units were prepared for trials by a small team of part-time editors and then distributed to teachers who had offered to test them with students. Feedback from trials was returned to the editors on questionnaires from teachers and students. The editorial team grew during the project by recruitment from the more active and innovative contributors.

AH contributors were warned that the editors would often reconstruct, rewrite, and re-illustrate draft units extensively before trials. This was very time-consuming and so units were only prepared for trials if the editors were confident that they would ultimately be suitable for publication. In the end only ten units were trialled but not published

Teaching and Learning Strategies

Every SATIS 16-19 unit had to pass the test of providing a stimulating and engaging activity for students. During the development phase the writers and editors'of ten found that this was the most difficult aspect of devising a good unit. There were lots of interesting stories to tell and issues to debate; the trick was to match them with appropriate tasks to capture interest and promote effective learning of knowledge and skills; Figure 1 lists some of the activities which appear in one or more of the published units.

The project editors took the view that teachers and textbook authors should not have all the pleasure of producing beautifully illustrated accounts of science and technology. All too often students are left to undertake much less rewarding tasks leading to an inferior product. With this in mind many SATIS 16-19 units were designed to give students a chance to prepare their own coherent account of the topic or issue in a suitable form for a given audience. So students might be asked to produce a poster for younger pupils, a leaflet for the general public, an article for a newspaper, a letter to a Member of Parliament, a flow diagram to describe a process or a technical report for the managers of an industrial company. SATIS 16-19 units were designed to be flexible and to support independent learning by students.

Figure 1: Activities Featured in Units of the Project

Brainstorming and speculation　Case studies
Data analysis　Designing and—possibly--making
Discussion based on an audio tape　Drawing up a chart, flow diagram or
poster Fieldwprk　Games and puzzles
Gathering data from libraries and data bases　Interpreting maps, diagrams, and
charts
Planning and/or carrying out a practical　Preparing and giving a talk or oral
report investigation
Problem-solving and decision-making　Reading
Research with the help of libraries and data　Role play and drama
bases
Statistics--interpreting statistical data and '　Structured
discussion applying simple statistical methods
Surveys and interviews　Teamwork
Using computers—wordprocessing and　Visits
spreadsheet programs
Watching and discussing a video or series of Writing a technical
report slides Writing for a 'popular' or non-specialist audience

An Outline of the Project Economics '-

The project was funded by a charitable trust and by contributions from over 30 industrial companies. The established position of the ASE, with its large voluntary membership of science teachers, was crucial to the success of the fund raising which was carried out in the name of the president of ASE. The president holds office for one year and is usually a distinguished industrialist, academic, or public servant.

Simply dividing the total sum raised to finance the project by the number of units published shows that the cost per unit was about £3,000. This, however, does not take account of the very substantial subsidy from teachers and other who contributed to the project for no fee.

An important financial concern was the cost of meetings. These included occasional meetings of the project central team (two or three times a year) to keep the purposes and strategy of the project under review and more frequent local meetings of development groups to help individual

Another budget item was the cost of secretarial support and the expenses involved in duplicating and distributing trial material. Single copies were posted to trial schools and colleges which then arranged to duplicate further copies for students use. Typically about 50 copies of a unit might be sent out for trials and review.

The biggest expense, however, was the last: the cost of professional design, artwork, picture research, and preparation of "camera-ready" copy. These costs were born by the project and not passed on to purchasing institutions. As a result the four files are now available to schools and colleges at a price far below what would be possible from a commercial publisher. Purchasing institutions essentially pay just for the paper, the file, and the printing costs (so that ASE can always afford to reprint when necessary). Schools also have to cover the cost of photocopying those units which they choose to adopt.

Trials in Schools and Colleges

Where the Units Were Trialied

Invitations to trial SATIS 16-19 units were sent out in many ways: through the local development groups, through meetings of ASE members, and in articles published in its journals, as well as by word-of-mouth. Teachers were free to choose the units they wished to try out with their students. So the teachers, if not the students, were generally predisposed to favor the aims and purposes of the project. Timing was always a problem. It was often difficult to arrange for trial units to be available at the time expected by the teachers. As a result conditions for the trials were not necessarily ideal. Teachers might not have had long enough, for example, to collect desirable support materials such as videos.

In the last year of the project trainee teachers at the Oxford Department of Education collated data from the questionnaires sent to teachers and students for the first 75 units to be published.

The teacher questionnaire was printed on both sides of a single sheet of paper. The front was quick and easy to complete and asked for details of the context of the trials together with an overall assessment made by ticking boxes in a grid. The back of the questionnaire invited teachers to comment at greater length on the various components of the unit tried. Teachers were also encouraged to suggest improvements to the unit. For one reason or another, teachers were not always able to trial the units which they had asked to see. This did not prevent them from commenting and many valuable ideas came back to the editors from experienced teachers who carried out an "armchair" review. The overall response from teachers was extremely favorable but the detailed comments made an important contribution to improving the published versions.

The student questionnaire was simpler and printed on only one side of a single sheet of paper. The editors gained the clear impression that the main concern of students was that their assignments should help them to achieve examination success. Given that they felt that the work was worthwhile, however, students responded very positively to units about up-to-date topics which made clear links between school science issues of current concern to the general public outside school. Typical comments from students appear in Figure 2.

Groups of students in a few schools were encouraged by their teachers to carry out a detailed, written report and evaluation of units complete with responses to all the activities. The information from these students was very helpful when it came to revising and checking the commentaries

Figure 2: Responses From Students After Experiences With a Variety of SATIS 16-49 Units

Favorable Comments	Unfavorable Comments
It was very interesting so the learning waseasier. Interesting because it was concerned with the environment. It helped me to relate theory to real lifeproblems. Promoted interesting discussion, especially when we all had conflicting arguments. It gave us more chance to work together in groups. It answered lost of unanswered questions I had about electricity. Helped to improve my research[1] skills. I learned to set out my ideas more clearly and coherently.	It would have been more interesting if more thought had been required. Long-winded and uninteresting.
	Needs more practical work and fewer questions. Some questions are insulting as the answers are staring at you. Irrelevant to my A-level course.
	It did little to improve my grade.
Increased my understanding. Good for discussion and debate. Good experience of analytical skills. Yes, gave me a chance to plan experimental method.	No, too much math. I would have preferred less information. Howabout leaving room for more personal researc

A Detailed Analysis of Unit 6: DNA Fingerprinting

An outline of the unit

The unit called "DNA Fingerprinting" played an important part in the history of the project because it was the first to show that the strategy could produce high-quality, novel resources which clearly met the needs of teachers and students. The authors, Susan Wells and Pauline Lowrie, were biology teachers in Staffordshire and they collaborated with Professor Alec Jeffreys who developed the technique of DNA fingerprinting at Leicester University, Paul Debenham of ICI Cellmark Diagnostics, the company which markets the technique in the UK, and Keith Hadley at the government's Forensic Science Training Unit.

The trial version of the unit was in four parts. The first part explained science and technology of the technique itself with clear diagrams provided by Cellmark Diagnostics. The explanation was followed by a set of questions. Part Two gave an outline of some of the many applications of DNA fingerprinting, again with questions and opportunities for students to suggest pew applications. Part Three included two case studies with DNA fingerprints to interpret. Students had to decide the rights and wrongs of two paternity disputes based on the scientific evidence. Finally, Part Four suggested a courtroom drama with students playing all the key roles and in particular trying to explain to the jury why they should or should not convict on the basis of the fingerprint evidence given in the unit.

Results from the teacher's questionnaire

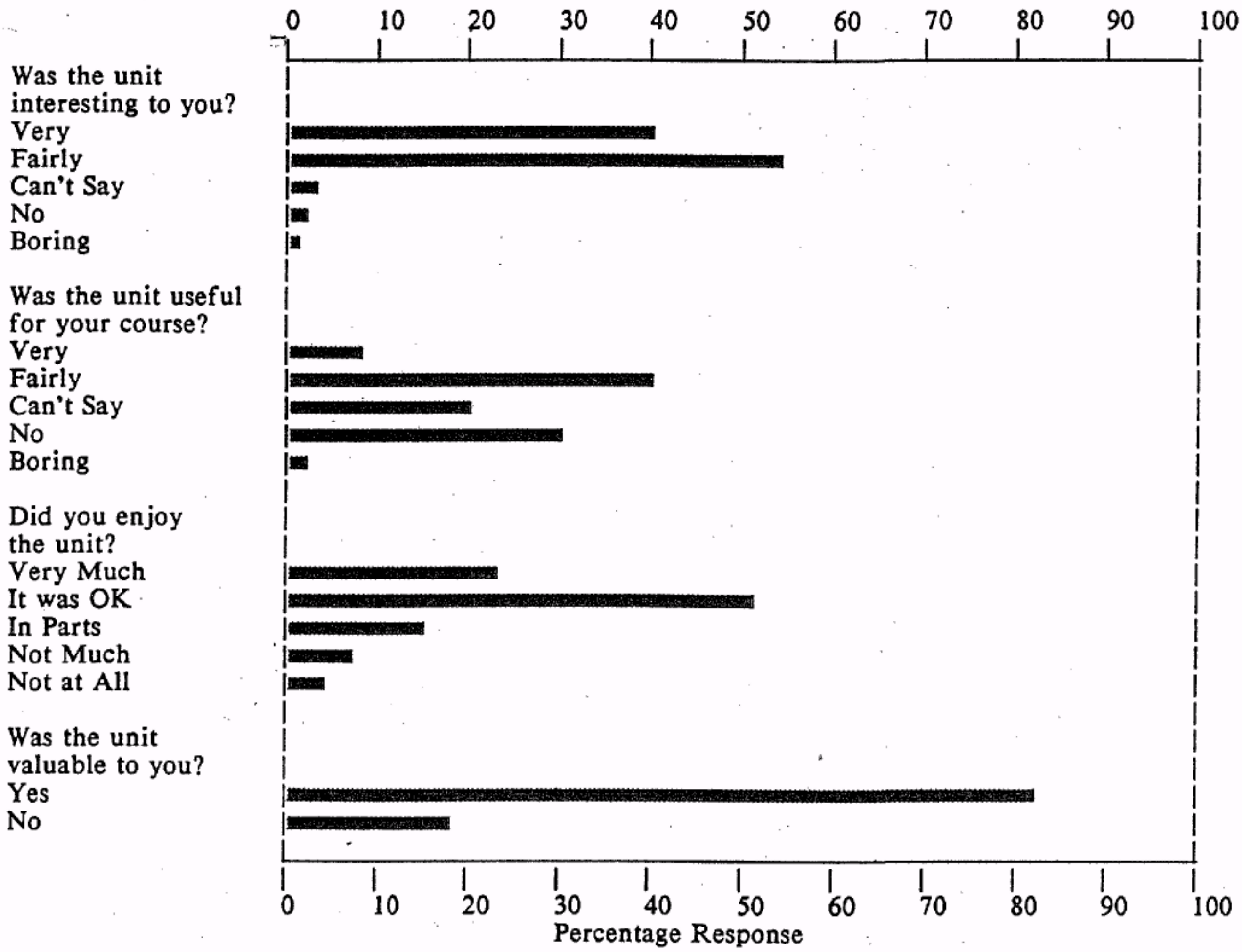
This unit attracted teachers who were interested by its topicality and also looked for practical applications of biotechnology and genetics. Trial questionnaires came back from 28 teachers and over 340 students. Of the 28 teaching groups involved, half were studying specialist biology courses and the other half were general studies or STS groups. Most groups only worked on selected parts of the unit and the average time spent on it was about 90 minutes (with a range of 30 to 240 minutes). Generally, the teacher ratings were all extremely favorable.

Results from the students* questionnaire

One of the most vivid example of trial feedback for this unit was a video of the courtroom drama played out by students at a College of Further Education. The video showed that the students had not restricted themselves to the information in the unit when preparing their roles. They supported their arguments for and against the defendant with the help, for example, of reference to recent controversies about DNA fingerprinting in the USA and elsewhere. In this simulated "trial" the defendant was unexpectedly "acquitted" despite the scientific evidence, because of the doubts in the minds of the "jury" created by the well-prepared "defense lawyer."

The overall response to the unit from those who filled in the questionnaire is how in Figure 3.

Figure 3: Students' Responses to the Unit DNA Fingerprinting



The editorial response to trial feedback

After analyzing the feedback, the editors realized that the description of the DNA fingerprinting process needed rewriting and reorganizing. This was done and the artwork was carefully redrawn to match the text.

The advice from teachers was used to enrich the "Notes for Guidance" with more suggested approaches and more references to supplementary resources. This included reference to an audiocassette with a BBC School Radio broadcast intended to supplement the unit. The broadcast includes interviews with Professor Jeffreys, with a police detective, and with a speaker from "Liberty" (formerly the National Council for Civil Liberties)

The trial text only referred to the first fingerprinting technique based on "multi-locus probes." During the trial period, however, it became clear that "single-locus probes" were becoming more important in forensic work. So the unit was updated to refer to the recent developments with the help of further advice from ICI. Mistakes in the trial comm'entary were corrected and the suggested answers extended where necessary.

The General Editorial Response to Trials

The over-riding feeling, after reviewing the trial feedback on all the units, was that it was impossible to predict when, where, and how a particular unit would be used and liked. At times this made it difficult to decide whether or not to proceed to publication with a particular topic. Given the voluntary nature of the trials, the editors were generally more impressed by an enthusiastic response from a limited number of teachers than they were by a rather less whole-hearted endorsement from a greater number of trialists.

Throughout the project the editors were heartened by the numbers of teachers who wanted to take part in trials and by the generally favorable feedback. The response to the project made it very clear that the units were meeting a need which was not being satisfied by other publications. Editors were encouraged to continue working on the unit if most teachers showed that they would probably or definitely use the unit after editing and publishing.

The speed with which questionnaires came back and the number of questionnaires gave a crude measure of the value placed on a unit by teachers. A very few units seemed to disappear into a "black hole," with no trial feedback coming in even after the editors had distributed 50 or more copies for trial. Such units were not published even though they seemed interesting and worthwhile to the editors.

Most of the units were restructured after trials. Many were shortened by deleting sections which seemed to lack interest or syllabus links. One aim of the editors was to make it easier for teachers and students to use just one or two parts of a unit.

Many of the units deal with controversial issues and in many cases further expert advice, supported by trial feedback, made it essential to adjust the balance of the treatment of opposing points of view. Other units were enriched by extra ideas and activities suggested by trial teachers.

All the units were completely redesigned and re-illustrated for publication. The trial versions did include some illustrations but these were generally poor-quality photocopies of any available artwork. For publication, a team of professional artists drew new illustrations. They adopted a bold style so that the drawings and diagrams "brighten" the photocopied black-and-white pages.

STS Opportunities and Questions

Now that all the SATIS 16-19 resources have been published, we need to find out how they are being used and whether or not they are achieving the aims of the project.

We know that teachers welcome SATIS 16-19 units because they are cheap, topical, easy to use, adaptable, and usually closely related to syllabuses. From the sales of Files 1 through 3, we also know that a high proportion of the schools and colleges with students in the 16-19 age range have bought copies of the materials. We can see already that the existence of the SATIS 16-19 publications is beginning to influence curriculum and syllabus development.

The growing importance of the STS component of science education in the UK is illustrated by this quotation from the aims of the 1992 advanced level chemistry syllabus from the University of Cambridge Local Examinations

This course aims to promote awareness that

13. the study and practice of science are cooperative and cumulative activities, and are subject to social, economic, technological, ethical, and cultural influences and limitations; and
14. the applications of science may be both beneficial and detrimental to the individual, the community, and the environment.

The UK National Curriculum Council has proposed that "Science and Technology in Society" should be a theme in the post-compulsory education of all students in the 16-19 age range. This suggests a growing demand for resources such as those published by the SATIS 16-19 project. What we now need is research to evaluate in detail the effectiveness of the project publications to see whether or not they help teachers and students to fulfill their aims and objectives.

The Jurisprudential Model of Study For STS Issues

Jon E. Pedersen
University of Arkansas

Science/Technology/Society (STS) issues have presented, over the past decade, food forthought for many educators. It is clear by most accounts that the STS theme İs important and should be included in all classrooms, K-12. it is proposed that allowing students to observe and explore their own surroundings, give explanations and solutions based on their own ideas, and taking action on these ideas will enhance student understanding and appreciation of science. Researchers such as Yager (1990), Wiesenmayer and Rubba (1990), Roy (1985), and Pedersen (1990) all have maintained that STS issues are important components of science and should be included in everyday study.

With all of the interest and discussion about STS issues, one must ask why it is that teachers are reluctant to use them in the classroom. Teachers at the secondary and college levels both agree that STS issues are important to study (Bybee & Bonnstetter, 1985). The National Science Teachers Association (NSTA) (1990-1991) indicates that current materials must be rethought, restructured, reorganized, rewritten, and revised. Two quotes from the NSTA paper illustrate the vision and purpose of the STS approach: 1) the bottom line in STS is the involvement of learners in experiences and issues which are directly related to their lives (p. 48); 2) STS empowers students with skills which allow them to become active, responsible citizens by responding to issues which impact their lives (P. 48).

Yet science teachers continue to express hesitation to embrace the STS theme. It would seem that a major factor limiting the implementation of the STS theme in classrooms is the unavailability of clear models for new instructional approaches and ne w materials (Bybee & Bonnstetter, 1985). If this is an accurate assessment, the goal should be to develop models of teaching and learning that give strategic information and criteria for STS.

A Model for STS

In developing a model for the study of STS issues one must first examine what is involvedin "an" STS issue. Yager (1988), Wiesenmayer and Rubba (1990), and Hickman, Patrick, and Bybee (1987) of fer similar perspectives of STS study. These views provide us with a framework for a model. First of ali, the study of STS issues does not occur in a vacuum, i.e., it is linked closely to the content of the science curriculum. it is, however, the STS issue that "drives" the study of the content rather than the content "driving" the issues. Within the study of science content the relationship and mutual influences of technology, science, and society are developed in STS classrooms. The connectİons between technology, science, and society are of the utmost importance. The development of values and attitudes by students from viewing the issues(s) from all perspectives and raising questions about opposing viewpoints is important. Problem-solving, also plays an important role since the study of STS issues develops in students ways of producing and applying knowledge about nature and society. Finally, the issues that the students have been studying should encourage them to become involved in a societal or personal action. A model was sought that would include these features, providing a systematic method for science learning and teaching.

The Jurlsprudeatİal Model

Oliver and Shaver (1966) developed a model of learning and teaching that was devised for social studies. Students were asked to study cases involving social problems in areas where public policy decisions and actions were needed (Joyce & Weil, 1986). It is from this ortginal model by Oliver and Shaver (1966) that the Jurisprudential Model for STS study is derived. The model is put together taking into consideration ali of the expectations and criteria for STS issues currently investigated. Six phases are recognized in this model for the study of STS issues. They are:

1. Orientation of the student to the issues being studied.

2. Students identifying and defining the issues that they are studying.
3. Students synthesize the researched information from Phase II İnto arguments supporting their assigned point of view.
4.The public meeting.
5.Opportunity for the students to clarify and reach a consensus on the issue(s) that they are studying.
6. Involves the students in becoming involved in the societal or personal issue by taking a course of action on the issue.

OrİenUtİoa of the studeat to the İssues belng studled.

The focus of this phase is on knowledge acquisition. it is during this phase that students develop the three fundamental concepts of science, technology, and society, and begin to see the connections between the three concepts. Orientation to the issue includes giving the students instructions on decision-making schemes, their impact, and the roles that they play in making decisions.

Students identifying and defining the İssues that they are studying.

Students draw from knowledge acquisition in Phase I. The students begin to identify values and value conflicts as well as begin to raise questions about the opposing view(s). Students in this phase develop a sense of the relations of technological or scientific developments to societally relevant issues. Students observe that science, technology, and society are mutually influenced by each other, and there are differing viewpoints about issues as well as different options for solving a given issue.

Students synthesize the researched İnformation from Phase II İnto arguments supporting their assigned point of view.

The emphasİs is to develop in the students an ability to solve problems and process information by applying knowledge gained from the study of societal problems and İssues. During this phase, the students established the violation of the value by usİng factual information for support. They prove the undesirable or desirable consequences of a position and clarify the value conflict with analogies. Students are also involved in setting priorities and asserting priorities of one value över another and demonstrating the lack of gross violation of a second value. The relevancy of each of the factual assumptions is tested, determining the consequences, and examining their factual validity. It is during this phase that the students prepare for a public discussion of the issue that they are studying. A mock public meeting will be held that involves all of the students.

The public meeting.

The fourth phase of the jurisprudentİal STS model involves the students in a mock public meeting. This meeting involves all students in presenting the different sides of the İssue being studied. Several students should be selected to be the board of arbiters during the public discussion. These should be chosen in advance of Phase IV and given specific directions on how to manage a discussion. During the debate it is important that the students on the board initiate and oversee the meeting. It is also important that the teacher sees that the following guidelines are adhered to:

1. Maintain a vigorous intellectual climate where ali views are respected;
2. Avoid the direct evaluation of each other's opinion;
3. See that issues are thoroughly expIored; and
4. Respect the authority of the board.

It is important that the directions the students receive be as clear as possible in preparing for the meeting. The less confusion about when to do what will help in meeting the goal of the debate.

Phase V provides the opportunity for the s tu de D ts to clarify and reach a consensus on the issue(s) that they are studying.

It is at this time that students come together collectively and cooperatively to identify possible solutions to the problems that they encountered. Students rely on information that they gained from debating the issues with their peers, from information gained through their own research, from information gained through traditional classroom strategies, and from information shared from other groups. This phase is recognized as cooperative in nature. The effort should reflect the opinions of all the students in the groups. This culminating activity engages the students in developing interpersonal working relationships and problem-solving/decision-making skills.

The final phase, Phase VI, of this model İnvolves the students in becoming involved in the societal or personal İssue by taking a course of action on the İssue.

The course of action taken by the students is a joint effort (decided by the class) and one of personal interest (on their own). The course of action that the students follow is decided on after a consensus on the issue is reached. This consensus (in Phase V) has the student look at weighing the tradeoffs drawn from various alternative options. The key to the entire model is that the students have opportunities to apply the investigation skills and action strategies in the community in which they live. This clarifies for the students that the science that they have learned is of value to them.

Teacher's Role

The teacher's role during this entire exercise is important. As the student are researching, discussing, and debating, the teacher should encourage the students to commit themselves to one side of the issue, praise students for changing their minds when confronted with new evidence, encourage students to consider alternatives from other points of view, and encourage full involvement of students in any perspective reversals. At all times, the teacher should remaİn neutral on the issues, encourage differentiation of positions, and encourage synthesis of the different positions presented to the class.

A Study

The Jurisprudential Model for STS study (JPM-STS) was implemented in a high school chemistry class (Pedersen, 1990, in press-a). Ninety-five high school chemistry students were assigned as intact classes to the treatment. Half of the students experienced chemistry in the form of lecture and laboratory. The other half of the students were split up into groups of four and teams of two. Each team was assigned one side of an issue (either pro or con). All students spent six weeks studying the material and ali materials were made available to all students. The differences between achievement in chemistry, attitudes toward science, anxiety tovvards science, and problem solving perceptions were examined.

The results of this study provide some important information concerning the use of STS issues in the classroom. Attitudes were significantly different in the STS group as compared with the traditional setting. Students found the study of science within the JPM-STS realm more interesting than conventional means of dispensing information. This supports Yager's (1990) conclusions which indicate that students involved in the study of STS issues have more positive attitudes toward science. Anxiety towards the science that the students took were also significantly different (Pedersen, in press-a). Students in the JPM-STS classes were less threatened by the science that they were studying. The sharing of information, working in cooperative groups, not being preoccupied with the fear of knowing all, and being provided specific tasks in the learning sequence may have all contributed to the reduction of anxiety. Pedersen (1990) also found that the students in the JPM-STS group had better perceptions of themselves as problem solvers. Indications were that the traditionally taught students were not as confident in their own abilities to solve personal problems.

Of the four variables examined, only achievement was found to have no difference between
the two groups examined. The study of STS issues (via JPM-STS) provided the students with similar knowledge to achieve on teacher-made objective tests.

Even though achievement was sımilar in both groups, one must ask about the form of testing. It would seem that the testing of the STS students via conventional methods would contradict the overall phİlosophy of STS study. Although learning content is an important component of STS, it is not by any means the only component. We, as educators, must look at alternative methods of measurement, testing, and evaluation. There must be a match between the objectives of the teacher, the activities by which the information was p resen ted and the manner in which the students were tested. If t his does not exist, one must question the validity of the İnstruments being used. If teachers continue to evaluate in tradİtİonal ways, the value of STS will be lost in the dogmatism of grading.

Limitations

The limitations of this model of teaching are few, but important. The comments provided by the teachers who used this model, highlight some of the limitations. The primary concern for the teachers were the resources needed to implement this particular model, or as they see it, any successful STS study. Coordination between the science teacher and the librarian is essential, so that the students can access information necessary to study current issues. Teachers were also concerned about the length of time needed to cover material. Indications are that it takes much longer to cover the same material with the JPM-STS than conventional methods. Although a concern of many teachers, the depth of study required by this approach has been shown to be superior to mere coverage of content. Basic to Project 2061 (1989) is the assumption that "less is more." More emphasis should be placed on the in-depth study, understanding, and application of science rather than the perfunctory coverage of material. As Newman (1988) indicates, "we cling to conception of education more appropriate to medieval times, when formal public knowledge was relatively well-defined, finite, and manageable" (p. 347).

Concluslons and Recommendations

The current trends in science education seem to be clear. We are heading toward educating İndividuals for science literacy. We are overcoming many common myths of science education, including: 1) my students are going to need my course when they get to college; 2) my students are going to need my course because most of them won't go to college; 3) studying science wîll help my students make logical decisions; 4) my course is tough because I want to find out what the kids are made of; and 5) science teachers are scientİsts; (Leyden, 1984). These myths have plagued us for decades. Now we seem to be lookîng first to the needs of the students. STS issues and the Jurisprudential Model not only fili the need for dealing with socially relevant issues; they provide a method of teaching and learning which is consistent with "the most promising new model (of learning) called the Constructivist Learning Model (CLM)" (Yager, 1991, p. 53).

The data provided by Pedersen (1990, in press-b) provide information which substantiates the effectiveness of the model and the study of STS issues. There are many instructional advantages for placing students in situations where they must share information cooperatively, present their perspective of the issues being studied, and come to a group consensus on the issue. Anxiety towards science is reduced; a more positive attitude toward science is taken; and the perceptions of the students'own problem solving abilities are enhanced. The implications of this seem direct. Students find that studying societal issues in a structured manner less stressful (anxiety reduced), find it more interesting and worthwhile (attitude towards science improved), and indicate they feel more confident to solve personal problems (perceptions of problem solving ability).

This is only one perspective of how an educator might deal with STS issues in the classroom. It is important to remember that STS issues are not things that a teacher can pull out of a book; they are not simply newspaper articles about issues in science; they are not "discussing" an issue for ten minutes once a week. It is the integration of societal and technological issues into the fabric of science content that represents STS. The jurisprudential/inquiry STS model is one way in which community issues can be integrated into science content. Students must see the value of science. By using STS issues in this manner, students can see how the issue impacts them and also how they impact the issue.

References

American Association for the Advancement of Science. (1989). Science for all Americans: Summarv--Proiect 2061. Washington, DC: Author.

Bybee, R. W., & Bonnstetter, R. J. (1986). STS: What do the teachers think? in R. W. Bybee(Ed.1. 1985 NSTA vearbook: Science/technologv/societv (PP. 117-127). Washington, DC: National Science Teachers Association.

Harms, N. C, Bybee, R., & Yager, R. E. (1979). Science and societv: A review of NAEP data with implications for policies and research (Interoretative Summarvl Denver, CO: National Assessment of Educational Progress.

Hellesnes, J. (1970). Education and the concept of critique. in E. Bredo & W. Feinberg, (Eds.), Knowledge and values in social and educational research (pp. 355-369). Philadelphia, PA: Temple University Press.

Hickman, F. M., Patrick, J. J., & Bybee, R. W. (1987). Science/technoloev/societv: A framework for curriculum reform in secondarv school science and social studies. Boulder, CO. Social Science Education Consortium, Inc.

Hungerford, H. R., Peyton, R. B., & Wilke, R. J. (1980). Goals for curriculum development in environmental education. The Journal of Environmental Education. 4j_(l), 42-47.

Joyce, B., & Weil, M. (1986). Models of teachine. Englewood Cliffs, NJ: Prentice-Hall, Inc.

Kahl, S_M & Harms, N. C. (1981). Project synthesis: Purpose, organization and procedures. In N. C. Harms & R. E. Yager (Eds.), What research savs to the science teacher. (Vol. 3) (pp. 5-11). Washington, DC: National Science Teachers Association.

Mullis, I. V. S., & Jenkins, L. B. (Eds.). (1988). The science report card: Elements of risk and recoverv. Princeton, NJ: NAEP Educational Testing Service.

National Science Teachers Assocİation. (1990-1991). Science/technology/society: A ne w effort for providing appropriate science for all (Position Statement). In NSTA Handbook (pp. 47-48). Washington, DC: Author.

Newman, F. M. (1988). Can depth replace coverage in the high school curriculum? Phi Delta Kappan. 69(5), 345-348.

Oliver, D. W., & Shaver, J. (1986). Teachine public issues in the high school. Boston, MA: Houghton Mifflin.

Pedersen, J. E. (1990). The effects of science. technologv and societal issues. imolemented as a cooperative controversv. on attitudes toward science. anxietv toward science. problem

solving perceptions and achievements in secondarv science. Unpublished doctoral
dissertation, University of Nebraska, Lincoln.

Pedersen, J. E. (in press-a). The jurisprudential STS model of teaching: An overlooked model for STS issues. Science Scooe.

Pedersen, J. E. (in press-b). The effects of cooperative controversies, presented as STS issues, on anxiety and achievement in secondary science classrooms. School Science and
Mathematics.

Roy, R. (1985). The science/technology/society connection. Curriculum Review. 24(3). 13-16

Rubba, P. A., & Wiesenmayer, R. L. (1985). A goal structure for precoüegc STS education: A proposal based upon recent literatüre in environmental education. Bulletin of Science. Technology and Societv. 5(6), 573-580.

Wiesenmayer, R. L., & Rubba, P. A. (1990, April). The effects of STS issue investigation and action instruction and traditional life science instruction on seventh grade students'
citizenship behaviors. Paper presented at the Annual Convention of the National Association for Research in Science Teaching, Atlanta, GA.

Yager, R. E. (1988). S/T/S: The place to begin. Chautauoua Notes. 3m. 1-2.

Yager, R. E. (1991). The constructivist learning model: Towards real reform in science
education. The Science Teacher. 54(6), 52-57.

Yager, R. E., & Penick, J. E. (1985). Societal issues at the heart of the science curriculum.
Educational Leadership. 41(5), 83.

Envİroamental Education: Sustainable Developmeot and Decİsion-Making

Koos Kortland
University of Utrecht, The Netherlands

Starting next year the Dutch system for junior secondary education (students aged 12-15) will be reorganized. A new national curriculum for the school subjects is one of the elements of change. Some of these subject curricula include a number of environmental issues to be dealt with in the context of decision-making by students--two key ingredients of Science/Technology/Society (STS) efforts worldwide. This innovative element of decision-making is reflected by attainment targets like "students are able to present an argumented point of view in a situation of choice" (physics/chemistry) and "students are able to identify alternative courses of action and to elucidate their evaluation and preference with respect to these alternatives" (biology). These attainment targets are conneeted to a number of socioscientific issues, among which are some environmental ones: waste processing, energy sources, and noise pollution (physics/chemistry), waste processing, food produetion, and food consumption (biology). In order to prepare for these educational innovations, a national program for developing and implementing environmental education within the existing school subjects was started (Boersma, 1991). An important part of this program was the development of a core-curriculum for environmental education (Pieters, 1990). The core-curriculum proposes common goals, content, and skills for a number of school subjects: a network of concepts related to a sustainable development of the relationship between human beİngs and the environment and a number of skills related to decision-making.

Unfortunately, classroom experiences with a systematic approach to environmental education are not yet widely available. But, a small scale project has been started, with the aim of investigating classroom experiences with the required educational innovations in the school subjects of geography, biology, and physics/chemistry af junior secondary level.[1] For this purpose some teaching units have been developed. The research concentrates on the development of the students'concept of sustainability and of the students' reasoning skills in decision-making situations. The procedure and some of the results of the research on one teaching unit developed for physics/chemistry, "Garbage-Dumping, Burning, and Reuse/Recycling", are presented.

Environmental Education: The Aims

Education should help students to understand environmental issues and should help them in making thoughtful decisions about their behaviour in everyday-life related to these issues. Or, in the wording of the core curriculum: students acauire knowledge and abilities which enable them. in their thinking and aeting. to take into account a sustainable development of the relationship between human beings and the environment.

With respect to the decision-making aspect in this general aim, it is not our intention that students as a result of environmental education will make their decisions exclusively based on environmental considerations. Education should aim at teaching students to choose independently and in a thoughtful way, systematically weighing as many relevant arguments pro and con as possible--among various arguments related to sustainable development.

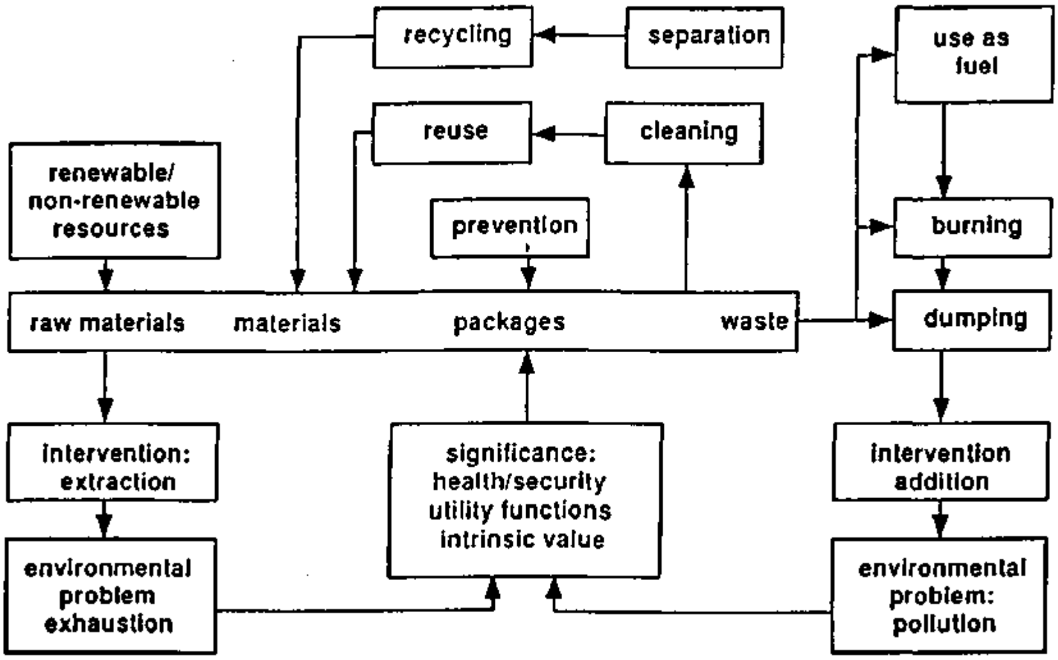
The first step in the research program consisted of construeting a framework for the development of the teaching unit on household garbage. The time available (seven classroom periods of 45 minutes each) and the age/ability level of the students (13-14 year olds/average ability level) made some further limitations necessary: a limitation of the issue (discarded packages in household

[1] The same kind of research is also carrİed out for the school subjects of biology and physics at the senior secondary level.

garbage) and of the aspects to consider (no details on different kinds of pollution and no energy aspects).

The resulting framework is presented in Figüre 1. in this framework the relationship between human beings and the environment İs visible in the lower part. The environment has a significance for human beings with respect to health and sccurity (e.g., food, oxygen, shelter) and utility functions (apart from merely surviving in good health) because the environment provides a source of (renewab!e and non-renewable) raw materials--used for producing packages (amongst a variety of other products). Human beings thereby intervene in the environment, i.e,, they extract raw materials. If this intervention leads to effects which threaten the above mentioned significance of the environment, an environmental problem emerges, i.e., exhaustion of the supply. On the other side, the environment is aiso used to dispose of waste by dumping and burning. This intervention (addition) might lead to another environmental problem, e.g., pollution of soil, water, and air; threatening the significance of the environment—not only for human health/security, but also for
the existence of plants and animals (intrinsic value of nature).

Figure 1: Framework for the Physics/Chemistry Teaching Unit on Household Garbage



For a <u>sustainable development</u> of the relationship between human beings and the environment, <u>matter</u> is to be extracted from or added to the environment only in a restricted way and natural cycles are to be left intact or are to be restored. The ecological considerations lead to the following measures to be considered as far as packages are concerned: prevention of unnecessary packing, use of renewable raw materials, reuse of packages and recycling of packing materials (with cleaning and waste separation as necessary conditions), and finally--as a lastoption—the use of waste as a fuel (e.g., for electricity production).

The framework presented in Figüre I can be seen as a partial elaboratîon of the concept of sustainable development in dealing with the human use of matter. Thinking along the lines of this framework is a necessary condition for thoughtful decision-making in everyday-life in situations of choice between different packages of products and different ways to dispose of those packages.

Concept Development

Studeat Interviews

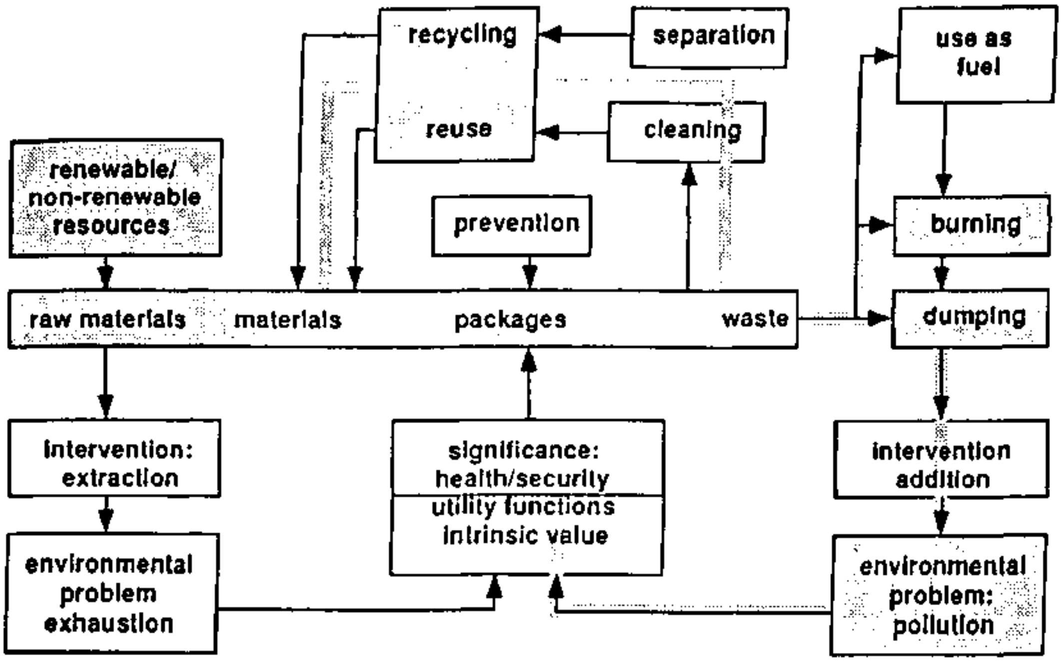
During the second step in the research program, the framework was used to design an interview questionnaire. Eight students from the target group were interviewed with the aim of assessing the extent that their ideas about the waste issue covered the framework represented in Figure 1.

During the interviews students were successively presented with a number of environmental effects (exhaustion of raw materials and pollution of air, water, and soil) and were asked whether or not (and why) this environmental effect is related to dumping or burning of household waste and whether or not (and why) they consider this effect as problematic.
in the next part of the İnterview students were presented with different ways of dealing with waste (e.g., prevention, reuse, recycling, use as fuel, burning, and dumping) and were asked to select the best wav. the second best wav. ete, for reducing the environmental problems: thev were also asked to explain their choices.
The results of this part of the interviews can be summarized with the following points:
* Students are aware of pollution through dumping and burning waste. Pollution is regarded as problematic, in most cases because of its effects on human health. Clean air, water, and soil are seen as necessary conditions for living. in some cases the students refer to an intrinsİc value of nature, e.g., pollution threatens the existence of plants and animals which also "have a right to live."

Especially when dealing with air pollution through waste burning, students mention more specific environmental effects, but in most cases these are not very relevant to the issue (acid rain) and/or are not understood properly (confusion between greenhouse effect and depletion of the ozone layer).
* Students do not see exhaustion as being related to the waste issue. Students were nevertheless asked the question about exhaustion being problematic or not, even though it might be disconneeted from the waste issue. £xhaustion is seen as problematic in the case of wood, again mainly because of the significance of the environment for human health: "no more trees, no more oxygen." As far as other, non-renewable raw materials (e.g., oil, aluminum) are concerned, the issue was much less elear.
* Without explicitly referring to a sustainable development, students see reuse/recycling as a solution for the perceived environmental problems, but a clear distinetion between the two environmental problems is not made by them. Only some students recognize the importance of household separation of waste as a necessary condition for recycling. The notion of recycling problems conneeted to the use of laminated materials in packages is also not very prominent. Finally, the negative environmental effects of reuse (water pollution through eleaning bottles) are not considered, with only one exception.
* The idea of waste prevention is either not understood or seen as identical to reuse/recycling.
* Also, the possibility of using waste as a fuel for generating eleetricity appears to cause conceptual problems. Some students argue that this way of generating eleetricity is not very helpful because fuel has to be added in order to burn waste. Other students are more in favour because in this case "waste is turned into something useful." However, no one mentioned the idea that waste could substitute for fossil fuels in a power plant, thus reducing the amount of pollution as compared to the existing situation.

The interviews lead to the conclusions that most of the eight students have a limited view of the waste issue, as shown in Figüre 2. Students are only partially aware of the significance of the environment (human health) and of the environmental problems connected to the waste issue (pollution). Measures representing a sustainable development are only partially recognized. And as far as these measures are recognized, they appear to be confusing (reuse/recycling) and not lınked to necessary conditions for those measures.

Figure 2: Student View of the Waste Issue (shaded)



The third step in the research program consisted of writing the teaching unit, taking into account the conclusion drawn from the interviews. it was decided to pay no attention (yet) to the existing confusion between the different specific environmental effects of waste dumping and burning and to stress the relation between these ways of waste processing and exhaustion of raw materials. Measures representing a sustainable development were described with the help of concrete everyday-life examples, combined with reflecting questions dealing with comparisons between different measures and their respective conditions.

Classroom Observations

The conclusion drawn from the interviews was checked during the fourth step in the research program: observations of the classroom trials of the unit in four classes at two schools. So far only the data from one of these schools (32 students) have been analyzed. These data tend to confirm the view of students concerning the waste issue represented in Figüre 2.

The data from the observations also give more details on conceptual problems possessed by students. These could affect decisions dealing with the waste issue in everyday-life. These results can be summarized with the following points.

* The first type of decision concerns making a choice between alternative ways of packing. From the observations it appears that students stili have considerable difficulty in making a distinction betvveen reuse and recycling, but not only that. The students' ideas on the

possibilitİes for recycling seem to be connected to the existing/emerging structure of separate collection of household waste, so that some materials are classified wrongly as non-recyclable. And by some students renewable İs seen as identical to recyclable. Under these conditions a decision in everyday-Iife situations of choîce between reusable packages and packages made of recyclable and/or renewable materials might turn out contrary to the intention of students.

* The second type of decision concerns the disposal of waste. The already mentioned conf usion between reuse and recycling could lead to the decision of dumping reusable bottles in the glass recycling container, as was indicated by a number of students during the intervievvs.

From the observations some other conceptual problems connected to the disposal of waste were identİfied. Some students connect recycling to the biological cycle of matter, and argue that for biodegradable materials "recycling is not possible, because the material decomposes." And although most students prefer a system of household separation of waste, the only reason for this is that it's "just a lot of work to şort it ali out" for recycling purpose af ter dumping. The notion that degradation of materials through mixing different kinds of waste can make some materials (like paper) quite unfit for recycling is not very prominent with most students. These ideas might influence an assessment of the usefulness--and willingness to participate in--separate collection of household waste.

* Finally, the observations show that many students think a completely closed cycle of materials possible, while İn practice this İsn't--due to unavoidable losses and deterioration of materials after a number of cycles. This might lead to an unrealistic assessment of the contribution of recycling to a sustainable development.

Decislon-Making

The students'limited view of the waste issues is reflected in their reactions to a decision-making situation, presented to them in the first part of each intervievv (when students did not yet know which issue was going to be considered): in the supermarket vou can choose between milk in a carton and milk in a bottle—what do vou choose. and whv?

This part of the interviews has been used to assess the students' aualitv of argumentation in v decision-making situations with respect to the range. depth. and weiehing of the arguments put forward. This implies looking for answers to question like: Are ali environmental aspects of both alternatives being considered? (range), How specific and valid is each argument and which indication of the relevance of an argument is being given? (depth). And finally: Which argument is the decisive one, and why? (weighing). The results of this analysis can be summarized with the following points.

* When asked to give reasons for their choice, most of the students do not mention any environmental aspect. When specifically asked, students indicate that the choice between the two alternatives has environmental impact The carton contrİbutes to the amount of waste and to pollution. Therefore, the (reusable) bottle has an environmentally friendly image. The negative environmental impact of reusing bottles (due to cleaning) is not considered. So the range of arguments put forward can be classified as narrow. incomplete, and unbalanced.

* Whenever environmental aspects are mentioned by students, the arguments are not very specific: "less waste" or "more pollution." At this level of specification, the arguments seem valid. Any indication of the relevance of an argument is lacking: There is no reference to the significance of the environment (as indicated in the Environmental Education sectİon) being threatened. So the depth of arguments put forward can be classified as superficial.

* Even when specifically asked a weighing of arguments is almost absent, and--if present--done in a limited way (see Figüre 3 for one of the very few examples). As far as the decision itself is concerned, most students choose the carton in spite of the environmentally friendly image of the (reusable)bottle. it seems that aspects of comfort and habits at home (carton)

are playing a relatıvely important role in that decision (see Figüre 4 for one of the more outspoken reactions).

Figüre 3: Interview Fragment Illustrating Some Weighing of Arguments

Q If you choose a carton, it would be because the bottle is fragile. But you also said the bottle is environment-frİendly. What is decisive for you: Which of those two do you think most important?

A Environmental friendliness. Because that bottle doesn't always shatter to pieces. I mean: you can drop it from your hands, but that doesn't happen ali too often.

Figüre 4: Interview Fragment Illustrating Habits at Home as a Decisive Argument

Q You have said: The carton has the disadvantage that you throw it away, and the advantage that you are used to it. What is more important for you?

A The environment.

Q That would mean--if you could choose--that you would take a bottle?

A No, because if I came home with a bottle my mother would look at me rather funny. I would never come home with a bottle.

At the end of the interview students were presented with another decision-making situation. After shortly describing some individual measures to reduce the environmental problems of waste dumping and burning (prevention, reuse, and recycling), students were asked <u>whether or not they consider takine these measures as beine useful (and whv)</u>.

All students are of the opinion that these measures are useful, also in the way of giving an example for other people to follow. Only one student expresses some doubt at this point "Now I say ‘yes,’ of course. But really doing it..." However, when the question is put in a less general way--more directly pointing at a specific behaviour--it appears that again habits and this time also practical obstacles are more decisive (see Figüre 5 for an example).

Figüre 5: Interview Fragment Illustrating Objections to Taking individual Measures

Q If the local go ve m men t decided to collect glass, paper, organic waste, and similar items separately, would you co-operate?

A I don't think so.

Q No?

A It's difficult to do that. Yes...you just throw everything in the refuse bin at home.

Q Yes, and then the local government says: No, No, ali that has to be separated. Then you would not...

A Oh no. We are not going to fiil up the kitchen with refuse bins, because those would be in our way.

In both decision-making situations the students' reactions show a discrepancy between attitude and behaviour intention. This discrepancy is explained by the model of the relationship between attitude and behaviour proposed by Fishbein & Ajzen (1975) in which the intention to act is not only influenced by an attitude towards that specific behaviour but also by the perception of--and the willingness to accept--the viewpoint of others.

In an attempt to improve the students'quality of argumentation, some decision-making activities were included in the teaching unit, representing Kortland's procedure of structured decision-making (Kortland, 1991). These activities include reflective questİons on the seriousness of the issue, on the assessment of the environmental impact of given alternative ways of wasteprocessing and packing products, and finally on the choice of the best alternative.

The observations during the trials gıve some idea of how vvorking on the unit changed the students' quality of argumentation. Near the end of the unit--after dealing with the different aspects of the waste İssue—students work on an optional topic. Each of these topics deals with a decision-making situation: choosing between two alternative ways of packing a product (e.g., soft drink in a bottle or a can) or between two alternative materials for a product (e.g., a plastic or paper shopping bag).

An analysis of the quality of the students' argumentation with respect to range, depth, and weighing when choosing between the alternatives leads to the conclusion that the depth of the arguments put forward does not change in comparison with the statements during the interviews.

However, the range of arguments used has broadened: now roughly half of the students use <u>exhaustion of raw materials</u> as one of the points of comparison between the alternatives, and more often the advantages <u>and</u> disadvantages of <u>both</u> alternatives are stated. To an extent this points to an improved quality of argumentation. From the viewpoint of concept development this can be interpreted also as a growth in awareness of the existing connections in the lower left part of the students' framework outlined in Figüre 2. Explicit weighing of arguments is stili rare, but in some cases a new element İn the argumentation is emerging: students are trying to defend their choice by pointing at solutions for the perceived disadvantages of the chosen alternative.

Reflections

The research program for investİgating classroom experiences with the required educational innovations has only begun. The short term task is to complete the analysis of data from the observations and to compare this with the outcomes of the similar research done in the other school subjects mentioned in the first section. During the fourth step in the research program, the results will be discussed with the teachers of the trial schools in order to prepare for the second trials of the teaching unit how to recognize and deal with the students'conceptual problems and how to improve their decision-making abilities.

Research and Development Program

Decision-making appears to be a consistently emphasized skill in STS position papers and teaching materials. in their report on the discussions İn the STS VVorking Group at the Fourth IOSTE Symposium, Hofstein, Aikenhead, and Riquarts (1988) stress the need to investigate the effects of STS instruction on students'decisions, on the way in which student arrive at their decİsions, and on the quality of their arguments.

The research on the STS subtopic of environmental educatİon described in this paper is but one step in that direction, aimed at getting an idea of the classroom feasibility of what is often a too highly set expectation and claim in position papers and curriculum documents (like the core-curriculum for environmental education mentioned in the first section). The intention is that this research will be the start of an interactİon between research and development as advocated by Eijkelhof and Lijnse (1988) in order to raise the credibility and quality of STS education. Based on their experiences, they describe a four-stage research and development program for STS education, in which the first two stages--connected to the first and second version of teaching materials—serve the purpose of showing what İs meant by authors of position papers and of studying some of the claims made by them. However, the third stage is crucİal for the future of STS education. This third stage consists of a legitimation of contents, selection of lay İdeas to which STS education should pay attention, and the development of strategies for dealing with these ideas.

The research program described in this chapter is paying attention to lay ideas and way of reasoning that might obstruct thoughtful decision-making in a very early state. in this way we hope to be able to reduce the timespan needed to produce high quality examples of teaching materials and teachİng practice, serving as an input to efforts dİrected at the required implementation of environmental education and STS teaching.

References

Boersma, K. Th. (1991). Policv and decisions in Dutch environmental education: Strateeies and developments. Paper presented at the Sixth IOSTE Symposium on World Trends in Science and Technology Education, Palm Springs, CA.

Eijkelhof, H. M. C, & Lijnse, P. L. (1988). The role of research and development to improve STS education: Experiences from the PLON-project. International Journal of Science Education. İÛ(4), 464-474.

Fishbein, M., & Ajzen, I. (1975). Belief. attitude. intention and hehaviour An introduction to theorv and research. Reading, MA: Addison-VVesley.

Hofstein, A., Aikenhead, G., & Riquarts, K. (1988). Discussions över STS at the Fourth IOSTE symposium. International Journal of Science Education. !û(4), 357-366.

Kortland, J. (1991). Environmental education: A matter of garbaee. Paper presented at the Sixth IOSTE Symposium on VVorld Trends in Science and Technology Education, Palm Springs, CA.

Pieters, M. (Ed.). (1990). Teaching for sustainable development. Enschede, The Netherlands: SLO.

STS İn the Preparation of Elementary Science Teachers

Dar-Sun Huang
National Taitung Teachers College, Taiwan

Ideally, the objectives for science teaching should produce students who can: 1) synthesize, analyze, and evaluate scientific knowledge; 2) use scientific processes for performing higher-order cognitive thought processes in questionİng nature; 3) apply the scientific processes and knowledge in coping with personal needs and societal demands; 4) make informed decisions dealing with personal and societal issues related to science and technology; 5) develop sound scientific attitudes; 6) enhance their interest and appreciation toward science, scientists, and the science community; and 7) nurture the creative capacity that characterizes basic science (Harms & Yager, 1981; Penick, 1982; Scharmann & Harty, 1986; Toffler, 1972; Yager, 1980a, 1980b, 1980c; Yager & Penick, 1987).

Actually, t here are enormous discrepancies between the goals stated above and the actual results of most science instruction. For example, İn biology instruction several research papers state that "Biology, as it appears in the school program, is püre in that there are few applications, little attention to current issues, no focus on personal needs of students, and little attention to career awareness" (Harms & Yager, 1981; Yager, Hofstein & Lunetta, 1981). Yager further indicated that;
"Too many biology teachers remain enamored with research biologists and consider them to be İn the best position to define research results and to establish the legitimacy of the biology being taught."

College science teaching is much like precollege science instruction, especially biology for non-science majors. Basically, the college science curriculum has perpetuated the view of the curriculum as being strictly content-oriented. Larson (1982) delineated this by noting that college science subjects are usually bogged down with jargon, symbols, arithmetic metaphors, equations, mathematic computations and analytical thought processes which can turn off and discourage non-major students.

In the United States, Harms and Yager summarized Project Synthesis which identified four goal clusters for science education which broaden the tasks assumed important for science in general education. Preparing citizens for effective living in the current world and in the 2İst century is certainly a fundamental purpose for any general course required for graduation. Presumably, these four goal clusters should serve as majör guidelines in leading to innovation, in delineating curriculum design, and in defining teaching strategİes for the college science courses for non-majors.

The four goal clusters from PROJECT SYNTHESİS and a brief rationale for each are:

1. Science for meeting personal needs: Science education should prepare individuals to utilize science for improving their own lives or health and coping with an increasingly technological world.
2. Science for resolving societal issues: Science education should produce informed citizens prepared to deal responsibly with science and technology related issues.
3. Science for career awareness: Science education should give ali students an awareness of the nature and scope of a wide variety of science and technology related careers öpen to students of varying aptitudes and interests.
4. Science as preparation for further study: Science education should allow students who are likely to pursue academîcal careers as well as professionally to acquire the academic knowledge appropriate for their needs (Harms & Yager, 1981).

On the other hand, the data from the three Assessments of Science (ETS, 1988; Hueftle, Rakow & Welch, 1982; NAEP, 1978), reveal that only 22% of young adults polled believe that science witl be useful in their future. Congruently, 70 percent of the students indicated that science classes made them unhappy. More sadly, most students responded that they had no input in deciding the sequence of topics studied in the science classroom. These negative attitudes toward science and science teaching and learnıng are soberİng and provide stimulus for reflection on the part of science educators. Voelker (1982) reported on science literacy and identified two central results about school science and science attentiveness: I) Ninety percent of ali high school graduates in the United States are not scientifically/technologically literate; 2) The school is ineffective İn influencing science interest, knowledge, or the further pursuit of either. Furthermore, the effects of various teacher traits upon student learning account for less that 10 percent of whatever affects student learning (Anderson, 1983). and, över 90 percent of ali science teachers viewed the ir goals as static, seldom changing, and "givens" (Yager, 1986).

In response to failures in school science reviewed above, educators have increasingly recognized that the definition of science education needs to go beyond including societal issues related to scientific developments and to incorporate the relationships between science and technology (McConnell, 1982). Yager defined the science education as the discipline concerned with the study of the interaction of society and science (1984). Such a view for school science suggests a close relationship between science and society; perhaps in science teaching we cannot separate the two and treat them as unrelated discrete human endeavors. Yager offered an analogy to help explain his definition: The discipline of science education. when defined as the interface between science and society, may be likened to the celi membrane which surrounds the living cell--separatİng the living raaterials from the surroundings. The membrane is a dynamic one through which ali materials enter and exit the celi itself. Studying the process and the factors controlling such movement, the direct involvement of the membrane in the actions can be used as parallel in terms of science education and its role in assisting professİonal scientists to understand and affect society."

Apparently, an effective science program should not ignore the relationships and interactions among science, technology, and society. in other words, we should assume that science instruction must develop a humane rationality growing out of scientific concepts; solving problems of human living requİres not only appropriate knowledge but interpretation of the content in terms of human values and relationships. Under such awareness, the Science/Technology/Society (STS) movement is considered by many to be the megatrend and impetus for science education for future citizens.

The STS Rationale İn College Science instruction

Up to now, very few STS programs have been developed for college science teaching around the world. Nevertheless, it does not mean that science educators and the science community are unaware of the influences of Science/Technology/Society on college science education. According to the data compiled by Bybee (1987), college instructors responded that twenty-five percent of the İnstructional time should be devoted to science related social, family, personal issues, and/or problems.

In another survey, the responses from freshman and sophomore college students also showed that instructors paid little attention to relating chemistry to personal, societal, and political situations (Streitberger, 1985). in reflecting on the growing demands for emphasis at ali levels on the social and human relevance of chemistry from the general public, Streitberger suggested that students do projects focusing on issues related to chemistry for college non-majors. Furthermore, he proposed seven guidelines of how the project should be introduced to the students in the class (1988).

In responding to the needs for promoting the interest on the part of the general public for chemistry and the quality of everyday life, an "introductory Wine course" for college student was created and offered at East Texas State University (Lee, McClung & Nixon, 1986). Basically, this course was an interdisciplinary effort since the topic of the course included the function of human sense organs for tasting and smellİng, wine history in France, organİc molecules, mİcroorganİsms, metabolism of alcohol in the body, and health problems of drinking w ine. Another interesting program in college chemistry based on the rationale of Science/Technology/Society was the "Brain Chemistry and Behavior" course at Saint Louİs University (Spanziano & Gibbons, 1986). The vast majority of students felt that these courses were interesting and informative and that the courses met their expectations for applying the principles of chemistry in "real life."

In college biology, it is claimed that more programs should be developed vvhich use societal issues or personal problems as organizers. Many topics are those closely related to the human community and daily lives of students. Actually, there are some college biology courses that provide

STS units in classes (Hoskins, 1979; Stencel, 1990). Bioethical issues provide attractive topics for use in college science classrooms. Most respondents who were surveyed in the two studies (Franke, 1983; Hendrix, 1977) approved of bioethics teaching and indicated it should be used more. Respondents recommended that related issues be discussed in general biology classes for both majors and non-majors. An instructional model for bioethics education at the college level was proposed by Barman and Hendrix (1983). They consİdered such a model successful if it resutted in information dissemination, classroom discussion, decision-making, evaluation by students.

Based upon the descriptions stated above, there can be little doubt that the rationale of STS would be the most appropriate approach for college science instruction in terms of educating our students to adapt their lives efficiently, harmoniously, and intelligently for the future.

The Rationale of STS İD College Biology Education for Non-majors

During the last decade, many biosocial problems and biotechnology issues such as euthanasia, legalization of abortion, in vitro fertİlization, surrogate motherhood, drug ab use, and eugenics have been presented and discussed widely in the mass media around the world. As a consequence, decision-making related to biosocİal/bioethical dilemmas has become an important element in the daily lives of most people. Doubtless, every cîtizen has to develop a sound understanding and gain the concepts and strategies needed to make responsible decisions about such issues. The new trend was discussed by research in the early 80s. Hurd, Bybee, Kani, and Yager (1980) stated that the biology curriculum for the 1980s should characterize by concepts and content that can be used in interpreting and improving human life. This should mean that the interdisciplinary or transdisciplinary ideas will gradually be more İmportant than content traditionally described as the discipline of biology because personal needs of students and the societal issues that are the basis for a ne w biology programs are not bound by single discipline studies defined by professional biologists. Recognitions of the relationship of science, values, and culture. should be stressed and encouraged--not ignored.

One of the recommendations in 1982 National Research Council report, "Science for Nonspecialists: The College Years" hİghlighted this orientation for current and future emphasis in college science teaching. Specifİcally, the report said college science education should enable nonspecialists to gain the scientific and technological knowledge needed to fulfill civic responsibilities in an increasingly technological society (National Research Council, 1982).

Inasmuch as biology is one of the science areas that is intimately related to human individuals and the community, biology teaching cannot afford to ignore the goals for meeting personal needs and in resolving social problems related to biological science and technology. Based on his many years of experience in teaching and observation, Hacker described vividly the students* concerns when he stated that as a teacher of biology for many years at both the high school and college levels, I often observed, for example, that whenever the urogenital system was introduced, students would linger af ter class asking such questions as: How do you know when you are in love?...What causes homosexuality?...These questions obviously went beyond biological principles (Hacker, 1981).

It has been argued that a curriculum which emphasizes traditional cognitive knowledge and an understanding of scientific processes will lead to an understanding of how to resolve science-related personal and societal problems confronting society. However, the accuracy of such thinking cannot be assumed. Traditional knowledge-focused curricula do not automatically assist student-citizens in applying their scientific knowledge and processes to the problems they encounter (Voelker, 1982). This concern is confirmed more profoundly by Mertens and Hendrix (1982) when they stated that although being in command of the correct "fact" is absolutely necessary for effective decision-making, the scientific facts alone will not allow for wise decisions. Unless decision-makers understand how their own values affect their choices, they can not be good decision-makers. What we hope to teach our students is that, just as they can learn to solve genetics problems, they can also learn how to clarify their own values and develop techniques for reaching decisions on controversİal issues that are personally satisfying and can be justified by the individual.

In the early 1980s, Hofstein and Yager (1982) suggested using societal issues as organizers for classroom science teaching. They argued that issues in science related to individual and personal needs of people are important problems to use as curriculum/course organizers. For biology teaching, McCormack (1983) claimed that an exploration of biological/societal problems, ethical dile m mas, and interactive consequences are not educational frills; they could influence our society's survival. it goes without saying that it is out-of-date to teach biological science in predetermined orderly conceptual schemes, free of societal impact, and free of any value judgments. The re f o re, using problems/issues related to biological science and technology as organizers represents a megatrend for biology education at any academic levels and for any program, perhaps especially at the college level for non-majors.

The Rationale of STS in Elementary Science Teach e rs Education

The biology course for the elementary teacher education is idealiy desİgned to meet the objectİves of college general education in science for future elementary science teachers. The STS rationale for science education may be the most approprİate teaching alternative for nurturing prospective citizens and developing their scientific/technological literacy. in the meantime, a great percentage of teachers model their content approach af ter their experiences in college science courses.
This argument was strongly claimed by Penick and Kyle (1982), when they said an opportunity for persons to be involved in such courses is important, especially for prospective teachers of science at any level since many teachers model their content teaching approach after their own experiences with college science courses.

Recently, dissertation research was completed by Huang (1991) in Taiwan. The study was desİgned to investigate and analyze outcomes of student learning in human biology when taught with two different organizational schemes, namely, one with biology related social/personal problems as organizers, the other with biological concepts as organizers. A pretest/posttest format was used to measure changes in student achievement in the domains of biology concepts, applications of biology concepts, the understanding of the processes of science, creativity, and attitudes toward science, science teacher, science careers, and using science in solving world problems. Data for each of the measurements were compared statistically to establish vvhether or not they were inİtİal differences among class sections at the beginning and the end of the study. The author found the general results as follows:

1. The problem-oriented mode in teaching college biology was as effective as the concept-oriented mode for improving student mastery of human biology concepts, facts, principles.
2. The students in problem-oriented classes applied biology concepts to new situatİons outside classroom better than did students who experienced concept-oriented college biology instruction.
3. Students in problem-oriented classes were more effective in understanding and using basic science processes than were students in the sections where concepts were the organizers.
4. The problem-oriented approach had a significant effect upon developing student creativity in terms of asking questions, suggesting causes, and predicting consequences unlike the situation in concept-oriented classes.
5. The problem-oriented teaching mode was significantly more effective in facilitating more positive scientific attitudes toward science, science community, science teacher, science careers, and for using science İn solving world problems by students than was the concept-oriented approach.

When considering the teaching effectiveness in terms of student achİevements in the five domain areas, the superiority of the use of the STS rationale in teaching biology courses in the preparation of elementary science teachers is confirmed. in addition, the problem-oriented mode which used biosocial issues and/or personal problems as organizers in biology teaching also gives the prospective teachers examples of how they can handle such issues in science classes in the elementary school. Use of the STS approach in teaching college science provides great potential in elementary science teacher education.

Conclusion

This century will vanish in less than ten years. But turmoil stili exists in every corner around the world. And, sadly, world problems of pollutİon, energy waste, world hunger and food shortage, overpopulation, disease, depletion of natural resources have no sign of alleviation, and in fact they are likely to worsen during the next decade.

Apparently, neither the governments nor the science educators in the whole world can waive the responsibility for assisting in the resolution of these problems. it is obvious that the crossroad has been reached in science education, i.e., a crisis exists. But a crisis can be a turning point. Actİon can be taken to use the turning point to benefİt the profession; or, lack of action can result in a downward spiral and further deterioration (Yager, 1982). in such a case, it is legitimate to say that the worldwide endeavor of using the STS paradigm as the main theme in science education would benefit the whole worId in resolving many of the current problems.

References

Anderson, S. (1983). Are yesterdays goals adequate for tomorrow? Science Education. *67(2),* 171-176.

Barman, C. R., & Hendrix, J. R. (1983). £xploring bioethical issues: An instruction model. The American Biology Teacher. 45(1), 23-31.

Bybee, R. W. (1987). Teaching about science-technology-society (STS): View of science educators in the United States. School Science and Mathematics. ü(4), 144-152.

Educational Testing Service. (1988). The science report card: Trends and achievement based on the 1986 national assessment (Rep. No. 17-s-0 l). Princeton, NJ: National Assessment of Educational Progress.

Franke, A. W. (1983). Ethical question and biologists. Journal of School Health. 13(2), 32-34, 64.

Hacker, S. S. (1980). it isn't sex education unless ... Journal of School Health. 51(4). 207-210.

Harms, N. C, & Yager, R. E. (Eds.). (1981). What research savs to the science teacher. Vol. 3. Washington, DC: National Science Teachers Association.

Hendrix, J. R. (1977). A survey of bioethics courses in U.S. colleges and universities. The American Biology Teacher. 22(2), 85-87, 92.

Hofstein, A., & Yager, R. E. (1982). Societal issues as organizers for science education in the 80s. School Science and Mathematics. 82(7), 539-547.

Hoskins, B. B. (1979). Sensitizing introductory biology students to bioethics issues. The American Biology Teacher. 41(3). 149-151.

Huang, D. S. (1991). A studv of the effectiveness of a collece biologv course taueht with problems as organizers compared with one with concepts as organizers. Unpublished doctoral dissertation, The University of Iowa, Iowa City.

Hueftle, S. J., Rakow, S. J., & Welch, W. W. (1983). Images of science: A summarv of results from the 1981-82 national assessment in science. Minneapolis, MN: Minnesota Research and Evaluation Center, The University of Minnesota.

Hurd, P. DeH., Bybee, R. W., Kahl, J. B., & Yager, R. E. (1980). Biology education in secondary schools of the United States. *The American Biology Teacher*. *42*(7), 338-404.

Larson, J. H. (1982). Two cultures: Topics for general studies science courses. *Journal of College Science Teaching.* *12*(2), 89-91.

Lee, D. R., McClung, F. A., & Nixon, G. A. (1986). Team-teaching an introductory wine course at the college level. *Journal of Chemical Education. 6*3(12), 1065-1066.

McConnell, M. C. (1982). Teaching about science, technology, and society at secondary level in the United States: An educational dilemma for the 1980s. *Studies in science education*. 9, 1-32.

McCormack, A. J. (1983). Biology and society: Facing a nagging dilemma. *The American Biologv Teacher*. 45(1), 10-15.

Mertens, T. R. & Hendrix, J. R. (1982). Responsible decision-making: A tool for developing biological literacy. The American Biologv Teacher. 44(31. 148-152.

National Assessment of Educational Progress. (1978). *The third assessment of science. 1976-77*. Denver, CO: Author.

National Research Council. (1982). *Science for non-specialties: The colleee vears*. Washington, DC: National Academy Press.

Penick, J. E. (1982). Developing creativity as a result of science education. in R. E. Yager (Ed.), *What research savs to the science teacher Vol. 4* (pp. 42-51). Washington, DC: National Science Teachers Association.

Penick, J. E., & Kyle, W. C. Jr. (1982). Societal and educational application of biological concepts. *Journal of Research in Science Teaching*. ü(5), 302-312.

Scharmann, L. C, & Harty, H. (1986). Shaping the non-major general biology course. *The* American Bi*ology Teacher*. 48(3), 166-169.

Spanziano, V. T. & Gibbons, J. L. (1986). Brain chemistry and behavior. *Journal of Chemical Education. 63*(5), 398-399.

Stencel, J. E. (1990). Community biology: Getting students involved in studying the biology of their community. The American Biologv Teacher. 31(2). 102-103.

Streİtberger, H. E. (1985). College students'recommendations to high school students. *Journal* of Chemical Education. 62(8), 700-701.

Streitberger, H. E. (1988). A method for teaching science, technology, and society issues in introductory high school and college chemistry classes. *Journal of Chemical Education*. 61(1), 60-61.

Toffler, A. (1972). Learning for tomorrow: The role of the future of education. New York, NY: Random House.

Voelker, A. M. (1982). The development of an attentive public for science: Implications for science teaching. in R. E. Yager (Ed.), What Research Savs to the Science Teacher. (Vol. 4) (pp. 65-79). Washington, DC: National Science Teachers Association.

Yager, R. E. (1980a). Analvsis of current accomplishment and needs in science education. Columbus, OH: ERIC/SMEAC Clearinghouse for Science, Mathematics, and Environmental Education.

Yager, R. E. (1980b). The crisis in science education. Technical reoort 21. Iowa City, IA: The University of Iowa, Science Education Center.

Yager, R. E. (1980c). Attitudes toward studv of science. Iowa City, IA: The University of Iowa, Science Education Center.

Yager, R. E. (1982). The crisis in biology education. The American Bioloav Teacher, 44(6). 328-334, 336.

Yager, R. E. (1984). Defining the discipline of science education. Science Education. 68(1), 35-37.

Yager, R. E. (1986). Searching for excellence. Journal of Research in Science Teaching. 23(3). 209-217.

Yager, R. E., Hofstein, A., & Lunetta, V. N. (1981). Science education attuned to social issues: Challenge for the 80s. The Science Teacher. 48(9), 37-46.

Yager, R. E. & Penick, J. E. (1987). Resolving the crisis in science education: Understanding before resolution. Science Education. 71(1), 49-55.

Experleoces wlth Research and Development to Improve STS-Education oo Radioactivİty and ionizing Radiation

Harrie Eİjkelhof and Piet Lijnse
University of Utrecht, The Netherlands

in a previous artİcle (Eİjkelhof & Lijnse, 1988), we have outlined four stages of a research-development cycie based on experiences with **a** Dutch physics curriculum development project (PLON) in which STS aspects are integrated. Through examples it was illustrated that research on first and second version STS materials is essential, but its value should not be overestimated. it was argued that STS education needs in-depth research studies in order to survive. Two important topics were mentioned. One is the legitimation of specific content (scientific concepts and personal and social contexts) of STS curricula. The second topic regards lay-ideas on those scientific concepts that are seen as important for pupils to use in personal and social contexts. Finally, an outline of a research-development program was described that dealt with learning to assess the risks of ionizing radiation.

İn this chapter recent experiences with this program are reported and some of its results discussed in a general way. An extensive report of the research is given elsewhere (Eİjkelhof, 1990).

Legitimation of Contents: Research Procedure

One problem with STS curricula is that the content is often not well defined and/or described. Decisions on the content often made on intuitive grounds are sometimes supplemented by consulting a few experts in a particular field. This is not a very satisfactory situation as it may lead to an abundance of contexts and concepts in which students drown and teachers waste valuable teaching time with unimportant and/or obsolete issues.

To provide a basis for such decisions we decided to consult external experts and to take their advice seriously. This seemed particularly important in view of the chosen aim of teaching the topic of ionizing radiation, namely to promote the ability of pupils to analyze and assess radiation risks for the following reasons:

1. this kind of radiation is, by choice, by nature or by accident, involved in many spheres of life and work; curriculum developers and teachers cannot be expected to be familiar with such a variety of spheres and to be able to assess which concepts are appropriate for assessing the risks in such a diversity of contexts; and

2. some applicatİons of ionizing radiation are rather controversial (even among experts) and discussions are dominated by an apparent general fear of radiation in the public at large; in the process of selecting the content to include this topic, one might have the opposite aim in mind, such as reassuring the pupils or demonstrating how risky certain applications are.

Therefore, in order to legitimİze the selection of subject-matter and contexts based on a risk perspective, it was decided to consult people who are professionally involved in the field of applications of ionizing radiation and radiation protection. it was expected that they would have a thorough knowledge of the applications in their own field of work and of the general principles of radiation protection, and be familiar with the requirements for radiation risk assessment. These radiation experts were approached in order to discuss with them in a systematic way the problem of what a physics curriculum should include regarding contexts and concepts if it were to make a contribution to pupils[1] ability to assess the risks of applications of ionizing radiation.

For reasons which we discussed elsewhere (Eİjkelhof, 1990) we opted for a conventional Delphi-method (Linstone & Turoff, 1975) to fİnd answers on the following questions:

1. VVhich context domains of ionizing radiation are suitable for inclusion in physics education in senior high school?
2. What scientific content should be covered in the physics curriculum in order to stimulate thoughtful risk assessment in the selected context domains?

The first question focusses on context domains and not on contexts. in our field of study such a context might be the use of X-rays by a dentist for diagnostic purposes. However, such a context would be, in our view, too specific to be included in a syllabus. Therefore, we decided to aim at İegitimizing context domains (sets of contexts which are related, both socially and scientifically, e.g. the use of ionîzing radiation for diagnostic purposes).

The second questİon illustrates our İntentİon to legitimİze the scientific content (or subject-matter) which should be covered in order to promote our general aim: learning to assess risks in situations in which ionizing radiation İs applied.

The study was held in three rounds. in each round the participants received a questionnaire which they were asked to return within three to four weeks. The completed questionnaires from each round were analyzed by the research team, after which the questions for the fo!lowing round were formulated.

İn order to select the participants the follovving criteria were set:

* the group should consist of experts from four fields in which İonizing radiation İs applied: health çare, electricity generation, defense and industry;
* in the group the diversity of opinions about risks of ionizing radiation should be represented; it should include not only people who are convinced that most of the public outcry on applicatİons of ionizing radiation is exaggerated, but also those who take the view that this outcry is generally justified;
* each particİpant should have experiences with instruction or should have contacts with lay-people: we preferred people who would have some notion of what one could expect lay-people to know and to be able to understand;
* each participant should have at least four years of relevant working experience in the field;
* each participant should be prepared to participate in at least two rounds İn order to limit the number of people who might leave the study after the first round.

The process of setting up the panel was initiated by consulting a board member of the Dutch Association for Radiation Protection, local radiation experts, and experts from environmental organizations. Based on this advice a list of 80 potential participants was drawn up. These people then received a letter which explained the aim and design of the Delphi-study and in which we asked them to participate. Actually 55 radiation experts participated in the first round, most of them working in the fields of health çare, nuclear energy, and industry. Although the number decreased in the second and third rounds (to 49 and 35 respectively), the diversity of fields of activities and the variety in opinions remained much the same during the study.

Results on the Legİtİmatİon of Context Domains

Table 1 presents the context domains whİch are recommended by radiation experts. This table has a ranking order from 1 to 9, 1 being rated the most important. it should be noted here that the context domains are not ali equivalent due to the fact that some (e.g., number 9) are too specific to group with others.

Table I: Recommended Context Domains for a Physics Curriculum

Category I (İmportant)

](Background radiation: from the cosmos, food, rocks, building materials.

2. Medİcal applications: diagnostic and therapeutic uses of ionizing radiation.
3. Nucİear energy: emİssion of radioactive substances, normal ly and af ter an accident.
4. Storage of nuclear waste: underground, above ground, on the ocean-floor.
5. Fall-out (as a consequence of nuclear weapons expIosions).
6. Some applications of ionizing radiation in scientific and industrial research (e.g., tracers).

Category II (faİrly İmportant)

7. Other industrial applications (e.g., materials research, sterilization, measurement and control).
8. Immediate consequences of nuclear weapons explosions.
9. Radioactivity from coal fired power plants.

Many contexts which were suggested in the first round by the research group or by the participants did not receive sufficient support to be included in Categories I and II, such as transport of nuclear materials, dating methods, production of radioactive sources for medical use, accidents in a reprocessing plant, decommissioning nuclear power plants, and fire-alarms containing radioactive sources. We also asked participants which criteria they recommended in order to judge which set of context domains to include in education. The experts agreed almost unanimously with the foIIowing four criteria:

1. a large part of the total collective dose should be covered by the set;
2. contexts which are most likely to be encountered by citizens should be included;
3. the set should reflect the variety of applications in society; and
4. the applications with the most important social implications should be included.

At the end of this chapter we will discuss these criteria and comment on them in view of other research findings in our program.

Results on the Legİtimatİon of Concepts

Table 2 lists those subject matter items which have been recommended by radiation experts. The items are classified into two groups: basic knowledge about atomic and nuclear physics and about radiation protection.

With exception of the concept of activity, the first group of items are characteristic of most school textbooks. Knovvledge of these items is required in order to be able to answer questİons such as:

* What are the characteristics of substances which emit İonizing radiation?
* How do you express the strength of a radioactive source?
* At what rate does the strength of such a source decrease?
* What new substances are formed during the emission of ionizing radiation?
* Which kinds of ionizing radiation exist and what are their characteristics?
* How is it possible to detect ionizing radiation?
* What is the nature and origin of radioactive substances which might be emitted by a nuclear power station?

Table 2: Subject Matter Items Recommended by Radiation Experts

A. Basic knowledge about atomic and nuclear physics

- ✶ Structure of the nucleus: nucléon, proton, neutron, atomic number, mass number, (Z,N)-diagram, isotope, atomic mass unit;
- ✶ Radioactive sources: stable and unstable nuclei, energy levels of a nucleus, disintegration, activity [Bq], radioactive decay curve, half-life;
- ✶ Ionizing radiation: alpha-, beta-, gamma-, and neutron-radiation, X-rays, nature and properties of these types of radiations, X-ray spectrum;
- ✶ Detection of radiation: Geiger counter, photographic plate, cloud chamber; and
- ✶ Nuclear energy: nuclear reactions, nuclear fission, chain reaction, principles of a nuclear reactor.

B. basic knowledge about radiation protection

- ✶ Irradiation: absorption, dose [Gy], interaction with living matter, dose equivalent [Sv], influence of distance and medium;
- ✶ Contamination: spreading of radioactive substances in the environment and in the human body;
- ✶ Effects of ionizing radiation: early and late effects of low and high doses, somatic and genetic effects; and
- ✶ Safety aspects: film badge, lead apron, radiation norms, ALARA-principle, safety measures.

Some of these questions were already formulated in a PLON-unit which was constructed before (PLON, 1984); some new ones have been added, for instance the last one, to take into account the nature of the recommended contexts. These questions are neither directly about risks, nor purely of scientific interest. These are the kinds of questions which seem to be helpful in focussing on the background to radioactivity and ionizing radiation. Someone who is able to answer these questions is likely to be better able to interpret risk information, as often in this kind of information some basic knowledge about the origin, nature, characteristics, and measurability of ionizing radiation is assumed. An advantage of formulating questions of this type is that they may be used in teaching to illustrate the function of scientific content, showing the fruitfulness of learning about these.

The second group of items (about radiation protection) is less common in school textbooks. These deal with irradiation, contamination, effects of ionizing radiation, and safety aspects. Knowledge of these items is required to answer questions such as:

- ✶ What may happen when radiation falls upon living matter?
- ✶ How do you express the amount of radiation which someone receives?
- ✶ What are the health effects of ionizing radiation?
- ✶ How much radiation is (relatively) safe?
- ✶ How can one protect oneself against ionizing radiation? and
- ✶ Which safety measures are effective in particular situations?

These questions are much more geared towards the risks of ionizing radiation.

Lay-Ideas About Ionizing Radiation

Compared with some other science topics, relatively little research has been carried out on students' ideas about radioactivity and ionizing radiation. Before we investigated students' ideas in this field we explored the existence of lay-ideas in out-of-school situations, assuming that students develop their preconceptions in contact with press reports and in discussions with others. As is well documented by Weart (1988), some fields of application of ionizing radiation evoke a great deal of public debate.

During 1986 and 1987, we studied lay-ideas by analyzing press reports in the Netherlands and the United Kingdom about Chernobyl and other nuclear incidents, and consulting the radiation experts mentioned above. Details about these studies have been reported elsewhere (Eijkelhof & Millar, 1988; Eijkelhof, Klaassen, Lijnse & Scholte, 1990; Lijnse, Eijkelhof, Klaassen & Scholte, .1990). Some typical quotations from newspaper reports about the Chernobyl accident are presented in Table 3.

Table 3: Some examples of Lay-Ideas in Newspaper Reports

About the Chernobyl Accident in 1986

"Radiation is still pouring into the air from a fire raging at the plant" (Mail, 1/5) "The radiation...catapulted into the sky" (Mirror, 1/5) .
"Two reactors...will continue to spew out deadly clouds of radiation" (Sun, 1/5) "The cloud of radiation from the Chernobyl accident which had been blown over Britain" (Mirror, 6/5)
"The wind is carrying the radiation over Scandinavia" (Guardian, 30/4)
"Radiation reaches Channel" (Times, 3/5)
"Students...were contaminated by radiation" (Observer, 4/5)
"We have recently collected samples of fresh standing rainwater and tests showed they contained fairly high levels of short-lived radiation" (Mirror, 6/5)

"Spinach has been exposed to too much radiation" (Utrechts N., 7/5)

"TTie Germans found a radiation dose of 1000 becquerels acceptable" (Utrechts N., 13/5)

"Accidents at which large doses of radiation are being released" (NRC-H, 15/5) "...insisted that his official figures for iodine 131 radiation in milk showed levels up to 60 becquerels per litre—'miles below' the safe limit of 1,000 above which there was a risk to infants" (Telegraph, 7/5)

"...said that the radioactivity in Kiev is thirty times normal, but still 5,000 times lower than is considered to be dangerous" (Volkskrant, 12/5)

From the media analysis we learned that:

* often no distinction is made between the meanings of the concepts of: a) radioactivity, radiation, and radioactive substance, b) irradiation and contamination, and c) activity and dose;
* radiation levels are seen as sharp demarcations of safety; below it is safe, above it is very dangerous; and
* the public appears to be more interested in answers to questions about safety than in the scientific background of safety issues.

The consultations of the radiation experts largely confirm the results of the media analysis. We learned that some lay-ideas are more important for proper risk assessment than others. Especially the importance of the lack of distinction between irradiation and contamination was illustrated with a number of examples which were reported by the radiation experts from their experiences in a wide variety of fields of application. These examples show that people are often too much and sometimes not enough worried due to their lay-conception of radiation risk.

Students' Ideas and Their Role in Education

A variety of methods were used to explore students' ideas before, during, and after education on this topic. We asked students of forms 4 and 6 to fill in questionnaires, interviewed students, and observed a series of lessons (Eijkelhof, 1990). Table 4 contains some illustrative examples of students' ideas.

Table 4: Quotes from Interviews with Students About Radioactivity and Ionizing Radiation

"Radioactivity is radiation which is released by radioactive isotopes."
"Radioactivity is a dangerous form of light."
"Radiation consists of radon."
"Contamination means that it has received so much radiation that at a certain moment it starts giving off radiation itself."
"Artificial radiation is more dangerous than natural radiation as the latter has always been with us and I never had any trouble with it."
"Background radiation is only dangerous when it comes from Chernobyl."
"If you look at how the workers in a food irradiation plant have to be protected with special clothing, it could not be right for an apple to receive a dose of radiation."
"Food irradiation is not dangerous, otherwise they wouldn't do it."

Some of the main conclusions of these investigations are:

* Very often students are unable to make a proper distinction between the concepts of: a) radiation, radioactivity, and radioactive substance, b) irradiation and contamination, and c) absorption, storage, and stopping of radiation. This conclusion even applies to pre-university students who previously studied ionizing radiation, using either the PLON-unit or more traditional materials.

* Students' ideas about radioactivity and ionizing radiation appear to be dependent on the context of use; ideas about the nature, effects, and risks of radiation are often based on the characteristics of the contexts, especially the function of the radiation and the saliency of the safety measures.

In the class observations we found several examples of 'miscommunication' due to a different interpretation of the meaning of the above mentioned concepts by teacher and students. A problem in this respect is the use of the term 'particle' in a number of meanings: dust, molecule, atom, nucleón, and a- or C-radiation. Some additional problems found in analyzing transcripts of dialogues during lessons are:

* Even for teachers it appears to be difficult to relate a particular radiation dose to its effects, especially if they take the quality of absorbed, energy per unit mass into account (which is very low).
* Students have difficulties in distinguishing between the concepts of radioactivity and nuclear fission.

Discussion

In the sections above we reported about a number of studies dealing with the legitimation of contents and tracing of lay-ideas in society and among students, all within the field of ionizing radiation. In this final section we will discuss these results using questions which have often been posed in discussing these results with other colleagues. Such questions are:

* Do you not overestimate the role of experts in decisions about the content of the curriculum?
* What consequences do the results have for teaching the topic of ionizing radiation in an STS- way?
* What lessons could others draw from these results in view of the development of STS- materials?

The Role of Experts

Radiation experts have a great deal of experience with contexts of ionizing radiation which is not held by other professional groups. The results of this part of the Delphi-study show that they have some original, well-argued ideas regarding the curriculum which might play an important role in discussions about possible reforms in physics education towards the aim of risk assessment.

However, the results of the Delphi-study should not be seen as prescriptive for the content of a physics curriculum with the chosen aim. The main reason for this is that none of the participants was directly involved in physics teaching at secondary school levels. So they cannot be seen as experts about the learning and teaching problems associated with ionizing radiation for the 16-18 year age group. In defining the content of the curriculum, other aspects have to be taken into account, such as the available time and the learning difficulties of pupils.

So the results of the Delphi-study should be supplemented with other results on teaching and learning before recommendations are made about the selection of curriculum components. As an example, we will use the results of our conceptual studies to suggest some additional criteria which should also play a part. One criterion arises from one of our findings in the interviews with pupils: pupils appear to be quite familiar with some contexts, such as some medical applications, nuclear energy and nuclear waste, and less with others, such as food irradiation and radon. Probably because of social influences, they have developed certain ideas and attitudes about the familiar contexts which seem to be quite strong and resistant to change. Here we meet the dilemma noted by Novak (1988) that pupils' prior knowledge is both an asset and a liability for subsequent meaningful learning. An advantage of including familiar contexts is that they could be used in class to promote discussion of pupils' ideas and to provide opportunities for pupils to apply scientific knowledge. A disadvantage is that it may be difficult to change their ways of thinking and arguing in these contexts. Their present ideas may obstruct the development of more scientific viewpoints. So it could be very useful also to include contexts with which they are not yet familiar and in which they may be better able to develop and use scientific ideas and ways of reasoning. So this criterion could be labelled as 'variety in familiarity.'

A second additional criterion we propose is that the contexts selected--and selection is necessary due to time constraints—should offer opportunities for attending to those lay-ideas and scientific concepts and processes which are of significant importance in a <u>number</u> of contexts. Examples are lay-ideas, which we have shown are often related, about the nature, propagation, absorption and effects of ionizing radiation, concepts such as 'ionizing radiation,' 'radioactivity,' 'activity,' 'half-life' and 'dose (equivalent),' and processes such as irradiation, absorption of radiation, and the dispersal of radioactive substances in the human body and in the environment. This would be an additional argument <u>against</u> contexts which mainly involve very specific knowledge.

If we apply both additional criteria to the context-domains of Table 1, the following conclusions may be drawn:

- context-domain 9 should not be included as it requires very specific knowledge related to one method of generating electricity;
- context-domain 8 deals with effects which occur only when nuclear weapons explode. The social significance of nuclear explosions cannot be denied but knowing how disastrous these weapons are does not require detailed scientific knowledge. The main direct consequences are not due to ionizing radiation but to blast and heat;
- context-domain 7 contains>and application which people could meet in daily life (food irradiation). Although pupils appear not to be familiar with this context, it appeared in the interviews and in the classroom to be a useful context for discussions with pupils about ionizing radiation;
- context-domain 6 does not have much direct social and personal relevance, but the context of tracers may be helpful in clarifying the distinction between irradiation and contamination; and

* context-domains 1-5 seem to be in accordance with all the criteria.

Therefore, we propose that curriculum materials should focus mainly on contexts within domains 1, 2, 3, 4, and 5, and some in 6 and 7.

Implications for Teaching

What changes are required in education as a result of these studies? First, new content elements should be included in the curriculum, if one aims at scientific literacy of the students in the field of nuclear issues. Hirsch et al. (1987) have provided a preliminary list of what literate Americans should know. This list includes about 50 items in the field of atomic and nuclear physics including concepts such as meson, quark, bubble chamber, and cyclotron, but leaving out important concepts such as activity, dose, radioactive contamination, and absorption of radiation. In our view Hirsch, Kett, and Trefill are too strongly focussing on applications such as scientific research, at the expense of contexts of use such as medical and industrial applications.

Second, compared with traditional physics teaching much more attention should be given to open sources. At present closed sources receive too much emphasis, while in the world outside the classroom open sources are extremely important and require different safety measures than closed ones.

Third, more attention should be given to the existence of lay-ideas in society and among students, especially about the meaning of 'radiation' and 'radioactive contamination.' Teachers should familiarize themselves with these ideas and should be able to deal with them in the classroom. This requires the development of new constructivist teaching strategies which take these lay-ideas into account. Quotations from newspapers and from interviews with students may be helpful in such strategies.

Fourth, teachers and textbooks should give more emphasis to the relationship among concepts. This serves two aims: learning to make distinctions between scientific concepts and realizing the difference between scientific and popular meanings of terms in this field.

Finally, more attention should be given to realistic situations in which radiation risks exist and safety measures apply. Only in this way will students learn to use scientific knowledge in the out-of-school world.

In a current study we are evaluating experiences with teaching materials which take these recommendations into account. We use pre- and posttests (with knowledge and reasoning questions) and compare the results with those of control groups. We also study dialogues in group and class discussions and interview teachers. We consider this study to be part of the fourth state of our research program.

Recommendations for STS-Research and Development

One of the main merits of STS-education may be that it introduces new aims for science teaching. These new aims are based on the idea that scientific knowledge is essential for modern life, as pupils very often meet applications of science and technology. Several problems then arise. In this chapter, detailed attention has been given to these in one small part of science, including the selection of suitable contexts and content and the role of lay-ideas. In order to improve the quality of this relatively new STS emphasis in science education, it is essential that its quality be continually monitored. For instance, research is needed that evaluates claims made. Also, research is needed which seeks answers to the problems of selection of contexts and content and of the role of lay- ideas in learning. Both kihds of problems are, in our view, important in STS-education.

It may be expected that similar studies in other areas of STS-education could play an important role in the improvement of quality, which is essential in order to make STS credible to scientists, science teachers, parents, pupils, and policy makers.

References

Eijkelhof, H. M. C. (1990). Radiation and risk in physics education. Utrecht, The Netherlands: CDC-Press.

Eijkelhof, H. M. C., & Lijnse, P. L. (1988). The role of research and development to improve STS education: Experiences from the PLON-project. International Journal of Science Education. 1£(4), 464-474.

Eijkelhof, H. M. C., & Millar, R. (1988). Reading about Chernobyl: The public understanding of radiation and radioactivity. School Science Review. 70(251). 35-41.

Eijkelhof, H. M. C., Klaassen, C. W. J. M., Lijnse, P. L., & Scholte, R. L. J. (1990). Perceived incidence and importance of lay-ideas on ionizing radiation: Results of a Delphi-study among radiation-experts. Science Education. 74(2). 183-195.

Hirsch, Jr., E. D., Kett, J., & Trefil, J. (1987). What literate Americans know: A preliminary list. In E. D. Hirsch (Ed.), Cultural literacy (pp. 146-215). Boston, MA: Houghton.

Lijnse, P. L., Eijkelhof, H. M. C., Klaassen, C. W. J. M., & Scholte, R. L. J. (1990). Pupils' and mass-media ideas about radioactivity. International Journal of Science Education. JL2(1), 67-78.

Linstone, H. A., & Turoff, M. (1975). The Delphi method: Techniques and applications. Reading, MA: Addison-Wesley.

Novak, J. D. (1988). Learning science and the science of learning. Studies in Science Education, li, 77-101.

PLON. (1984). Ioniserende straling. Utrecht, The Netherlands: Rijksuniversiteit Utrecht, Vakgroep Natuurkunde-Didactiek. (English Version. [1988]. Ionizing radiation. Melbourne, Australia: Monash University, Faculty of Education.)

Weart, S. R. (1988). Nuclear fear: A history of images. Cambridge, MA: Harvard University Press.

SECTION III - Evaluation of STS Efforts

STS is reform that is advocated and tried by many. However, until this reform is studied and evaluated, the ideas are little more than advocacy positions. In this section some specific studies are reported that provide evidence that STS initiatives are actually examples of reform. Reform demands change in learning; it occurs only when something has happened. What are students who experience STS like? What can they do that students in more traditional science courses cannot do? Where is evidence that new materials and/or teaching approaches are more effective? Have the claims for STS been met?

VOSTS: A Way of Expanding Classroom Assessment to Meet The STS Agenda in Secondary School Science

Aian G. Ryan

University of Saskatchewan, Saskatoon, Canada

The STS agenda for school science is moving forward. Progress is slow, that's for sure (Olson, 1982; Yager & Penick, 1987), but it is real (Yager, Blunck, Binadja, McComas & Penick, 1988). As the new emphasis on the interconnectedness of science, technology, and society becomes the organizer for new curricula and textbooks (e.g., Aikenhead, 1991), so will corresponding attention be drawn to the issue of how we evaluate our students on their learning. If teachers do not feel that they can adequately evaluate their students on certain objectives, they will tend to steer away from teaching those objectives (Mitchener & Anderson, 1989). Although the assessment of traditional content acquisition will always form an important component of our assessment of students, it will need to be augmented with assessment strategies that can indicate how well the students are achieving the other objectives of STS courses.

In this chapter, I introduce an instrument—Views on Science, Technology, and Society (VOSTS)—that offers teachers one way of assessing and evaluating what their students believe about a host of STS issues. I begin with a short overview of why STS curricula require an expanded repertoire of student assessment and evaluation techniques. (Assessment refers to the collection of information on students' performance levels on curricular objectives; evaluation refers to the process of judging how satisfactory these performance levels are.)

Characteristics of Student Assessment In STS Curricula

In their Framework for Curriculum Reform in Secondary School Science and Social Studies, Hickman, Patrick, and Bybee (1987) characterize the goals of an STS curriculum as comprising a) the acquisition of knowledge of STS interactions, major topics and concepts of academic disciplines in science and the social studies, and STS issues, b) utilization of the cognitive process skills of information processing, problem solving, and decision making, and c) development of values, attitudes, and assumptions about ways of knowing and knowledge, persons who engage in science, and about citizenship, that pertain to uses of science/technology in a democratic society. Teachers have long experience in assessing students on their attainment of the acquisition of knowledge, less experience in assessing students on cognitive processes, and hardly any experience in assessing students on their beliefs and values. Secondary teachers of science, especially, tend to use teacher-made tests as their most frequent assessment technique (Gullickson, 1985). Such tests are useful in measuring the acquisition of knowledge, but less useful in the other two categories of the Hickman et al. classification. For assessment and evaluation within these categories, teachers are being encouraged to expand their repertoire of student assessment strategies to include such techniques as observation checklists, portfolios, and rating scales (Wiggins, 1988). Secondary science teachers tend to be less comfortable with these alternative assessment techniques, partly because they are not sufficiently familiar with them, but also because such strategies appear to require a more subjective approach to assessment and subsequent evaluation than does the written test. This perception clashes with the science teachers' veneration of objectivity in assessment.

But if teachers are to embrace the total range of STS curricular objectives, including the development of such holistic, ^slowly-developing, and difficult-to-quantify attributes as the intellectual and social processes'of science (e.g., "Ability to identify and frame a problem so that subsequent inquiry can be focused on it" Hickman et al., 1985, p. 20) and the values and attitudes (e.g., "Patience and perseverance are important qualities for scientific research" Hickman et al., 1985, p. 25) required of a scientifically literate student, then they must become comfortable and skilled in assessing them. The answer to this problem in assessment is for science teachers to take willing ownership of the subjective nature of their judgments on students. This is an integral part of their professional responsibility.

This is an easy answer to offer, but an extremely difficult one to put into practice. In these days of increased accountability pressures, teachers have good reason to take refuge behind objective-sounding numbers. Only with the recognition of the legitimacy of teacher professional judgment—a recognition that must be bolstered as much by school and district administrators and elected representatives as by teachers themselves—can teachers become at ease with the use of subjective measures in assessing their students' progress.

The problem is compounded when we move from assessment to evaluation of students. In the classroom context, the teacher's knowledge of the students and of course their observation that they are studying is of paramount importance when evaluative decisions are taken. Only the teacher is in a position to make the value judgment on the students' performance. When we remember that STS courses contain many objectives that lie outside the content domain, we realize that student grades in STS courses may, in substantial measure, be determined by students' performance on holistic, subjectively-assessed objectives.

Teachers need all the help possible to assist them in becoming comfortable and effective in these additional assessment and evaluation techniques (Stiggins & Bridgeford, 1985; Stiggins, Conklin & Bridgeford, 1986). If teachers knew what views a wide cross-section of other students held on a variety of STS issues, then they would be in a better position to assess the views of their own students and take evaluative decisions on their performance. A recent research study that Glen Aikenhead and I have completed may offer some help.

Views on Science-Technology-Science (VOSTS)

VOSTS is derived directly from students' own views on a wide variety of science-technology- society issues. Thus, it differs from traditional instruments which derive from a researcher's conceptual scheme. It consists of a pool of 114 multiple-choice items on a wide variety of STS topic$. Each item consists of a statement on an STS issue, often worded provocatively, together with a series of student positions that have been derived from student writings in reaction to the statement. A brief outline of the process will be given here so that readers can understand the development process and realize how constructing a VOSTS item departs from the customary test construction pattern. The development of the instrument is described in detail elsewhere (Aikenhead & Ryan, 1989; Aikenhead, Ryan & Desautels, 1989).

Step 1. The content for VOSTS statements is defined by the domain of STS content appropriate for high school students. The conceptual outline of the VOSTS content is shown in Table 1. The structure of the outline allows for future expansion of the number of topics within each major section, as well as of the number of sections themselves. At the present time, section three has been left blank in order to leave room for future development in this area.

The numbering system in Table 1 defines the numbering system for the VOSTS item pool. Each VOSTS item is assigned a five-digit code, e.g., 90521. The first digit (9) corresponds to section nine in Table 1 ("epistemology of science"). The next two digits (05) refer to the topic number within that major section ("hypotheses, theories, and laws"). The fourth digit (2) indicates the item number within that topic. For instance, 90521 is the second item for the topic "hypotheses, theories, and laws." The last digit differentiates items that have slight but meaningful variations in their wording, such as different example or a different key word.

Table 1: The VOSTS Conceptual Scheme

Definitions

1. Science and Technology

   1. Defining science (e.g., instrumentaIism, curiosity satisfaction, social enterprise)
   2. Defining technology (e.g., social and human purposes, hardware, socio-economic and cultural components)
   3. Defining research and development (R&D)
   4. Interdependence of science and technology (e.g., rejection that technology is simply applied science)

External Sociology of Science

2.. Influence of Societv on Science/Technology

   1. Government (e.g., control over funding, policy, and science activities; influence of politics)
   2. Industry (e.g., corporate control dictated by profits)
   3. Military (e.g., utilization of scientific human resources)
   4. Ethics (e.g., influence on research program)
   5. Education institutions (e.g., mandatory science education)
   6. Special interest groups (e.g., health societies, non-government, and non-industrial groups)
   7. 7 Public influence on scientists (e.g., upbringing, social interactions) 3, (future category)

3. (future category)

4. Influence of Science/Technology on Societv

   1. Social responsibility of scientists/technologists (e.g., communicating with public, concern and accountability for risks and pollution, "whistle blowing")
   1. Contribution to social decisions (e.g., technocratic vs. democratic decision-making, moral and legal decisions, expert testimony, lobbying for funds)
   1. Creation of social problems (e.g., trade-offs between positive and negative consequences, competition for funds)
   1. Resolution of social and practical problems (e.g., technological fix, everyday type of problems)
   1. Contribution to economic well being (e.g., wealth and jobs)
   1. Contribution to military power
   1. Contribution to social thinking (e.g., lexicon, metaphors)

5.. Influence of School Science on Societv

   1. Bridging C. P. Snow's two cultures
   2. Social empowerment (e.g., consumer decisions)
   3. SociaI characterization of science

Internal Sociology of Science

6.. Characteristics of Scientists

   1. Personal motivation of scientists
   1. Standards/values that guide scientists at work and home (e.g., open-mindedness, logicality, honesty, objectivity, skepticism, suspension of belief; as well as the opposite values; closed-mindedness, subjectivity, etc.)
   1. Ideologies of scientists (e.g., religious views)
   1. Abilities needed to do science (e.g., commitment, patience)
   1. Gender effect on the process and product of science
   1. Underrepresentation of females -

Collectivization of science (e.g., loyalties to research team and employer)
Scientific decisions (e.g., disagreements among scientists, consensus making)
Professional communication among scientists (e.g., peer review, journate, press conferences)
Professional interaction in the face of competition (e.g., politics, secrecy, plagiarism)1
Social interactions
Individual's influence on scientific knowledge
National influence on scientific knowledge and technique
Private vs. public science
8.
Technological decisions
Autonomous technology (e.g., technological imperative)
Epistemology

9.
Natureofobservations(e.g.,theoryladenness,perceptionbound)
Nature of scientific models
Nature of classification schemes
Tentativeness of scientific knowledge
Hypotheses, theories, and laws (e.g., definition, role of assumptions, criteria for belief)
Scientific approach to investigations (e.g., nonlinearity, rejection of a step-wise procedure, "the scientific method" as a writing style)
Precbion and uncertainty in scientific/technological knowledge (e.g., probabilistic reasoning)
Logical reasoning (e.g., cause/effect problems, epidemiology and etiology)
Fundamental assumptions for all science (e.g., uniformitarianism)
Epistemological status of scientific knowledge (e.g., ontology as an assumption, questioning logical positivism)
Paradigms vs. coherence of concepts across disciplines

The process begins by the researchers composing an STS statement to which the students will respond. The goal is to write a clear statement on a well-defined issue. For every VOSTS statement, a converse statement is written. In some cases, this simply means casting a statement in the negative. In other cases, it means composing the opposite view. For example, if a democratic view on decision-making was the focus of the initial statement, a technocratic view was written as the converse. This is illustrated by the following two statements:
Scientists and engineers should be the last people to be given the authority to decide what types of energy Canada will use in the future (e.g., nuclear, hydro, solar, coal burning, etc.). Because the decision affects everyone in Canada, the public should be the ones to decide.
Scientists and engineers should be given the authority to decide what types of energy Canada will use in the future (e.g., nuclear, hydro, solar, coal burning, etc.) because scientists and engineers are the people who know the facts best.
^
Each statement iş then typed onto a standard student answer sheet. To ensure that students compose an argumentative paragraph response to a statement (VOSTS emphasizes reasoned arguments over personal feelings), they are asked to complete two tasks. The first is to check a box whether they agree or disagree with the statement, or whether they cannot decide. The second task is to write, in the space provided on the answer sheet, a paragraph which justifies their choice in the first task. It is these paragraph responses which constitute the data for the subsequent steps.

Step 2. The argumentative paragraphs written by the students are analyzed to discern common arguments or common justifications. The paragraph analysis identifies categories ("student positions") that represent common viewpoints or beliefs. These student positions should paraphrase the students' writing and adopt the students* vernacular whenever possible. This analysis is the most difficult and Hjj labor intensive part of the entire process. The analysis yields a crude draft of an empirically developed multiple-choice item, designated "form mc. 1." There were three researchers involved in the analysis of paragraphs. Two researchers would discuss the analysis of the first. This led to reworking of the categories until consensus was achieved.

For each YOSTS statement pair, 50 to 70 paragraphs are usually sufficient to ensure ■theoretical saturation" of the categories that emerge (Glaser & Strauss, 1967). The VOSTS project used a stratified sampling of a cross section of students from grades 11 and 12 (average age * 17.3 years) representing all regions of Canada

One of the two opposing statements is selected as the definitive VOSTS statement. The selection is made on the basis of the student responses; sometimes one of the statements was discarded because students wrote socially desirable responses to one of the statement pair, or they found one of the statements to be confusing. At this stage, student responses can suggest ways to simplify or clarify the wording in the statement. As an example, the final version to the two statements given in Step 1 above became Item 40211:

> Scientists and engineers should be the ones to decide what types of energy Canada will use in the future (e.g., nuclear, hydro, solar, coal burning) because scientists and engineers are the people who know the facts best.

The final task in this step is to recast the student positions into a more traditional multiple-choice style (e.g., with parallel sentence structure). The number of student positions for a VOSTS item typically runs between 5 and 13. Three additional choices (I don't understand; I don't know enough about this subject to make a choice; None of these choices fits my basic viewpoint) are always added. The end result of this step is form mc.2.

Step 3. The next step is to obtain empirical feedback on how well form mc.2 of a VOSTS item captures the views that students were attempting to express in their paragraphs. Approximately 10 students per item participate in a semi-structured interview. They first write paragraph responses to four VOSTS statements, as described in Step 1. Then the students read the multiple-choice (form mc.2) for those same items and choose the "student position" that best expresses what they had wanted to write in their paragraph.

Next, the researcher reads a student's paragraph and categorizes it according to the student positions of the multiple choice. This analysis is then compared with the choice actually made by the student. Discrepancies are used to structure the interviews that follow. An interview begins by a student re-reading the VOSTS statement and his or her paragraph. The interviewer has the student discuss his or her interpretation of the VOSTS statement and clarify, if necessary, the view expressed in his or her paragraph. Then the student re-reads the student positions for the same statement and the choice he or she had made. Any discrepancy between the paragraph response and the multiple- choice response is explored. These interviews provide data that guide the researcher to construct items containing the least amount of ambiguity. These modifications yield form mc. 3.

Step 4. With a different group of students (about 10 per VOSTS item), the researcher carries out one last check on the clarity of each item. The student works through several VOSTS items, expressing his or her thoughts out loud as each choice is considered. This allows the researcher to tell if the student makes the same distinctions between the choices as the researcher makes. Students also comment on the clarity of the student positions, the suitability of the physical layout of the items, and the ease of responding. The subsequent polishing of the items yields form mc.4.

Step 5. The last step in the development of VOSTS items entails surveying a large sample of students for the purposes of: 1) shortening an item by deleting student positions that receive very low responses, and 2) establishing baseline data against which other educators can compare their

VOSTS results. An optical scan answer sheet was specially developed to facilitate the gathering and processing of the data. The data are presented in the form of percentage of student responses for each position. Item 90811 is an example of a finished VOSTS item. It is taken from the Epistemology section and deals with student views on cause/effect relationships.

If scientists find that people working with asbestos have twice as much chance of getting lung cancer as the average person, this must mean that asbestos causes lung cancer.

Your position, basically:

15. The facts obviously prove that asbestos causes lung cancer. If asbestos workers have a greater chance of getting lung cancer, then asbestos is the cause.

The facts do NOT necessarily mean that asbestos causes lung cancer:

16. because more research is needed to find out whether it is asbestos or some other substance that causes the lung cancer.

17. because asbestos might work in combination with other things, or may work indirectly (for example, weakening your resistance to other things which cause you to get lung cancer).

18. because if it did, all asbestos workers would have developed lung cancer.

19. Asbestos cannot be the cause of lung cancer because many people who don't work with asbestos also get lung cancer.

20. I don't understand

21. I don't know enough about this subject to make a choice.

22. None of these choices fits my basic viewpoint. Item 908

VOSTS items have many potential uses in science teaching. They can stimulate discussion (students make their choices and defend their positions); they can lead to group investigations (students form groups according to their choice of student position and find evidence to support their positions or refute other positions); and they can be used to assess student beliefs and to evaluate students on those beliefs. Only assessment and evaluation uses will be considered here.

Using VOSTS as a Classroom Evaluation Tool

There are no "right answers" to VOSTS items. The instrument cannot, therefore, be used as an "objective" assessment tool for classroom evaluation. However, it does allow the teacher to diagnose the beliefs of students as they enter the STS course; helps the teacher to assess during the course what stage the students have reached in their scientific literacy development, with respect to a large sample of other comparable students; and offers a jumping-off point for the evaluation of the students. Each of these will be discussed in turn.

Diagnosis

Students come to any course with a wide diversity of background knowledge. In the case of STS knowledge, this is usually acquired from the mass media and previous courses in science and social studies. The extent of this knowledge, and its correctness, is not always predictable. For example, we found that most (81%) students were highly attuned to the idea that scientific classification schemes were artificially constructed by scientists to fit their needs (Item 90311, not displayed here), but they were much less discerning in their beliefs about the artificiality of scientific piodels (Item 90211, not displayed here); only 36% realized that scientific models were not copies of reality. VOSTS items can be used diagnostically to help pinpoint where the teacher needs to stress and clarify certain concepts. Item 60611 is a case in point. If the teacher wishes to assess the students' beliefs on gender issues in science, the responses to this item will help. Do the student adopt a male chauvinist position (Position A)? Or do they attribute the disproportionate number of male scientists to nature (B) or nurture (D)? Do they see the pattern changing (F, G)? Or do they believe that the pattern has changed (H)? Item 60611: Today in Canada there are many more male scientists than female scientists. The MAIN reason for this is:

%________ Yovr position, basically;

2 A. males are stronger, faster, brighter, and better at concentrating on thei studies.

2 B. males seem to have more scientific abilities than females, who may excel I other fields.

8 C. males are just more interested in science than females.

14 D. the traditional stereotype held by society has been that men are smarter ai dominant, while women are weaker and less logical. This pre judice has caus more men to become scientists, even though females are just as capable science as males.

4 E. the schools have not done enough to encourage females to take science courj Females are just as capable in science as males.

34 F. until recently, science was thought to be a man's vocation. (Women didn't television's stereotype image of scientist.) In addition, most women v expected to work in the hope or take on traditional jobs. (Thus men have more encouragement to become scientists.) But today this is chang Science is becoming a vocation for women, and women are expected to v in science more and more.

4 G. women have been discouraged, or not allowed, to enter the scientific f Women are just as interested and just as capable as men; but the establi scientists (who are male) tend to discourage or intimidate potential fe scientists.

H. There are NO reasons for having more male scientists than female scier Both sexes are equally capable of being good scientists, and todaj opportunities are equal.

23. I. I don't understand

24. I don't know enough about thi

classification schemes were artificially constructed by scientists to fit their needs (Item 90311, not displayed here), but they were much less discerning in their beliefs about the artificiality of scientific models (Item 90211, not displayed here); only 36% realized that scientific models were not copies of reality. VOSTS items can be used diagnostically to help pinpoint where the teacher needs to stress and clarify certain concepts. Item 60611 is a case in point. If the teacher wishes to assess the students* beliefs on gender issues in science, the responses to this item will help. Do the student adopt a male chauvinist position (Position A)? Or do they attribute the disproportionate number of male scientists to nature (B) or nurture (D)? Do they see the pattern changing (F, G)? Or do they believe that the pattern has changed (H)? Item 60611: Today in Canada there are many more male scientists than female scientists. The MAIN reason for this is:

% ________ Your position, basically:

2 A. males are stronger, faster, brighter, and better at concentrating on their studies.

2 B. males seem to have more scientific abilities than females, who may excel in other fields.

8 C. males are just more interested in science than females.

14D. the traditional stereotype held by society has been that men are smarter and dominant, while women are weaker and less logical. This prejudice has caused more men to become scientists, even though females are just as capable in science as males.

4 E. the schools have not done enough to encourage females to take science courses. Females are just as capable in science as males.

34 F. until recently, science was thought to be a man's vocation. (Women didn't fit television's stereotype image of scientist.) In addition, most women were expected to work in the hope or take on traditional jobs. (Thus men have had more encouragement to become scientists.) But today this is changing. Science is becoming a vocation for women, and women are expected to work in science more and more.

4 G. women have been discouraged, or not allowed, to enter the scientific field. Women are just as interested and just as capable as men; but the established scientists (who are male) tend to discourage or intimidate potential female scientists.

25. There are NO reasons for having more male scientists than female scientists. Both sexes are equally capable of being good scientists, and today the opportunities are equal.

26. I don't understand

65

Assessment techniques are usually categorized as norm-, criterion-, or self-referenced. VOSTS items can be used in either the norm-referenced or self-referenced modes. The results of a class of students can be compared to the norms reported for the VOSTS items (Aikenhead & Ryan, 1989). In this way, patterns in student responses can be seen. It is important to remember, of course, that the VOSTS percentages were based on a very large sample (> 2,000 responses per item) and local variations may be appreciable (even though Ryan, 1987, found only minor variations in student responses based on gender, number of science courses taken, or region of the country). Teachers who wish to record changes in student beliefs over time (self-referenced assessment) can re-test students on VOSTS items used at the beginning of the year. Because VOSTS items tap students* reasoned beliefs, there is little learning possible from the mere completion of the VOSTS items *per se*. Thus, any changes in student response patterns upon retaking the items can be attributed to the effect of the class transactions or to maturational or historical effects. Using VOSTS items in this way offers insights into the efficacy of the curriculum and of the teacher's teaching.

Evaluation

Using VOSTS items in an evaluative mode means that the teacher must decide which student positions are to be desired and which are not. In this instance, what is important is how our students measure up to our expectations; it is less important how well they perform relative to some other group. Let us take Item 40521, one of the items from the "Influence of science and technology on society" section, as an example. Our knowledge of economic forecasts suggests strongly that the future growth in jobs will be in the service sector. High technology industries will tend to employ fewer people than the industries they replace (e.g., steel manufacture). If our STS courses stress this point, then we would expect students to choose Position F. Now we need to decide how the marking scheme would look. Perhaps we will award five points for that answer and no points for any other position. But we might decide that Position E is fairly close to the desired response: receiving four points. Positions A, B, and C seem unrealistic, so they deserve zero points. And Position D contains a kernel of insight, so it will earn two or three points.

SAYFA 66

Item 40521: High-technology industries will provide most of the new jobs in the next twenty years.

% _______ Your position, basically;

9 A. Yes. New information and rapid change are the keys to society's future.

5 B. Yes, because Canada's industries will have to become more efficient by installing hi-tech systems in order to compete.

5 C. Yes, because new Canadian industries will produce hi-tech products. Public demand for these products will create new jobs.

9 D. Yes. There will be many new jobs. Specially trained people will be needed to run and repair the new technology and to develop new kinds of hi-tech industries.

31 E. Yes. Specially trained people will be needed to run and repair the new technology, BUT it will replace some of today's jobs. Overall, the total number of jobs will be about the same.

27 F. No. Only a few new jobs will be created. More jobs will be lost because of mechanical Or computerized hi-technology.

1 G. I don't understand.

27. H. I don't know enough about this subject to make a choice.

28. I. None of these choices fits my basic viewpoint.

Assigning values in this way confronts teachers with the need to examine their beliefs, their own background knowledge, and their course of study—all of which will help teachers clarify their objectives and teaching strategies. One note of caution: any instrument designed to assess student beliefs or attitudes is subject to the danger of student providing socially desirable responses. Therefore, the teaching would not focus directly on the specific topic in the item that will be used as part of the evaluation; instead, the item would be chosen to reflect the general engagement of the issue of the impact of high-technology industries on the future of the society.

Conclusion

Assessing and evaluating students on many of the objectives of STS courses requires the use of subjective, professionally informed measures. VOSTS, in fact, was created this way; the students provided the data and the researchers interpreted them. Because that work was done with the luxury of resources which are not available to an individual teacher, VOSTS carries a relatively higher validity than could most classroom instruments of this type. Its use should therefore strengthen the assessment and evaluation of student attainments in their STS courses.

Acknowledgement

The research was funded by Grant #410-87-1051 from the Social Science and Humanities Research Council of Canada. The assistance of Glen Aikenhead in the preparation of this paper is gratefully acknowledged.

67

Copies of the complete YOSTS inventory of 114 items are available on a cost-recovery basis by writing to: VOSTS, Department *of* Curriculum Studies, College of Education, University of Saskatchewan, Saskatoon, Saskatchewan, S7N 0W0, Canada.

References

Aikenhead, G. S. (1991). Logical reasoning in science and technology. Toronto, Canada: Wiley.

Aikenhead, G. S,, *A* Ryan, A. G. (1989). The development of a multiple-choice instrument fpr monitoring views on science-technologv-societv topics. Ottawa, Canada: Social Sciences and Humanities Research Council of Canada.

Aikenhead, G. S., Ryan, A. G., & Desautels, J. (1989, April). Monitoring student views oq science-technologv-societv topics: The development of multiple-choice items. A paper presented to that annual meeting of the National Association for Research in Science Teaching, San Francisco, California.

Glaser, B. G., & Strauss. A. L. (1967). The discovery of grounded theory: Strategies f<?r qualitative research. Chicago, IL: Aldine.

Gullickson, A. R. (1985). Student evaluation techniques and their relationship to grade and curriculum. Journal of Educational Research. 72(2), 96-100.

Hickman, F. M., Patrick, J. J., & Bybee, R. W. (1987). Science/technology/ society: A framework for curriculum reform in secondary school science and social studies. Boulder, CO: Social Science Education Consortium, Inc.

Mitchener, C. P., & Anderson, R. D. (1989). Teachers' perspective: Developing and implementing an STS curriculum. Journal of Research in Science Teaching. 26(4), 351- 369.

Olson, J. (Ed.). (1982). Innovation in the science curriculum. Kingston, Ontario, Canada: Nichols.

Ryan, A. G. (1986, June). Some elaboration on what our school leavers are saving abut science. technology and society issues. Paper presented at the Annual Conference of the Canadian Society for the Study of Education, Winnipeg, Canada.

Stiggins, R. J., & Bridgeford, N. J. (1985). The ecology of classroom assessment. Journal of Educational Measurement. 22(4), 271-286.

Stiggins, R. J. Conklin, N. F., & Bridgeford, N. J. (1986). Classroom assessment: A key to effective education. Educational Measurement: Issues and Practice. £(2), 5-17.

Wiggins, G. (1988). Rational numbers: Towards grading and scoring that help rather than harm learning. American Educator, winter. 20-25, 45-48.

The Classroom Discussion of STS Issues: Public Understanding of Science in the Making

Joan Solomon Oxford University, United Kingdom

The next century will certainly differ from the present one in unpredictable ways, but some outlines of new living styles and problems are already discernible. Citizen values about medicine and the environment will almost certainly prove increasingly important in public politics. The scientific and political domains already overlap in a more obvious way than they have ever done before. Governments are crucially concerned with how the electorate reacts to controversial science-based topical issues. Within school science education the questions students ask differ from their requests for information that would figure on any objective test. But the information itself is often contentious, and the social context of the problems are such that personal values are involved in almost any question that we can give. These factors suggest that the Science/Technology/Society (STS) approach to education will become increasingly important (McConnel, 1982; Yager, 1989; Ziman, 1990). ^jjg^^

In 1985 the British Royal Society issued a report on *The Public Understanding of Science* (Bodmer, 1985) which began considerable academic debate. It recommended certain action and the Science Policy Support Group has been conducting a research project concerning the subject over the past four years. Some aspects of the projects are concerned with the scientific understanding of groups within society who found themselves in rather special situations—such as a self-help health group whose members all suffered from a genetic dietary complaint, or apprentices in a nuclear reprocessing plant. Another similar research project studied some residents living near a complex of chemical works whose safety regulations now include warning the public about possible hazards.

There were also studies using more traditional survey and questionnaire methodologies which tried to map out the knowledge, interests, and attitudes of random samples of the whole population (Durant, Evans & Thomas, 1989). A third group looked at the construction of scientific information passed on to the public through museum exhibitions or television programs.

Discussion of Issues in School Science (The DISS Project)

The DISS Project is part of the same research program. It takes place in schools but is not primarily concerned with teaching. Its implications for science education are important. Work on DISS began in 1988. How small groups of students talk together about controversial issues has been recorded consistently.

Previous research into attitudes on environmental issues among American high school students (Wiesenmayer, Murrin & Tomera, 1984) has indicated that television is the most frequently quoted source of information, although those studying an environmental course at school referred to this as being an equally valuable source of knowledge. Other data (e.g., Greenfield, 1984; Hodge & Tripp, 1986) suggest that individuals who are "high interacters" acquire a larger part of their information from discussions with friends than from reading. Television inputs need to be talked over for the process of understanding to take place. These three factors—the type of school science courses, and influence of television programs, and peer interaction—were the cornerstones of our methodology for exploring public understanding in the making.

Data on the discussion of scientific issues in the public domain by pupils from many different countries (Eijkelhof, 1990; Fleming, 1986; Solomon, 1985) have been somewhat discouraging. They indicated that very little formal school-derived knowledge is used by students in their decision making.

Our project, DISS, has been researching 16-18 year-old students' deliberations on issues after they had viewed video extracts about the topics. We encouraged the students to choose their own friends with whom to talk and to record their discussion. We were careful not to set the agenda out *simply* asked the teachers to get the ball rolling with a general comment such as "there is a lot to discuss there!"

We chose schools from different parts of England which already took a complete year's course in Science, Technology, and Society. In these STS courses discussion forms a regular and assessed component, so the work of this research fitted easily enough into the school course and could be planned as a longitudinal study during the year. The work has been carried out in two successive years with 13 schools involved.

The six television excerpts used were from general, not educational, programs. They had all the usual characteristics of media communication about science emphasizing the worrying or controversial features and assuming little previous technical knowledge. Each excerpt had special *features* which might have affected the attitudes taken by the students. One video concerned the donation of kidneys for transplantation. It not only showed the operation by which a patient is given a new kidney, and the shortfall in the supply of kidneys for transplanting; it also raised several ethical and cultural issues. The program started in Britain, visited the USA and Japan, and listened to a religious Pakistani who had acted as a live donor. This was an issue with different cultural *reactions and it also* presented the possibility of personal action by acting as a live or dead donor.

The second video was on the vexed question of nuclear power—its risks and costs. Once again the camera visited different countries with different governmental attitudes towards energy policy and public opinion: Britain, France, Sweden, and the USA. This issue was contentious and the video showed a number of differences of opinion between risk assessors from different countries in the light of the Chernobyl disaster. It finished in the midst of a heated debate between the Chairman of the (then) Central Electricity Generating Board and the British organizer of Friends of the Earth, thus inviting controversy.

Other video excerpts were about genetic counselling, compensation for veterans of the Atomic tests which took place on Christmas Island in the early 1950s, and industrial pollution and public risk. The sixth and final video excerpt concerned Third World medicine. This showed efforts to combat blindness due to Vitamin A deficiency in parts of Africa and India, and finished by following a mobile eye clinic which stopped in a remote location in India to carry out a series of cataract operations. This cultural environment was clearly more foreign to our students than any of the others and presented special problems for comprehension.

Television may be a great educator, but it is neither created nor received in the manner of school science (Silverstone, 1990). As educators we are familiar enough with the fallibility of schooling as a vehicle for passing on knowledge. Television messages probably fall even wider of the mark. They are programed to convey social as well as scientific information: all of us expect this, and so we interpret and reconstruct them in the same spirit using social as well as scientific knowledge. The Royal Society report had castigated television producers for not giving enough information, and for being too sensational. However, the DISS project was to find a situation more complex than such a stark contrast between knowledge and sensation suggests. Information from school, personal anecdote, and previous television viewing all figured in the students* discussions. It was the process of constructing understanding--personal, social, and scientific—which these discussions have most clearly illustrated.

Classroom Talk

The importance of discussion for STS work is two-fold. In the first place it could be argued that only in an exchange of views with others does the full dimension of a social problem become evident. The "others" become representatives of a broader society so that the discussion mirrors reality more closely. Indeed in STS education there is always much less call for solitary problem-

solving than in the more conventional kinds of science lessons. The second reason related to the public understanding of science. Citizens very commonly discuss in the family setting as well as with work colleagues. On such public science-based issues people talk more than they write. As educators we should encourage oral discussion as well as writing, since it gives our children a very useful life skill.

Adolescent students do not have to be encouraged to talk under most circumstances, but in the present work it was clear that they needed to see their endeavors as purposive and valued* rather than just gossip (see Barnes & Todd, 1977). The presence of the tape recorder helped in this process. Some schools already seemed to have a tradition of serious discussion, and their students lost little time in awkward false starts. Where this skill was absent the quality of listening and exchange of ideas started from a lower level but often showed marked improvement during the year.

There was a wide variety of styles of talk ranging from question-and-answer, to a kind of collaborative talk so close that one student would finish off another's sentences. Some students regularly gave out items of information; other did not. Some persisted strongly in their views and tried to convince their friends by reiteration, while others told stories about themselves, or others whom they know, to illustrate points. The forms of logical argument characterized by "if... then..." were very rare indeed, although this must not be taken to imply that talk was either illogical or irrational. Most of what when on in the way of exemplification, calls for empathizing with the victims, and suggesting possible outcomes was closer to the rhetoric of normal serious argument (Billig, 1987) than to the rigid steps of formal logic.

Receiving and Reconstructing Knowledge

The students possessed information from three general sources: from the video, from outside school, and from their formal school learning. The first of these we shared with them, but the second was information which neither we nor others in the group could be expected to recognize, so this was often made more explicit both by quoting the source ("I was reading in a book..." or "my uncle told me that..."). Items in the third knowledge category, from school science, were harder to identify because they were shared within the group, or at least thought to be so, and so had no special introduction which we could recognize.

The way in which the students received knowledge from the video was instructive. From the simplest details, such as referring to the Japanese as "Chinese," to the rejection of expert information because it was thought to be partial, we soon learned that *public understanding* was not simply related to the information provided. Misunderstanding, prejudice, commitment, and personal values all played their part in the filtering and reconstruction of messages which the television was attempting to communicate.

In some of the films there was a disagreement between experts on a scientific matter. Occasionally the students made valiant efforts to understand the technical grounds of this disagreement with one student tutoring the others on how to cope with the significance of leukemia clusters or the probability of accident. More frequently, however, the students used social knowledge rather than scientific knowledge to resolve the controversy. This was indeed an entirely understandable course of action when even the scientists in the program could not agree. The students considered the background and interests of the individual and judged their arguments accordingly. "Well he would say that, wouldn't he?" Such judgment then significantly affected the student's attitude towards the information.

On occasions this capacity to empathize with the motives, fears, or ideologies of others could be valuable. It was easy enough to be critical of the use of empathy to evaluate "expert" information, such as whether the human body needed two kidneys to operate efficiently. But where personal risk or controversy between experts is concerned, cognition alone is rarely a possible route for citizen evaluation. Only by considering how vou would feel if a nuclear power station were built close by, or if vou were found to carry a genetic defect, can information of this kind be appropriately absorbed. And when the film on kidney transplants revealed that donors often did suffer later from fatigue or other illnesses related to their loss of a kidney, it suggested that even expert medical

information might not always be so unequivocal. Scientific "messages" to the P«
of apparently value-free information, are not received like some caught bal m» [1]
need to be reconstructed, as they were through these discussions, in order to dw- ^T-- ™**»
the viewer. - For this scientific knowledge »nil HK'nVY-nfflcra^
valuable.

School science was the most "invisible" of all three categories of ^^^^S^coS^?[11]^ was not mentioned. No students, for example, expressed surprise that a kidney snuu uuuxw the flow of urine, or that one particular element was radioactive while another was noc- not question the information, but used it as a platform for their discussion, we must assume the concepts involved were at least familiar to the students (if not mathematically tormuiaieoj.• Other information was easy to receive because it matched what was already known. To understand this sort of socio-scientific material a kind of general familiarity with science is needed which uses existing concepts easily and then knits new information into its general structure. This is essentially ^ invisible and inaudible process. Only on the rare occasions when the familiarity was missing, whea a student said "Oh that's physics, I don't understand it," or "I never did chemistry, or Why don';t they speak English!" could we be sure that the relevant scientific knowledge was missing.

Conversely there were some occasions when we could tell that a specific item of scientific or technological knowledge was playing a part in the reception and reconstruction of information from the video. This was when students attempted to use their understanding to go beyond the information provided and speculate on what might be done to improve matters. "Why don't they use one of those catalytic converter things?" was a case of this kind. The addition of the last word "things" indicates either a self-consciousness about displaying knowledge or a recognition of only partial understanding. In either case we could score the student for extra scientific knowledge over and above what was in the film. What we could not be sure was whether it came from school or outside school. (Giving "mini-lectures" on any theme to an audience of adolescent peers does not engender popularity. A kind of apologetic preface was often given by students in these discussions before any knowledge was offered in order, we supposed, to mitigate any possible feelings of resentment amongst the others!).

Three Types of Talk

It is almost impossible to make a hard distinction between phases in discussion which were knowledge-centered and those which related to value positions, for reasons which the previous section has mentioned—knowledge reception is itself value-laden. If we cross this ill-defined boundary, one feature which becomes increasingly clear is a movement towards some kind of resolution, agreement, or proposed action. It is as though knowledge alone does not empower, but that its conjunction with personal values through a kind of "weighing up" procedure (Kitwood, 1984) leads to the possibility of civic or personal strategy. The procedure may well be a hidden one which is merely going on inside the student's head, or it may even take place after the main discussion is over. In about half the discussions, however, enough was said between the students for the movement from value-filtered knowledge reception, and towards value-orientated action proposals, to become apparent.

The first step on this path was the kind of "framing" talk which clarifies images derived from the video. This involves describing to each other what happened in the film so as to understand the social context of the film together with the underlying information. In some cases, notably where the background was the Third World, access could seem to be badly blocked by a lack of the necessary social and empathic understanding. Sometimes "invented" speech was used to characterize or lampoon the main information givers, and to establish their reliability or possible bias. This also seemed to help in the construction and understanding of the social background against which the students would be developing from their own value positions. In all these senses this sort of talk "framed" the discussion in the sense that Minsky (1976) used the term, to suggest that an agenda of questions for discussion was being drawn up.

The next stage in this process was deliberation which included the personal reactions to the content of the film. This was often mixed up with the type of talk described in the previous section

• I get quite a lot of information about science issues from reading. (60% control, 61 experimental)

Most of my knowledge about science issues comes from talking with friends. (11% control, 12% experimental)

My science teachers have often mentioned science issues during lessons. (87% control, yjm experimental)

There was also an introductory question which was used to establish what a "science issue" was, as well as for picking up unreflective attitudes.

> I think modern science issues—such as nuclear power, new medical treatments, genetic engineering—are all good for society.

(Two questions at the end of Section C, "Reflections on Own Knowledge and Views," were repeated in almost exactly the same form later in the questionnaire to establish the reliability of the students* answers. The Yule coefficient of association obtained for this was a satisfactory 97%.)

The students* discussion profiles exhibited some familiar features. There has been research from the USA (Iozzi, 1984) and from public initiatives in South America and Africa (reviewed in Marks Greenfield, 1984) showing that there is very little overlap in the information-processing needed for watching and for reading, although there is much more between watching and discussing with friends. This matches nicely with our finding that those who claimed to get most of their knowledge from television, and those who claimed to get most from talking with friends, shared other features. There was an association of 0.30 between the two groups as well as common tendencies to talk in a collaborative fashion and not to mention taking individual action. "Readers," on the other hand, had a negative association with mentioning TV, just as "talkers with friends" had with reading.

However comparison between the questionnaire responses and the discussion profile showed remarkable differences. The associations between claiming that most of their knowledge came from television and mentioning television programs during discussion, between claiming that they got quite a lot of information from reading and mentioning reading during discussion, and between claiming that most of their knowledge came from talking with friends and being persistent in discussion, were slight or insignificant.

This is far from being the only occasion in research literature where expressions of attitude have failed to show any correlation with subsequent behaviour. Indeed, Eiser (1986) in his review of this matter has commented that it is a common finding.

> "Nonetheless such results have generally failed to shake the conviction on the part of most attitude theorists that attitudes are an important, if not the major, cause of the kinds of behaviour which interest social psychologists" (p. 53).

The associated clusters of responses about attitudes towards knowledge obtained from our questionnaire showed consistency and described student "types" of attitude, including gender difference (Solomon & Harrison, in press) which are far from unfamiliar in the literature.

Once again, however, there was little or no correlation between the attitude responses in any part of the questionnaire and behaviour exhibited in discussions. Responses to the attitude statement "When I feel certain I am right about some issue, I do try to convince others" similarly showed no correlation with actually showing persistence, or giving knowledge, during discussions. Similarly the associations between agreeing with the statement "Really caring about issues means joining a group and doing something about it yourself" had only weak associations ($a < 0.20$) with either mentioning individual action or civic strategies during discussions.

In view of this we might maintain with Eiser that attitude measurements, such as the claimed knowledge sources, "...do have behavioral implications. The question of which specific behaviors are implied by a particular attitude, however, will depend on circumstances, and is therefore an empirical one" (p. 82).

One possible perspective on these results is to assume that the three groups categorized by their claimed knowledge sources were expressing a definite information-processing preference. However, there is internal evidence that these students have NOT processed the science knowledge very effectively (e.g., no association with remembering titles/topics for the "TV knowers," nor with mentioning reading for the "reading knowers"). A more convincing approach, therefore, might be to accept that claims about knowledge sources form a part of each students* attitudes. They describe fcnQwledge self-images which the students project, through the medium of the questionnaire, as a weak form of social interaction with their construction of the reader of their responses. This interpretation is also supported by some of the gender-related work (Solomon & Harrison, in press).

Implications for Science Education

The project set out to explore the kinds of knowledge used in students' discussions of science-based issues. In the process our research provided an opportunity to evaluate group discussion work for STS educational purposes. What has been claimed about values clarification during the exchange of views, and the exploration of different perspectives on social issues, is an essential part of that education.

A reading of the transcripted discussions suggests that allowing students to construct their own agenda for discussion has encouraged them to explore science-based social issues and to argue about justice and civic solutions, as they saw them. While the comparison of pre- and posttest attitudes on issues provided no more conclusive evidence of influence than have previous findings, other data, from students' writing, was of more educational interest.

In some educational literature searching for evidence of the learning/construction process has comprised no more than a series of interviews or pre- and posttest scores. Group discussion data may be far harder to evaluate, but it does provide first-hand evidence of the actual process of persuasion and argument which is an essential stage in .the social and personal construction of understanding. The process of reflection continued, ensuring that ideas were remembered and even built upon. Even several months later the teachers reported their students were still referring back to the video topics. This suggests that taking part in small group discussions on such issues can be a durable educational experience.

Schooling cannot fail to be a most potent force in the construction of public understanding. We found differences between schools in the number of references to school science knowledge and also, far more noticeably, in the students' facility for collaborative discussion. It is this latter point which should most concern teachers and educationalists. If the final aim of science education is to produce an informed generation of new citizens who

While this list is based on creativity literature, it well describes the STS class, teacher and student. All teachers are encouraged to try these ideas and to insure that the STS approach is being used as a teaching approach which facilitates creative development.

References

Anderson, H. H., & Brewer, J. E. (1946). Studies of classroom personalities II: Effects of teacher's dominative and integrative contacts on children's classroom behavior. Applied ,

Bozik, M. (1990). Teachers as creative decision makers. eacher Education 50-54.

Dacey, J. S. (1989). Discriminating characteristics of the families of high creative adolescents The Journal of Creative Behavior. 22(4), 263-71.

Helsen, R. (1967). Sex difference in creative style. **35(2), 214-233.**

Mackinnu. (1991). Comparison of learning outcomes between classes taught with science- technology-society (STS) approach and a textbook oriented approach. Unpublished doctoral dissertation. University of Iowa, Iowa City.

Maw, W. H., & Maw, E. (1965). Personal and les differentiating children with high and low curiosity (Cooperative Research Project No. 1511) Newark, DE: University of Delaware.

McComas, W. F. (1989). Sparking creative thinking with S/T/S education: The results of the 1987-88 Chautauqua workshops. . 4(8), 1-2.

Mullis, I. V. S., & Jenkins, L. B. (Eds.). (1988). **science** port **card:** Elements of risk and recovery. Princeton, NJ: NAEP Educational Testing Service.

Myers, L. H. (1988). Analysis of student outc al science taught with science/technology/society focus versu ook orientation. Unpublished doctoral dissertation, University of Iowa, Iowa.

Rogers, C. R. (1962). Toward becoming a fully functioning person. In A. *Combs* (Ed.), Perceiving, behaving, becoming (ASCD Yearbook) (pp. 21-33). Alexandria, VA: Association for Supervision and Curriculum Development

Torrance, E. P. (1974). Torrance test of **creative t**hinking: Norms technical manual. **Princeton,** NJ: Personnel Press, Inc.

Torrance, E. P., & Myers, R. E. **(1970). Creative learning and teaching. New** York**, NY:** *Dodd,* Mead and Company.

Yager, R. E. (1989). Development of student creative skills: A quest for **successful** science education. Creativity Research Journal. 2(3), 196-203.

Yager, R. E., ***Sc*** **Ajeyalemi**, D. (1991). Effects of STS curriculum **implementation** on student achievement in four domains of science education. Unpublished manuscript.

Yager, R. E., & Ajam, **M.** (1991). Changes in student growth in five domains with STS instruction. Unpublished manuscript.

Greater Ability to Apply Concepts Using An

Science/Technology/Society Approach to Teaching Science

Gary F. Varrella

The University of Iowa, USA

active of students seeking that can be applied to solve real problems is a feature of Science/Technology/Society (STS) teaching. The student central position as goals, curricula, instruction, and evaluation are considered in the learning environment Most exciting, however, is the value placed upon student generated questions requiring of knowledge and processes for solution. The learning and study based on need to deal with a topic is by the question(s). The questions initiate the search for explanations and solutions. The of science knowledge/concepts and processes necessary for eventual solutions and validates the usefulness of the experience for the student. The personal impact on the successful application(s) to their questions gives the science meaning which in turn incorporation of the newly learned material into the student's personal science framework.

What is Meant by Application?

Contained within the six domains of science education as defined in *The Iowa Assessment Handbook* (Tamir, Yager, Kellerman & Blunck, 1991) is Domain III--Applications. Some dimensions of this domain include: seeing instances of scientific concepts in everyday life experiences; applying learned science concepts and skills to everyday technological problems; understanding scientific and technological principles involved in household technological devices; using scientific processes in solving problems that occur in everyday life; making decisions related to personal health, nutrition, and life-style based on knowledge of scientific concepts rather than on "hear-say" or emotions. The term application has been described specifically in the taxonomy developed by Bloom (1956). Here application takes on a more specific meaning which can be described as solving a problem by using a concept

Similarities can be drawn between Domain III and the "Science Process/Content and Developmental Stages" found in the *Science Framework Addendum for California* (1984). As presented, application takes on a much broader meaning and represents a more complex task in relationship to the student learning. Incorporation of creating, inventing, problem solving, and the determination of probabilities are all ways of using information that will lead to gaining further information. Applying is placed in the formal operational level in Piagetian terms and is preceded by observing, communicating, comparing, organizing, relating, and inferring in the summarizing chart of the California addendum.

For convenience, a simple parallel with Bloom (1956) can be made to illustrate the relationship.

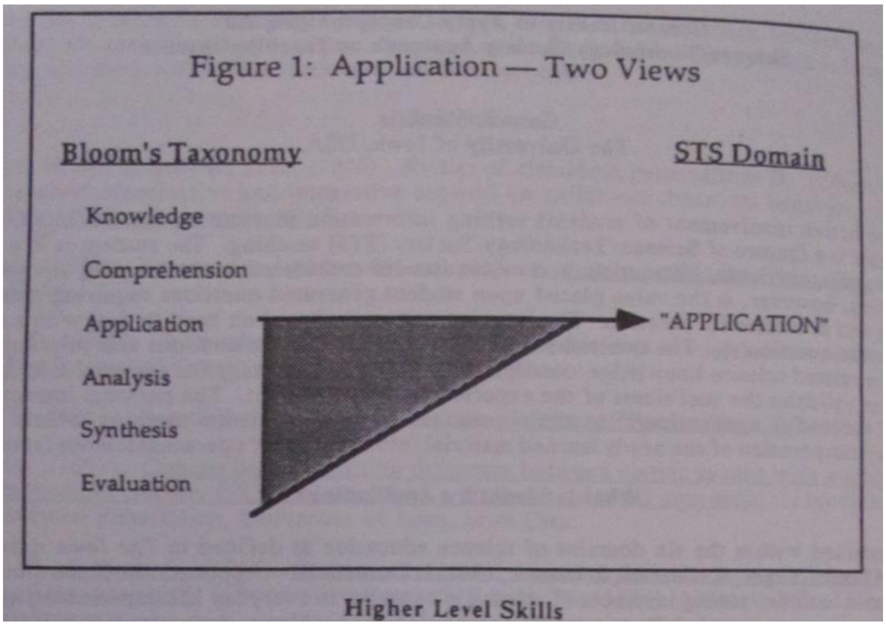


Figure 1: Application — Two Views

Unfortunately, we do not address higher level skills to the degree that we should Gettinger, 1985). As described by McComas (1989), Pancella (1971) reported that an analysis of 2,689 test items from 41 commercially prepared biology tests, judged by a panel of 12 experts, had the following breakdown in terms of Bloom's (1956) cognitive levels: 87% knowledge comprehension and 13% application, analysis, synthesis, and evaluation.

Certainly, to a modest degree, categorization of the test items was a matter of opinion: however, the panel of experts included several contributors to the cognitive taxonomy itself. From this we learn that only one out of seven questions examined by Pancella (1971) assessed knowledge beyond knowing and comprehending. McComas puts it well "...it seems as if [the assessment of] tie student's ability to use what they have learned is simply an afterthought" (1989, p. 2).

In a more recent study, Lyon and Gettinger (1985) found that students performed significantly better ($p < 0.01$) on knowledge or comprehension tasks when compared with application tasks. Two explanations were offered: 1) that the three tasks are hierarchical in complexity (which was Bloom's original contention); and 2) that schools may provide the greatest amount of experience with knowledge tasks, but increasingly less exposure and opportunity to perform comprehension application tasks.

Indicators of Success of the STS Initiative in Teaching Applications

In the Iowa STS experience there has been clear proof that gains in the Application Domain (III) have been made. McComas (1989) reported significant increases in students' abilities to apply science to new and unique situations. The application tests were individually teacher-prepared by the participants in the 1987-88 Iowa Chautauqua Program, using *The Iowa Assessment Package for Evaluation in Five Domains of Science Education* (1988) as a resource and reference. In this case no companion or control group was employed; however, a very large number of students was sampled. Of those students, 11% showed a decrease in achievement within the application domain. **However,** a dramatic 89% of the classes showed an increase in scores with some reported as high as 50 percentage points improvement between pre- and posttests (see Figure 2). McComas notes that the typical increase was approximately ten percentage points.

The total *sample of students represented 55 different* high school science classes ***in Iowa.*** Of the *55* classes McComes *(1989)* reported that *only 40* sets of data were suitable for application of a t-test. *Sixty-five* percent of the classes showed a statistically significant increase in student scores *on applications* questions *Fire percent of* the classes (two classes) showed what is considered a marginally significant gain *in test* scores ($p < 0.10$). Thirty percent of die changes in pre- to posttest *scores, including two* small decreases in achievement, were not significant at all.

Figure 2: Population and Other Relevant Data 1987-88 Applications Assessment Measures

(pre- & posttest only with treatment)

Number of students	Number of classes	Increase in achievement (percent**)	Decrease in achievement (percent)
1,269	55	89%	11%

** Typical increase was approximately 10%

Yager (1990) *reported on* 12 instructors' (who were experienced is constructivist and STS teaching experiences in teaching situations including two randomly selected classes (from within teaching assignments *for* each of the 12 teachers). Each of the 12 addressed the same general subject in their identified pair of classes. One class in each followed an STS approach the other followed a parallel track using a textbook. A simple pre- and posttest used. The teachers wrote test items designed to allow observations of student ability to use information in settings; to relate happenings observed in a new situation; to identify related but divergent practices from a given situation; to select appropriate and relevant information for solving a specific new problem; and to choose action based on new information provided, discovered, *or* constructed. Each *of the* 12 instructors administered the same test as a pre- and posttest. (In instance the instructors had generated their .)

The score (on a percentage basis of students from each of the 12 teachers was averaged for application areas described above. In each instance, much larger percentage of the students experiencing the STS approach demonstrated the ability to apply learned science concepts successfully reported via the test scores as percentages) when compared with those in the experience.

Most recently, Mackinnu (1991) has investigated the effects on learning outcomes of an STS apporoach as compared to a textbook approach. The general parameters and methods are summarized in Figure 3.

Figure 3: Comparisons Between Classes Taught with STS and Textbook Approaches

(STS), N = 360; (Textbook), N = 362

Class size	Number of Teachers	Method
16 - 29	15	• treatment & comparison • pre- & posttest

Mackinnu's study involved teachers and over students. Administration of posttests to students established a baseline of application abilities and provided the data to measure change, any, in those abilities after treatment.

Using simple inferential statistics (Figure 4), Mackinnu showed that there were no significant differences on pretest scores for the pairs of classes related to applications (one pair of treatment and comparison classes for each of the teachers). However, the results of the t-tests comparing the posttest scores of each treatment group with its counterpart group (the traditional textbook group) were significant at the p < level for all of the teachers paired classes. (In each instance, the STS treatment groups logged better scores than their comparison groups.) Mackinnu concluded that, related application of science concepts and principles, the students in the sample taught with an STS approach scored significantly higher than those taught with a comparable textbook oriented approach.

Figure 4: Comparison of Scores on Posttest STS and Textbook Approaches

Teacher	Nc + Nt	Xc	Sc	xt	St	**t**-value	p-value
1	26+25	8.04	3.38	18.32	3.80	10.22	<.000**
2	26+27	2.23	1.34	7.30	2.27	10.03	<.000**
3	20+18	6.00	2.47	13.00	3.71	6.91	<.000**
4	23+22	3.52	1.44	6.27	1.52	6.23	<.000**
5	25+26	2.12	1.10	6.00	2.24	7.80	<.000**
6	22+21	2.5	1.53 *	8.38	2.69	8.85	<.000**
7	24+26	2.17	1.17	6.85	2.15	9.46	<.000**
8 .	24+22	2.54	1.50	10.64	3.87	9.49	<.000**
9	24+26	5.79	2.47	12.04	3.02	7.78	<.000**
10	26+27	4.85	2.24	10.18	2.60	7.99	<.000**
11	16+17	3.56	1.59	11.41	3.00	9.30	<.000**
12	28+29	3.00	1.36	12.31	3.22	14.13	<.000**
13	27+25	5.70	2.63	15.12	3.19	11.65	<.000**
14	26+25	6.19	2.86	13.72	2.72	9.64	<.000**
15	25+27	6.32	2.73	15.93	3.39	11.20	<.000**

""Significance at alpha = .01 = average score;
N = number of students; c = textbook; t = STS;
S = standard deviation. X

Discussion

STS/constructivist approach to teaching science may take longer and fewer concepts may be covered (i.e., less content is covered in a specified time frame) when it is compared with the traditional march through the textbook. However, the conviction that less is better is not limited to the STS classroom alone. Reform movements in many states echo a similar theme. Furthermore, the STS/constructivist approach may not be the sole reason that less material is covered; the eventual learning outcome or goal (i.e., students will do something with what they learn) can also have an impact. Specifically, Lyon and Gettinger (1985) noted in their study of student performance on knowledge, comprehension, application that, "In general students need more time to attain mastery of school learning tasks as they advance up the hierarchy of Bloom's taxonomy" (p. 18). They found that most (89%) seventh and eighth grade students in their sample could master knowledge tasks within a 5:1 time ration, but only one-third reached mastery on application tasks in similar time. If agreement is reached by educators that students must be able to use what they learn to solve problems or construct solutions and explanations for previously unknown events and occurrences, the factor of time becomes less important. Efficacy of the approach then remains as the most important issue related to the development of higher order skills in our students.

The reports of research related to application by McComas (1989), Yager (1990), and Mackinnu (1991) all report notable and consistent gains in students' abilities to use what they have learned in new and unique situations.

Certainly, (he report by McComas (1989) with the large number of students (1,269) is a good indicator of the promise of the STS initiative in this domain. It becomes an even more powerful indicator of success when one considers that the sample was drawn from the Iowa Chautauqua Program which, for most of the teachers enrolled, is their initial to STS. The first portion of the program (fall) is limited to 16 hours and is followed by contacts via telephone, visits, and newsletters. From this first brief experience, for the students of these teachers to show a 66% success rate (as reported as statistically significant at $p < 0.05$) in improvement of ability to apply science learning is exciting. All of the tests are teacher (Chautauqua participant) generated which invites inconsistency and a greater margin of error.

The Mackinnu (1991) and Yager (1990) reports deal with smaller numbers of teachers and classes total of no more than 27 different teachers among the two), but report 100% improvement in students' ability to apply science knowledge and comprehension in the STS setting. The environment of these three studies was more carefully managed and included control or "contrasting" groups of students experiencing more traditional modes of teaching. The teachers involved were more experienced with STS and its constructivist foundations. Teachers' experience with STS as it relates to student success has not been quantified; however, anyone having taught K-12 will attest to the power of practice in employing any new teaching strategy. Teacher experience in these three studies (when compared with the McComas novice STS teacher population) may be considered the second reason for the exceptional rate of success reported in these two more recent studies.

References

Bloom, B. S. (Ed.). (1956). al objective . New York, NY: David McKay Co., Inc.

Lyon, M. A., & Gettinger, M. (1985). Differences in student performance on knowledge, comprehension, and application tasks: Implications for school learning. Educational . 72(0, 12-19.

Mackinnu. (1991). of learning outcomes b es taught with a science-technology- ok oriented approach. Unpublished doctoral dissertation, University of Iowa, Iowa City.

McComas, W. F. (1989). The application of scientific knowledge: The results of the 1987-88 Chautauqua workshops. . 4(6), 1 -2.

McComas, W. F,, & Yager, R. E. (Eds.). (1988). . Iowa City, IA: The University of Iowa, Science Education Center.

Pancella, J. R. (1971). logy examinations. Paper presented at the National Association of Research on Science Teaching Annual Meeting, Silver Springs, MD.

Science Curriculum Framework and Criteria Committee. (1984). for Califor hools, kindergarten and . Sacramento, CA: California State Department of Education.

Tamir, P., Yager, R. E,, Kellerman, L., & Blunck, S. M. (1991). . Iowa City, IA: The University of Iowa, Science Education Center.

Yager, R. E. (1990). Instructional outcomes change with STS. . 27(1), 2-20.

Assessing Student Ability to Apply Science Concepts in STS Classrooms

Eric Zehr
John F. Kennedy High School, Cedar Rapids, Iowa, USA

One of the current movements in education which is of particular importance in the STS classroom is an effort to expand classroom assessment into broader venues. Historically, exams given by the preponderance of classroom teachers have emphasized assessment in the concept domain. Whether the tests were teacher-made, provided by textbook publishers, or generated by committee, most items measured student recall of factual information or recognition of basic scientific processes (Pancella, 1971). Several studies have even categorized questions from nationally recognized exams like the ACS Chemistry Exam, AAPT Physics Exam, and the BSCS Final Exam, and found these exams no better at assessing student development beyond the concept domain (Razali, 1986; Susilo, 1987).

Recently, however, an increasing number of educators are pointing to the need to assess student progress in other domains, especially the application domain which is a critical one for STS. International efforts like the *Manitoba Science Assessment Program* (1980) and the international study reported by Suzuki (1988) have preceded U.S. efforts in this area. A Massachusetts assessment illustrates the disparity between knowing information and being able to apply that information. In one question regarding the nature of bicycle tires, two-thirds of respondents listed metal and nearly 80% named rubber as necessary materials for a bicycle tire. However, less than 40% could offer any plausible explanation as to how the properties of those materials led to their selection as components of the bicycle tires (Badger & Thomas, 1989).

This alteration of focus in the area of student assessment has prompted the College Board (1990) to alert teachers to a previously minor testing concern with their statement:

"It is important that teachers understand for themselves which outcomes are assessed in their tests as well as which ones are not. Tests designed to measure content mastery will provide entirely different information from tests designed to measure conceptual understanding and problem-solving ability. Therefore, before we use or act upon the results of tests, we need to know if they assess what we deem important" (p. 110).

Balch (1964) demonstrated that the nature of class exams has a major effect on what type of material will be learned. When exams were written to ask specific bits of information, student learning was characterized by memorization of as many isolated facts as possible with little effort made to synthesize the information into larger, more general principles or processes. Milton (1982) noted that when students ask "Will that be on the final?", a response of "No" generally ends the learning process, while a response of "Yes" generally prompts the question, "In what form?". It seems that what students learn in any class is at least partially a product of what is asked of them on the class exams, and how it is asked. This being the case, and if acquisition of the ability to apply science knowledge is a stated goal of the class, it is increasingly important to make application level questions a focus of the exams.

Some research has been completed which indicates that students in STS classrooms score higher than students in conventional classrooms on tests designed to measure students' ability to apply science concepts. However, the value of these studies rests in some measure on the reliability of the assessment tools to actually measure change in the application domain. The assumption that all teachers are effective at writing or selecting questions which measure in the application domain is not supported by studies which categorize teacher-made exam questions. One study showed that students of teachers demonstrating greater capabilities at writing application questions made greater gains during STS activities than students of teachers with less proficiency at the application generation. In that study of the 327 analyzed teacher-generated questions, only 36% were deemed likely to assess student gains in the application domain (Zehr, 1991). Support for these findings come from several studies. One interesting study asked instructors from several disciplines to analyze their own test items for taxonomic level. The instructors' analyses of their own questions categorized 31.5% of the test questions as measuring gains in higher-order thinking skills, levels three through six on Bloom's scale. However, when the same test items were evaluated by a panel of trained judges, only 8.5% of those same questions were deemed to measure higher-order thinking levels. Semb and Spencer point out from these data that the difficulty here is really two problems occurring at the same time. "In general, it would appear as if many instructors are testing mostly over recall tasks. What is disturbing is that they do not even know it" (Semb & Spencer, 1976, p. 121).

Some of the difficulty in constructing good application measures stems from poor teacher preparation in test writing skills. Ward (1974) reported that the majority of teachers had not taken even a single course in testing. One of the general guidelines she suggests to improve test construction is to start with some type of sorting system for the levels of test items; like simple knowledge, simple applications, complex applications; or knowing, understanding, thinking. Once established, the teacher can sort questions and see which levels are deficient.

Research tends to support further that questions are often poorly or ambiguously worded, often stated in the negative sense, including "all of the above" and/or "none of the above" as foils, and in general emphasizing the lowest levels of knowledge (Evans, Dodson & Bailey, 1981; Wingard & Williamson, 1973). An insight into part of the problem is evidenced in a study by O'Brien and Hampilos (1984). The study was conducted to examine the feasibility of creating a bank of test items from teacher-made tests. Sixty-seven test questions were evaluated for difficulty level and reliability during the fall semester, and again during the spring semester. In general, well-written application questions showed similar scores in the two tests. However, the following is an example of a question which seemed to test in the application domain, but scored poorly.

47. Bill's government job is GS-12. Is GS-12
    A) Nomina!
    B) Ordinal
    C) Interval
    D) Ratio.

For the spring term the question was rewritten as:

47. Sylvia won the silver medal in speed skating. Is silver medal
    A) Nominal
    B) Ordinal
    C) Interval
    D) Ratio.

In the rewritten form the question scored much better. At the time of the spring exam the winter Olympics had just concluded and apparently everyone was familiar with what the silver medal represented. In contrast, while the instructor must have been familiar with government job classifications, and felt it was knowledge common to everyone, there must have been significant confusion about what GS-12 really meant to make the question invalid. Instead of testing whether students knew terms used in the foils, the question better measured the students' understanding of government job classifications. This emphasizes that in assessing students' abilities in applying their knowledge in new situations, it is essential to use situations that are familiar to all individuals being tested. Apparently, Gronlund's (1988) simple directive that for application domain questions "the student must demonstrate that they not only grasp the meaning of information, but can apply it to concrete situations which are new to them" (p. 41) is not as easily implemented as it is theorized.

Finally, to accentuate the need for classroom teachers to implement broader more accurate assessment measures Zehr (1991) compares students scores on posttests in three domains (concept, process, and application) from a given STS science unit. Students were assigned a letter grade of "A" if they were in the top 15% of their class. This produced a total, in the three domains, of 287 "A"s distributed among 189 students. Only 20 students received "A"s on all three exams. Fifty-eight students received "A"s on two of the three exams, and 111 students received an "A" on only one of the three exams. A broader measure of the agreement among the three sets of scores comes from the calculation of Pierson's Correlation Matrix for the three domains. None of the three correlations exceeded 0.5, and one was below 0.4. Even presuming that the teachers write clear and effective test questions, it is obvious that a student's grade in that class depends upon which domain the teacher chooses to assess.

If the focus of class evaluation continues to be as uni-dimensional as has historically been the case, the risk is both that we reward students in so narrow a context as to make the recognition of little value; and secondly, and more importantly, that failure to recognize other students for gains in areas beyond the view of our limited evaluative microscope will suggest to them and others that gains in those areas are not worthy nor valuable. The National Assessment of Education Progress (1978), suggested that; "educators everywhere have the opportunity to use the NAEP results to great advantage—by reflecting upon the deeply entrenched beliefs, policies, and behaviors that impede the very changes we wish to make—and setting a charted course for change" (p. 41). In our endeavor to broaden the classroom assessment of students, we must be prepared to face challenges and frustrations. Halpin and Halpin (1980) reported that as instructors ask more diverse and challenging test questions, student achievement increases as measured on standardized exams. However, lest we erroneously think that this endears the teachers to their pupils, the same study showed that as student achievement went up, student ratings of the instructors went down! The problems with assessing student growth in the application domain are great. This is a problem of great urgency as STS initiatives are undertaken and expanded. An important measure of success for STS instruction is how student can use basic science concepts and processes in new situations.

References

Badger, E., & Thomas, B. (1989). . Quincy, MA: Massachusetts State Department of Education, Bureau of Research, Planing, and Evaluation.

Balch, J. (1964). The influence of the evaluating instrument on student learning. . I, 169-182.

Evans, E., Dodson, P., & Bailey, D. (1981). Assessment of instructors perceptions and use of textbook test-time manuals for measuring student achievement. . &, 88-90.

Gronlund, N. E. (1988). . Englewood Cliffs, NJ: Prentice-Hall, Inc.

Halpin, G., & Halpin, G. (1980). ? Unpublished manuscript.

Manitoba Department of Education. (1980). . Winnipeg, Manitoba: Manitoba Department of Education, Measurement and Evaluation Branch.

Mestre, J. P., & Lochhead, J. (1990). . New York, NY: College Entrance Examination Board.

Milton, O. (1982). ? Paper presented at the Annual Meeting of the American Psychological Association, Washington, DC.

National Assessment of Educational Progress. (1978). . Denver, CO: Author.

O'Brien, M., & Hampilos, J. P. (1984). . Paper presented at the 68th Annual Meeting of the American Educational Research Association, New Orleans, LA.

Pancella, J. R. (1971). Cognitive levels of test items in commercial biology examinations. Paper presented at National Association of Research on Science Teaching Annual Meeting, Silver Springs, MD.

Razali, S. N. (1986). Comparison of perceptions of the importance of high school chemistry among various instructors and students in the United States and Malaysia. Unpublished doctoral dissertation, University of Iowa, Iowa City.

Semb, G., & Spencer, R. (1976). Beyond the level of recall: An analysis of higher-order educational tasks. In L. Fraler and E. Vargas (Eds.), Proceedings of the third national conference on behavioral research and technology in higher education. Society for Behavioral Technology and Engineering.

Susilo, H. (1987). Perceived needs of students wishing to study college biology in the United States and Indonesia. Unpublished doctoral dissertation, University of Iowa, Iowa City.

Suzuki, I. (Ed.). (1988). International comparison of science achievement among 17 countries: Interim report of the second international science study. Tokyo, Japan: National Institute for Educational Research.

Ward, A. (Ed.). (1974). Guide for school testing program. Washington, DC: National Council on Measurement in Education.

Wingard, J., & Williamson, J. (1973). Grades as predictors of physicians career performance: An evaluative literature review. Journal of Medical Education. 48. 311-327.

Zehr, E. E. (1991). A comparison between teacher scores on application posing ability and

Development of Science Process Skills When Science is Taught With a Focus on Science/Technology/Society

Achmad Binadja FPMIPA - IKIP Semarang, Indonesia

Although a focus upon science process skills (also called inquiry and critical thinking) has been advocated since the 31st Yearbook of the National Society for the Study of Education (1932), there is little evidence that student growth in this domain has ever been significantly affected by typical science instruction. In fact Hurd (1978) offered a concise analysis of the situation when he observed that:

> "The development of Enquiry skills as a major goal of science instruction appears to have had only a minimal effect on secondary school teaching. The rhetoric about enquiry and process teaching greatly exceeds both the research on the subject and the classroom practice. The validity of the enquiry goal itself could profit from more scholarly interchange and confrontation even if it is simply to recognize that science is not totally confined to logical processes and data-gathering" (Hurd, 1978, p. 62).

A concern for science process skills has almost become a part of the belief system for science educators. In fact many feel that the split between an emphasis upon science concepts versus science processes is the most significant controversy faced by both scientists and educators as reforms are sought (Mestre & Lochhead, 1990).

The NSF Status Studies of the late 70s produced no evidence in terms of reviews of 25 years of research (Helgeson, Blosser & Howe, 1977), extensive survey of professionals (Weiss, 1978), or direct observations by trained ethnographers (Stake & Easley, 1978) that students improve in understanding or use of science process skills across the K-12 spectrum.

With the advent of Science/Technology/Society (STS) initiatives from the Project Synthesis research (Harms & Yager, 1981), new interests were generated to determine if improvements in student growth and proficiency with science process skills could be discovered. Many felt that neither science concepts nor processes would likely be enhanced over more traditional approaches. However, with a focus on meeting personal needs of students, the resolution of current societal issues, and concern for career/occupational awareness, many postulated the major advantage of STS programs would be improved student attitudes, creativity skills, and ability to apply information.

Nonetheless, general interest in science process skills suggested that attention to the effect of STS instruction should be investigated as a part of the general assessment efforts associated with the Iowa Chautauqua Program (Blunck & Yager, 1990). The Chautauqua Program began in 1983 with an NSF grant to the National Science Teachers Association. The Iowa Center focused upon STS strategies in classrooms at the fourth through ninth grade levels. The Chautauqua Program adopted the features of the AAAS program for updating college science teachers that was supported by NSF for nearly two decades before. Basic to the design was a fall introduction to new information and techniques, planning and carrying out of an interim project by each participant registered, and a spring workshop where participants could share the results of their interim projects—all utilizing the information and the procedures presented at the initial/introductory short course. The program utilizes experienced and successful STS teachers from past programs as important members of the instructional team. These teachers undergo leadership training and thereby are prepared as potential staff members and termed "Lead Teachers."

Design

Eighteen Lead Teachers in the Chautauqua Program during the 1987-88 academic year sought to determine the effect of their science teaching with an STS focus on the development of process skills by their students. Three taught at each grade level, four through nine. Th grade level Included the features defining an STS approach (NSTA, 1990). The process skills were defined as the fourteen identified by the A A AS team responsible for ***Science--A Process*** **Approach** (AAAS, 1963), These fourteen process skills include: selecting best experimental procedure., hypothesizing, comparing and differentiating, measuring, using numbers, predicting, drawing conclusions, controlling variables, communicating, inferring, interpreting data, classifying, observing, and using space/time relationships.

Students from each of grades four through nine were the subjects of the experiment. The teachers and their students all came from three public schools in Iowa. The student numbers at each grade level Included: grade 4-69; grade 5-81; grade 6-71; grade 7-62; grade 8-64; and grade 9-70. The students took a pretest at the beginning of the experiment. At the end of the STS focussed teaching, a posttest was conducted in each of the six classes. The same instrument was used for both the pretest and the posttest. The final version was developed as a part of the assessment handbook (McComas & Yager, 198S) used for the 1987-88 Chautauqua Program. Twenty-five Lead Teachers (exemplary STS teachers), as well as assessment specialists, reviewed and reworked the 39 test Items to achieve construct validity. This analysis and improvement of items tried with 4th-5th, 6th-7th, and 8th-9th grade students took place within a two-year period of time, The reliability coefficient was found to be 0.80 obtained by the Test-retest method, using the Minitab.

Analysis of the Experimental Data

The Wilcoxon (matched pair) test was used to compare the pretest and posttest scores on science process skills of the students in each of grades 4 through 9. This was done class by class. The hypotheses being tested were that the teaching of science with an STS focus enhances student development of process skills at each of the grade levels four through nine and that the enhancement would increase across grade levels.

Analysis of variance was used to test the students' mastery of science process skills. Comparisons were made across grade levels to discover significant growth with such skills as grade level Increases.

Discussion of Results

Analysis of the results from all six classes showed a significant growth in student process skills from pretest to posttest. The rate of this growth also increased across grade levels. Thus science teaching with an STS focus for these students in grades 4 through 9 enhanced their skills with science processes.

Figures 1 and 2 are graphs showing the increases of the two groupings of grade levels, namely grades 4-6 and grades 7-9. Although all the 4-6 grade items were included on the 7-9 grade instrument, several of the most abstract and higher level items on the 7-9 grade version were not included on the one used f o r grades 4-6.

Figure 1: A Comparison of Pretest and Posttest Scores of Process Scores for Students in Grades 4 Through 6 When Science is Taught with an STS Focus

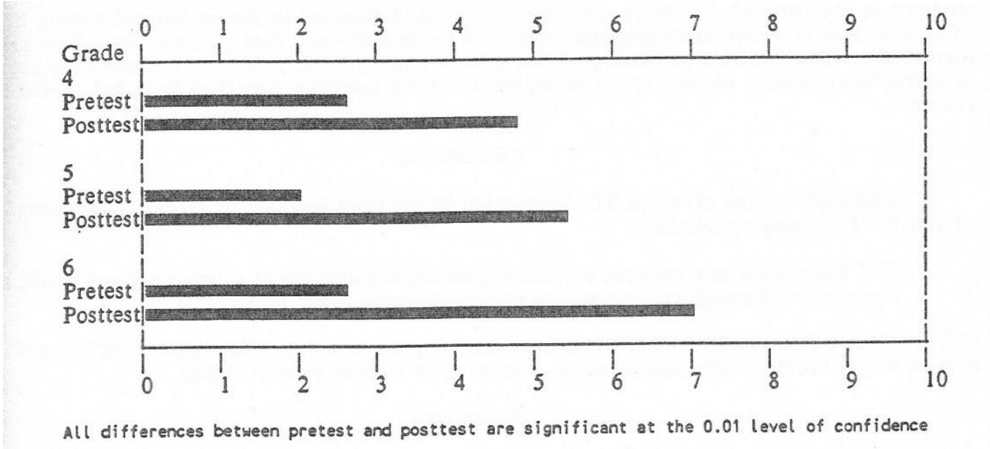
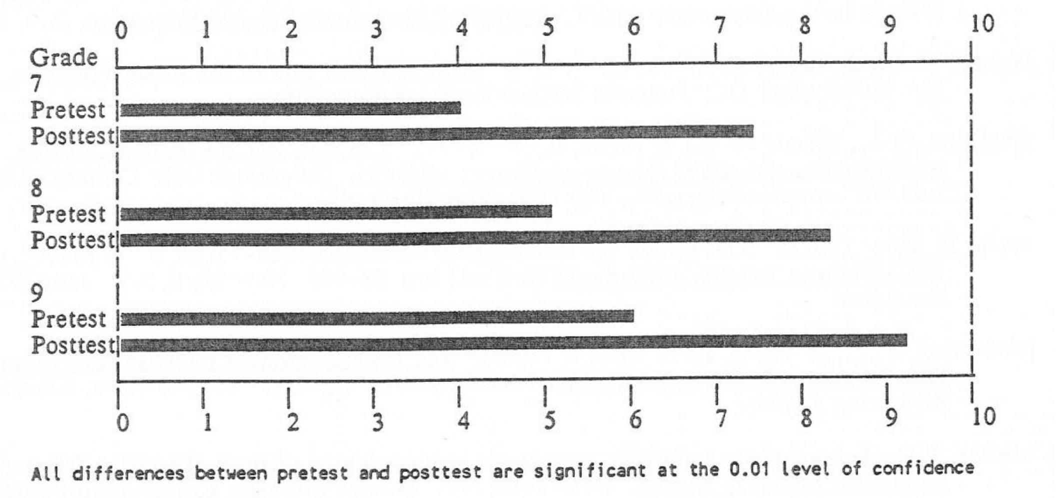


Figure 2: A Comparison of Pretest and Posttest Scores of Students' Process Skills for Grades 7 Through 9 When Science is Taught with an STS Focus



Generalizations

From this study and the foregoing discussion, it is apparent that science teaching with an STS focus can significantly increase the development of science process skills of students in grades 4 through 9. The incremental rate also increases with grade level. The results of this experiment suggest that teachers and administrators can stimulate growth of process skills when science is taught with an STS focus. Using science processes as important and valuable skills stimulates student preferences on instruments designed to test the 14 process skills identified by SAPA (A A AS, 1963).

The results of these studies do not support the observation offered in 1978 by Hurd. He asserted that typical science instruction has minimal effect on the development of science process skills. STS efforts may be effective where traditional approaches fail because students start with

100

their own problems, collect their own data, apply it to their problems, and make decisions regarding their actions, The procedures require the use of personal skills (much like science process skills)0 However, the skills are not taught as glamorized skills used by scientists that "will be useful to the students in the future,* Similarly science concepts are presented in the traditional setting because of teacher and textbook assertions that they swil 1 be useful"--and that students need first to know them before use. Perhaps all students learn science concepts and processes because they see them as immediately useful instead of believing the teacher's assertion that they "will be53 useful in the future.

Coeeiysiens

The study of the effect of STS instruction by six Iowa teachers in grades four through nine permit the following conclusions;

1. STS instruction can improve student understanding and use of science process skills; and Such understanding and use can be enhanced across grade levels.
2. STS provides a real-world context for science teaching and learning. This real-world context seems to be a major factor in stimulating student learning of science process skills.

References

American Association for the Advancement of Science. (1963), Science-- A process approach, Washington, DC: Ginn & Co.

Blunck, S. M,, & Yager, R. E. (1990). The Iowa Chautauqua Program: A model for improving science in the elementary school. Journal of Elementary Science Education, 2(2), 3-9,

Harms, N, CM & Yager, R, E, (Eds.), (1981), What research savs to the science teacher, (Vol, H. Washington, DC; National Science Teachers Association.

Helgeson, S. L., Blosser, P, E., & Howe, R. W. (1977). The status of ore-college science, mathematics, and social science education: 1955-75. Columbus, OH: Center for Science and Mathematics Education, The Ohio State University.

Hard, P, DeH, (1978). The golden age of biological education 1960-75, In W. Y. Mayer, (Ed.), BSCS Biolosv Teacher's Handbook (3rd ed.) (pp. 28-96), New York, NY: John Wiley & Sons, Inc.

McComas, W. F., & Yager, R. £. (Eds.), (1988), The Iowa assessment package for evaluation in five domains of science education. Iowa City, IA: The University of Iowa, Science Education Center.

Mestre, J. P., & Lochhead, J, (1990). Academic preparation in science: Teaching for transition from high school to college. New York, NY: College Entrance Examination Board,

National Science Teachers Association. (1990). Science/technology/society: A new effort for providing appropriate science for all (The NSTA position statement). Bulletin of Science- Technology & Society, 10(5&6), 249-250.I

National Society for the Study of Education. (1932), A program for science teaching, 31st Yearbook. Bloomington, IL: Author

Stake, R. E., & Easley, J. (1978). Case studies in science education, volumes I and II, Urbana, IL: Center for Instructional Research and Curriculum Evaluation, University of Illinois at Urbana-Champaign.

Improvement In Student Perceptions of Their Science Teachers, The Nature of Science, and Science Careers With Science/Technology/Society Approaches

Anil C. Banerjee Regional College of Education, Mysore, India
and
Robert E. Yager The University of Iowa, Iowa City, Iowa

The Science Education Center at The University of Iowa, Iowa City, U.S.A., has been encouraging STS initiatives in schools through the Iowa Chautauqua Inservice Program since 1983. Important features of this program are:

29. a two-week leadership conference for 30 of the most successful teachers from previous years who want to become a part of the instructional team for future workshops;
30. a two-week summer workshop at each new site for 30 new teachers electing to try Science/Technology/Society (STS) modules and strategies; the workshop provides experience with STS (teachers as students) and time to plan a five-day STS unit to be used with students in the fall;
31. a two and one-half day fall short course for 30-50 teachers (including the 30 enrolled during the summer); the focus is upon developing a month long STS module and an extensive assessment plan;
32. an interim communication with central staff, lead teachers, and fellow participants, including a newsletter, special memoranda, monthly telephone contacts, and school/classroom visits;
33. a two and one-half day spring short course for the same 30-50 teachers who participated in the fall; this session focuses upon reports by participants on their STS experience and the results of the assessment program.

"Lead Teachers" are essential ingredients for the Chautauqua project in terms of serving as staff members (ratio of 10:1) with new STS teachers and in terms of modeling new and innovative assessment strategies. "Lead Teachers" have had one to five years of successful STS teaching. Many have transformed their whole teaching program to STS. All are actively involved with active research projects. Many encourage the new STS teachers with whom they work to try action research projects as a part of their initial experience with the STS approach.

In STS instruction, the teacher encourages students to ask questions frequently and the teacher admits to not having answers to all questions. The teacher adopts problem solving strategies that encourages students to think, plan, and explain their own solutions to problems. The teacher uses student ideas and opinions in her/his teaching. The STS teachers also encourage students to consider the nature of science. Science career awareness is also considered as experts are sought out and used as sources of information. Work in the community and field is a common occurrence, making science relevant and career awareness a natural part of instruction. Some of the important features of this STS program and the contrast with traditional textbook-oriented instruction are given in Table 1.

Research reports on perceptions of school students toward science teachers, science classes, and the value of science indicate that many students in typical classrooms have negative attitudes (NAEP, 1978, 1988; Yager & Penick, 1986; Yager & Yager, 1985). In fact, the negative perceptions deepen and worsen as students go from elementary, to middle, and to high schools (Yager, 1988; Yager & Penick, 1986, 1989; Yager & Yager, 1985). Some exemplary programs, identified by NSTA in the Search for Excellence project, develop better attitudes among students about science (Yager & Penick, 1986, 1989; Yager, 1988).

Table 1: Some Essential Characteristics of STS and Textbook Instruction
STS
Student-centered.
Individualized and personalized, recognizing student diversity.
Directed by student questions and experiences.
Uses a variety of human and material resources.
Cooperative work on problems and issues.
Students are considered active contributors to instruction.
Teachers build on student experiences, assuming that students learn best from their own experiences.
Teachers plan their teaching around problems and issues that links science, technology, and society.
Learning goes beyond classroom and school.
Emphasize career awareness related to science and technology.
Textbook
Teacher-centered.
Group instruction geared for the average student.
Directed by the textbook.
Uses basic textbook almost exclusively.
Some group work, primarily in laboratory. Students are seen as recipients of instruction.
Teachers seldom use students experiences.
Teachers plan their teaching from the prescribed curricula and textbook.
Learning confined to textual materials. No emphasis on career awareness.

Some studies (Iskandar, 1991; Mackinnu, 1991; McComas, in press; Myers, 1988; Simmons & Guy, in press; Yager, 1990) indicate that students develop better attitudes towards science and science teachers in STS classes compared to textbook-oriented classes. Recently completed studies of the impact of STS on student perceptions also indicate very encouraging results (Banerjee, Yager & Woodworth, 1991a, 1991b). One of the desirable goals of the STS program is to develop better perceptions of students about their science teachers, the nature of science, and science careers. The STS teachers make every effort to develop better student perceptions by adopting suitable questioning, problem solving, and teaching strategies in their classrooms. These strategies are incorporated in the perception instruments being used for assessing student perceptions in the Iowa Chautauqua program. The items of the perception instruments are positive and negative descriptors of STS instructional strategies. Envelopment of positive student perceptions is one reflection of the effectiveness of the STS approach to science teaching.

This study reports the changes in perceptions of students of grades 4 through 9 concerning science teachers, the nature of science, and science careers following instruction by STS teachers.

Method

As a part of an elaborate on-going research program on STS, 30 Lead Teachers and 42 new STS teachers in science participated in this study. They taught 1,243 students in grades 4 through 9 (age group 9-15) with STS approaches for six months.

The following three perception instruments were used as pre- and posttest measures:
Perception Instrument 1: Student Perceptions of Their Science Teachers (see 20 items included as Table 2)
Perception Instrument 2: Student Perceptions of The Nature of Science (see 5 items included as Table 3)
Perception Instrument 3: Student Perceptions of Science Careers (see 5 items included as Table 4)
Table 2: Student Perception of Their Science Teachers
My science teacher...

1. **Questioning**
1. asks questions frequently, (positive)
1. asks questions that make me think, (positive)
1. answers my questions, (negative)
1. likes me to questions, (positive)
1. encourages me to ask better questions, (positive)
1. admits to not having answers to questions, (positive)
2. **Problem-solving**
7. encourages me to answer my own questions, (positive)
8. encourages me to think and explain on my own. (positive)
9. encourages our class to plan solutions to problems, (positive)
10. encourages all students to collect and evaluate information, (positive)
11. encourages me to test my ideas/solutions to problems, (positive)
12. encourages me to use actual materials to solve problems, (positive)

C. Teacher Strategies

13. uses student disagreements and varying ideas, (positive)
14. uses student ideas and opinions, (positive)
15. informs me of my progress, (positive)
16. works with other teachers I have, (positive)
17. expects me to compete with other students, (negative)
18. wants me to use science outside the classroom, (positive)
19. provides information via lectures, (negative)
20. provides for my special ways of learning, (positive)

"Student Perceptions of Their Science Teachers" instrument contains six items on questioning (Items 1-6), six items on problem solving (Items 7-12), and eight items on teaching strategies (Items 13- 20). The responses students are asked to select are: "Often," "Sometimes," "Seldom," and "Never" with weighting of 4, 3, 2, and 1 respectively assigned. For the negative perception items, Item 3 on questioning and Items 17 and 19 on teaching strategies, the weights were reversed as 1, 2, 3, and 4 for Often, Sometimes, Seldom, and Never, respectively. The perception instruments concerned with the nature of science and science careers include five items each with response categories ranging from "Highly Agree" to "Do Not Agree" categories. Only the positive responses selected by students in the "Highly Agree" category are reported in this paper.

The perception instruments on science teachers, the nature of science, and science careers were developed as a part of the research study on Science/Technology/Society. Some of the items in these instruments have similarity with the instruments used for the National Assessment of Educational Progress (NAEP, 1978, 1988) and some are included in *The Iowa Assessment Handbook* (Yager, Blunck & Ajam, 1990) for the Chautauqua inservice program. The reliability of the instruments was found to range from 0.83 to 0.91 with test-retest a week after its first use.

Table 3: Changes in Student Perceptions of the Nature of Science After STS Instruction

Descriptor	Grades 4-5 Student N = 281 Teacher N * 10		Grades 6-7 Student H = 273 Teacher N = 10		Grades 8-9 Student N = 260 Teacher M = 10
	Pre Post	Change	Pre Post	Change	Pre Post Change
1. Science means questioning, explaining, and testing, (positive)	29 68	+39	38 71	+33	40 68 +28
2. Science means studying the concepts produced and known by scientists, (negative)	61 33	-28	65 43	-22	68 49 -19
3. Science means working with various objects and materials in classrooms and laboratories, (negative)	58 55	-3	63 55	-8	56 56 0
4. Science deals with activities that affect living, ie., in home, schools, communities, and nations, (positive)	24 56	+32	18 64	+46	19 60 +41
5. Science is a htman activity that involves acting upon questions about the universe, (positive)	31 61	+30	28 15	+37	24 58 +34

A pre-posttest questionnaire, without control group, was used as the research design. The same instruments were used for both pretests and posttests. The pretests were given at the beginning of the semester before STS instruction, followed by STS instruction for six months and then the posttests. The directions for the students for the perception instruments for teachers reads:

"This questionnaire contains various statements about science teachers. There are no 'right* or 'wrong' answers. Your opinion is what is wanted. Place an "X" on the circle that best fits your opinion."

Sample Item

My science teacher asks questions that make me think.

Statistical analyses were carried out to compute the mean difference (difference of means between post- and pretest responses), standard error difference (standard error of the difference between pre- and posttest means), and t-values. Effect size was also calculated to get a qualitative indication of the level of significance of the difference in post-pretest mean responses. In order to compare the change in perceptions at different grade levels, mean differences of post- and pretest scores between two grade levels were also calculated and t-values computed to assess statistical significance of results.

Table 4: Change in Student Perceptions of Science Careers After STS Instruction

Descriptor	Grades 4 Student N Teacher N Pre Post	-5 = 281 = 10 Change	Grades 6-7 Student N = 273 Teacher N = 10 Pre Post Change	Grades 8-9 Student N = 260 Teacher H = 10 Pre Post Change
1. Science would be en area where I would be interested to work after I graduate fran school, (positive)	26 54	+28	24 53 +29	19 56 +37
2. Science as a way of earning a living would be exciting for me. (positive)	30 61	+31	28 56 +28	24 49 +25
3. Being a scientist requires talents only a few have, (negative)	50 33	-17	54 48 -6	57 51 -6
4. Society needs to support the preparation of more scientists for the future, (positive)	52 63	+11	49 64 +15	51 59 +8
5. Work as a scientist would make me rich, (negative)	50 26	-24	47 30 -19	48 26 -22

Results and Discussion

Perceptions About Science Teachers

The changes in student perceptions of their science teachers on six items of questioning after STS instruction are very positive and quite perceptible as evident from effect size for most items for all grade levels. The changes are also statistically very significant in most cases ($p < 0.001$). Item

34. "My science teacher answers my questions" is a negative perception. A good teacher should not answer student questions often; rather the teacher should encourage students to find the answers themselves. A positive perception is developed with more perceptible results in grades 4 and 5 (effect size 0.50) as a result of STS instruction. The responses under the "Often" category in grades

35. and 5 are 40% before and 10% after STS instruction, respectively.

There is a very positive development of perceptions of the science teacher through the six items on problem solving strategies as indicated by the high value of effect sizes. The development of positive perceptions is statistically very significant for all the items with the level of significance at $p< 0.001$.

Analysis of the responses for Items 13 to 20 regarding teaching strategies indicate the development of very positive perceptions as evident from the high values of effect sizes (0.6 to 2.4) for most grade levels. The changes are also statistically very significant ($p < 0,00001$) for all the items except Item 2 for grades 4 and 5 and Item 4 at all grade levels. The development of the perception on the Item "My science teacher works with other teachers I have," though desirable in an STS context, is marginal and statistically not significant except for grades 6 and 7 ($p = 0.008$). Items 5 and 7 are negative perceptions for STS teaching, as students are not expected to compete with other students and the teacher is not supposed to provide information via lectures.

positive trend is found in the very positive development of student perceptions on these two items (effect size 0.16 to 2.18) after STS instruction. The results confirm that the teachers during the STS teaching encourage students not to compete but to learn in cooperative ventures; the results also indicate that teachers use lecture in the class to a minimal extent.

The overall changes in student perceptions of their science teachers based on the questioning, problem solving, and teaching strategies adopted by the science teachers in the STS classrooms are tabulated in Table 5. The development of positive student perceptions of their science teachers about questioning following STS instruction is statistically very significant ($p < 0.00001$) at all grade levels. This is also evident from the high value of effect size (0.4 to 0.59).

Table 5: Overall Changes in Student Perceptions of Their Science Teachers After STS Instruction

		Crades 4-5			Grades 6*7			Grades 8-9	
		M 429			N = 431			N - 211	
Descriptor	Mean Diff	Std err	Effect Size	Mean Diff	Std err	Effect Size	Mea n Diff	std err	Effect Size
STS Questioning Strategies	0.41	0.06	0.59	0.29	0.06	0.39	0.41	0.10	0.58
STS Problem Solving Strategies	0.54	0.05	0.81	0.60	0.07	0.71	0.99	0.09	1.29
STS Teaching strategies	0.60	0.06	0.88	0.69	0.06	0.94	0.91	0.09	1.32
Overall STS Strategies	0.53	0.06	0.77	0.54	0.07	0.71	0.79	0.09	1.09

As a part of the STS strategies, the teacher asks frequent questions which make students think and encourage them to ask questions, and the teacher also admits to not having answers to all questions. These STS strategies on questioning develop better positive perceptions of students toward their science teachers. The overall changes in student perceptions of their science teachers as a result of the problem-solving strategies adopted by the teachers are very high at grades 4 and 5 (effect size 0.81), grades 6 and 7 (effect size 0.71), and grades 8 and 9 (effect size 1.29), and the results are statistically very significant ($p < 0.0001$).

All six items (Items 7-12) are indicators of good problem-solving strategies. These strategies are an integral part of STS instruction and the use of these strategies by science teachers during STS instruction improves the perception of students about their science teachers.

The overall increase in student perceptions based on the teaching strategies are also very high in grades 4 and 5 (effect size 0.88), grades 6 and 7 (effect size 0.94), and grades 8 and 9 (effect size 1.32). The results are statistically very significant ($p < 0.00001$) at all grade levels.

The overall STS strategies develop very high positive student perceptions at grades 4 and 5 (effect size 0.77), grades 6 and 7 (effect size 0.71), and grades 8 and 9 (effect size 1.09). The changes are statistically very significant ($p < 0.00001$).

Perceptions About the Nature of Science

The changes in student perceptions about the nature of science following STS instruction are reported in Table 3. The data indicate the development of a strong positive perception of the nature of science for almost all the descriptors. There is a significant growth in terms of effect size and also the difference in mean responses are statistically significant ($p <0.01$) in all cases except for the Item 3 "Science means working with various objects and materials in classrooms and laboratories." Item 2 "Science means studying the concepts produced and known by scientists" and Item 3 are negative perceptions in an STS context. Negative effect sizes and mean difference values, indicate the decrease in negative perceptions or increase in positive perceptions.

The STS instruction emphasizes the very important aspect of the nature of science on questioning, explaining (hypotheses, theories), and testing of explanations. STS teaching strategies link science with technology and society and emphasize issues that relate science to daily life and society. Such strategies also emphasize the universal role of science as a human activity.

There is a statistically significant development of positive perceptions about the overall nature of science at the elementary level ($p < 0.01$) and at high school level ($p < 0.001$). Earlier studies reported a decline in students attitudes towards science, particularly at the high school level (NAEP, 1978, 1988; Yager, 1988; Yager & Penick, 1986, 1989).

Perceptions About Science Careers

The changes (positive responses in the Highly Agree category) in student responses after STS instruction about science careers are reported in Table 4. Positive perceptions about different aspects of science careers, such as "science is a desirable and fascinating vocation," are developed after STS teaching. Results show a considerable increase in effect size and the results are also very significant ($p < 0.001$). Items 3 and 5 are negative perceptions since science is not "only for the most talented" and since science may not "make somebody rich." There is an increase in the responses under "I do not agree" category for these two items at the end of STS instruction, indicating development of positive perceptions.

Conclusion

Development of positive perceptions among students concerning their science classes, science teachers, the nature of science, and careers in science is an important goal of science education. The Science/Technology/Society approach to science teaching emphasizes the development of these perceptions. The results of this study indicate that students in STS classrooms develop positive perceptions about their science teachers, the nature of science, and science careers. STS teachers ask questions that make students think, encourage students to ask better questions, and to find answers of their questions. The teachers also encourage students to collaborate and to cooperate in their learning; students are encouraged to plan solutions to their problems, evaluate information, and test their ideas. The STS teachers use student ideas and student disagreements for development of the lessons, provide opportunities for special ways of learning, and encourage students to use science outside the classroom. The development of positive perceptions about science teachers is mainly caused by these questioning, problem solving, and teaching strategies adopted by the STS teachers in their classrooms. The emphasis on the nature of science and science careers through STS approaches also develops positive perceptions among students about these aspects of science.

References

Banerjee, A. C., Yager, R. E., & Woodworth, G. C. (1991a). Changes in student perceptions of their science teachers following experience with the STS approach. Manuscript submitted to Journal of Research in Science Teaching.

Banerjee, A. C., Yager, R. E., & Woodworth, G. C. (1991b). Changes in student perceptions of science teachers, nature of science, and science careers following exemplary science/technology/society instruction. Manuscript submitted to International Journal of Science Education

Iskandar, S. M. (1991). An evaluation of the science-technology-societv approach to science teaching. Unpublished doctoral dissertation, The University of Iowa, Iowa City, IA.

Mackinnu. (1991). Comparison of learning outcomes between classes taught with a science- technology-societv (STS) approach and a textbook oriented approach. Unpublished doctoral dissertation, University of Iowa, Iowa City

Inclusion of Indigenous Technology in School Science Curricula—A Solution for Africa?

Marianne Nganunu Ministry of Education, Gaborone, Botswana

The present worldwide trend to make science education more relevant to the society and the individual coincides in Africa with an increasing appreciation of African culture and heritage. In education most countries in Africa have depended heavily on foreign examination systems, foreign syllabi, foreign textbooks, and foreign examinations. Science, in particular, has been regarded as an "international" subject with little or no association with Africa, a view that has been strengthened by the use of foreign products, for many extensive foreign financial aid, and the widespread use of foreign manpower. In spite of heavy financial investments, science teaching has not been very successful in Africa. Schools are not producing enough students with good grades in science and mathematics; university science faculties are not filled; many scientific and technical posts are filled by foreign manpower. As long as education is limited to a small African elite, the curriculum is not identified as a problem. The inappropriateness of the curriculum has only become evident over the last couple of years as most African countries have opened up educational opportunities to an increasing proportion of their population.

As educational opportunities are made available to the masses, the curriculum aims must change. The majority of pupils need a curriculum that prepares them for life in their society rather than a foundation for higher level training. The foreign and often very academic curriculum did not provide for that. A different approach to the teaching of the science may also be needed. Yager (1991) reports that few students see the relationship between science as a school subject and science as it presents itself in daily life. Pupils may need to be taught science principles in the context of a real-life situations if students are to appreciate its value and apply it later in life (Nganunu, 1988).

Another important educational principle, i.e., drawing on the child's own experiences, was totally disregarded during this era of foreign science curricula. A number of African science educators (Amara, 1987; Jegede, 1988; Ogunniyi, 1988; Okebukola, 1990; Urevbu, 1984) are now asking questions like: Why teach only foreign science when, for centuries, there has been science and technology in Africa which need to be studied and developed? Should the teaching and learning not start from the local technologies and experiences and then develop from there?

Such ideas have penetrated into the primary science curricula in a number of African countries. Fewer countries have dared to tamper with the secondary science curricula, as this may jeopardize the opportunity for their students to enter universities abroad (Knamiller, 1984). Even in cases where local textbooks for secondary schools have been written, the concepts, the topics, the format, and the experiments are often based on foreign models although the applications may be local.

Reducing the Cost of Science Education

Imported science means imported science equipment. Countries which can afford, import a high percentage of their school science equipment from Europe or elsewhere. In less fortunate schools/countries, practical work is replaced by "chalk and talk" lessons. Many schools in Africa do not even offer science as a subject because of the expense.

Some countries have solved this problem by designing and distributing science kits to schools. The idea behind a science kit is to provide a fixed set of equipment which makes it possible to carry out all the practical work required by the course in an ordinary classroom—buckets are provided to carry and store water, spirit burners for heating, and torch cells for electrical work. Examples of such efforts are the science kits produced in Kenya (SEPU), Ethiopia (EMPDA), and South Africa (SEP). These kits are designed to cover all the experiments in the course using minimum pieces of equipment; each piece is carefully planned and designed for use in one or more standard science experiments (Nganunu, 1991). The approach used in Zimbabwe (ZIMSCI) is different. Instead of designing specialized pieces of equipment, a study was made of available materials, domestic and industrial (including waste materials), that could serve as pieces of science equipment (Nganunu, 1991).

Such kits reduce the cost of science teaching considerably; but with the economic realities of Africa it is still not sufficient.

The experience from Botswana and a number of other African countries is that by giving emphasis to real-life issues and traditional technologies, many of the school science topics can be taught using commonly available materials. For instance, by including topics such as "Chemicals in the Household" and "House Construction," detergents, paint, milk powder, clay, wood, and cement become "science equipmentIf one of the objectives of the curriculum, as in Kenya primary schools, is to develop appropriate technology, then obviously the materials must come from the immediate environment (Nganunu, 1991).

"Scientific" Science vs Useful Science

When Botswana got its independence in 1966, it inherited a British Education System, together with its syllabi and textbooks. It is interesting to note that, although very major curriculum initiatives have been implemented in the United Kingdom, these have not significantly affected the so called overseas syllabi and examinations. Botswana is still using these overseas syllabi and examinations in senior secondary schools. Some steps have, however, been taken to make science education more relevant and also more cost-effective, especially junior secondary education which gradually from the mid-80s is being opened to all. The integrated science syllabus for years 8 and 9 had to be rewritten to accommodate both the 30% who would proceed to the senior secondary and the 70% for whom this would be the end of their formal schooling. While the aim of the former junior secondary science curriculum had primarily been to meet the needs of the pupils proceeding to the Cambridge Overseas School Certificate (Botswana Government, 1981), the aims of the new science curriculum were aimed at providing pupils with knowledge, skills, and attitudes needed for understanding and responsible participation in our society (Botswana Government, 1985).

This was a radical shift of emphasis (Kahn, 1990). Efforts therefore had to be made to write a science syllabus that serves the needs of the individual in his daily life in Botswana, but also the needs of the nation—a useful science having application to the real world (Kahn, 1990). The approach used was:

36. to identify the needs of the society through consultation with various departments and organizations; areas of national interest and concern included issues like water conservation, diarrhea and death from dehydration, car accidents, mining, and pollution; these areas had to be covered in the syllabus; and
37. to identify the needs of the individual by identifying the activities people do in their daily lives (e.g., describing the activities done by a school-boy in town, a woman in the rural areas, a city worker, and a mother); then identify what science is needed to do these activities; from there, syllabus objectives were framed and finally the objectives sorted into topical themes such as Water for Living, House Construction, and Keeping Healthy (Nganunu, 1989).

The outcome was a syllabus that contains topics and skills not found in the traditional academic science curriculum. For example, it includes comparing and testing materials for house construction, investigating aspects of building design (in rural areas of Botswana people build their own houses), building solar devices (Botswana has 320 cloudless days per year), preparing an Oral Rehydration Drink (diarrhea is the number one killer among young children in Botswana) - all very relevant and useful knowledge and skills for life in Botswana. However, some people are not convinced and ask the question: Is this Science?

A lesson where the periodic time for a pendulum is measured against a certain variable while other variables are kept constant would be regarded as a very "scientific" science lesson. Such scientific skills will be very useful as preparation for higher scientific training and for daily life in Botswana. The students would not see its relevance to activities outside the classroom. For the students, this is merely science you must do to pass your examination.

If "science" is a fixed set of topics, concepts, principles, and rules set long ago, and at that time for an academic elite, then maybe it is not "science" we need now. The name is not important. The emphasis now, in Botswana and in most other African countries, is that "if the biggest portion of the national budget is going into education, then it must be education people can use - both for their own use and for the use of the society" (Nganunu. 1991).

The title of the new textbook for junior secondary schools, *Science by Investigation in Botswana* (Makgothi et al, 1990), assumes that a substantial part of the course will be devoted to investigative activities. Such investigations are not limited to laboratory experiments. It could involve such activities as field trips, indoor and outdoor project work, research, surveys, and design tasks. In an approach to science which is linked to a given society, science also involves going out into the community to observe how things are done in real-life, to discuss processes and materials with users, to discuss real life problems, to make observations and to develop opinions. For example, as one of the suggested activities in the topic on environmental awareness, students write a letter to the Town Council to express their opinion about an environmental problem they have identified in their area and which affects their community.

Science for Self»Employment?

All African countries which have increased access to basic education have ended up with large numbers of unemployed school leavers. The intention of the new curriculum in Botswana was to teach skills needed for life in the society; it was not intended to be vocational. However, with more and more school leavers looking for jobs that do not exist, the country is forced with a dilemma of whether or not to put more emphasis on skills for self-employment. While this is being discussed, experiences from other countries are being studied.

An ambitious program was introduced in primary schools in Kenya, both incorporating new practical subjects and self-employment skills into existing subjects. Fears have been expressed that by reducing the time for general subjects (e.g., mathematics and languages) to accommodate the increased time for technical/practical subjects, the overall academic standard will be lowered (Martin, 1987).

The Role of Indigenous Technology

Once you relate the science syllabus to real-life, it automatically becomes more technical as the applications of science are technical. The Botswana Integrated Science contains, amongst others, a number of solar technology applications (solar stills, solar water heaters, solar voltaic panels) all of which are widely used in Botswana, but also technologies which are still being developed (solar cookers and ovens). Students build their own solar stills and solar ovens. The course also includes opportunities for the students to design their own energy saving devices (solar or other). More recent thinking is that the science curriculum should not only include modern or appropriate technology, but also aspects of traditional technology (Nganunu, 1991).

The arguments for this are many:

1. It will make the learning more relevant to the everyday experiences of the child or to use the words of Amara (1987) "bring society into the classroom."
2. It lends value and respect to what the child knows. The majority of Botswana school children have strong links with traditional beliefs and technologies and bring these to the classroom as part of their own knowledge base. This should also assist in the conceptual development by moving from the known to the unknown (Nganunu & Kahn, 1989).
3. Amara (1987) suggests that by including indigenous technology into the school science, girls will feel more confident in the science class. This, Amara says, will provide an opportunity

for girls to work with materials and processes with which they can identify, and this in turn will rebuild their self-confidence and self-esteem, which is crucial to success in the sciences.

4. It will makes science education affordable. By teaching science based on traditional technologies and experiences, many of the school science topics can be taught using materials found in the immediate environment.
5. By studying the science relating to the indigenous technologies and investigating ways of improving upon them, these traditional skills and practices may also form a basis for self- employment (Nganunu & Kahn, 1989).

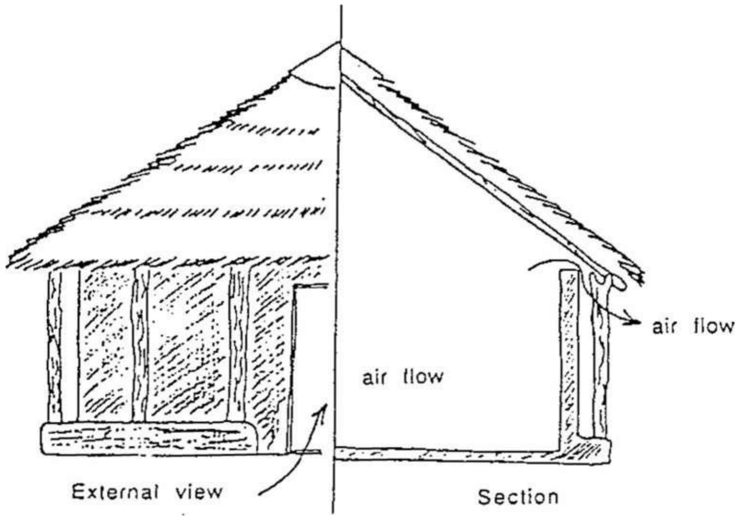
Or, to go a step further:

6. To study these technologies and, through research, see how they can be improved upon and become modern technology for Africa, i.e., transform our indigenous technology to high technology of a different kind from that of the presently industrialized nations (Okebukola, 1990).

Some aspects of indigenous technology have recently been introduced in the junior science course in Botswana, e.g,. in the module on house construction. The module starts with a study of traditional house construction. Students establish what they already know about and what are well- known facts on house construction; consultations with parents and elders are encouraged. They then move on to modern house construction and make comparisons on availability, cost, properties and uses of various building materials. The studies on house design that follow, e.g., how to build a house that is cool in summer and warm in winter, are applicable to both modern and traditional houses (Nganunu, 1991).

The biggest problem encountered in including indigenous technologies into the curriculum was lack of documentation. For this reason a research project has been started to survey and document indigenous technologies in Botswana, Once this has been carried out we will be better placed to consider incorporating aspects of these technologies into the curriculum making it a more familiar environment for the pupils to learn in (Nganunu & Kahn, 1989).

Many will think that once you replace foreign technology with local technology, you provide science of an inferior quality. This does not have to be the case. A simple example is ventilation. What could be better than an African traditional rondavel to illustrate this?



Evaluating Curriculum Change

There was no pilot study for this project, which involved not only curriculum change but also a massive school building program and implementation of Integrated Science in all junior secondary schools. Pressure of the time-scale for implementation, which was politically derived, as well as the shortage of personnel meant an immediate and full-scale implementation, a situation not uncommon in developing countries (Kahn, 1990). Since there was no pilot study, there was no evaluation before implementation.

Curriculum evaluation is still at a very early stage in Botswana. For the former junior science syllabus, the results in the Cambridge O-level examination were used as an indicator of success as the syllabus aim was to meet the needs of the pupils proceeding to the Cambridge Overseas School Certificate (Botswana Government, 1981). It is far more difficult to evaluate the impact of a science syllabus, for which the aim is to provide pupils with knowledge, skills, and attitudes needed for understanding and responsible participation in our society (Botswana Government, 1985).

There are some aspects though of curriculum change that can be more easily evaluated and researched. These include environmental factors, some of which could be external and some of which are of the type that can be controlled by the education system. This would include such factors as class size, available funding, supply of equipment, availability of teachers, teaching aids, and textbooks. In Botswana these controllable factors are fairly uniform across the country, so it would be difficult to find a control group.

Of more importance is the need for classroom based research on the teaching process and the methods used. The only data available are those by Prophet (1990) which involved classroom observations in five junior secondary schools in Botswana in 1987-88. He observed considerable discrepancies between curriculum intent and actual practice. For example, teachers are often too willing to give the "correct" answer instead of allowing the students to investigate and find out for themselves. Students are not given sufficient opportunity to practice manipulative skills.

Prophet's observations are correct. However they must be seen in the context of the situation. The "discrepancy" at this early state of implementation is hardly surprising considering the hasty implementation schedule. Although pupil workbooks and teacher guides have been produced and distributed, the textbook had not yet been written, inservice personnel had not yet been recruited, and the imported equipment was still being shipped to Botswana. However, the study does bring to attention the importance of teacher inservice. The Ministry of Education has since introduced a nationwide in-school inservice scheme, where professional officers assist teachers with lesson preparation, management of practical lessons, new teaching approaches and improvisation. A more extensive classroom interaction research is now needed to find out how the teachers are coping with the new curriculum, its content, and methods.

Prophet does not expose the nationality of the teachers used for his case studies. This is unfortunate as such information could help in taking corrective action. It should be noted that in Botswana 70% of the teaching force in science is made up of foreigners serving the country on two- year contracts, representing about 20 different nationalities and education systems. In the short term this is a good arrangement as it reduces the number of unqualified teachers in the system. In the long term the problems are many. The high turn-over of teachers makes inservice over a period of time ineffective. The cost is, of course, astronomical for a developing country.

However, a more important reason for speeding up the training of local teachers for science is to have teachers who are familiar with the society, its culture, its tradition and technologies, and its way of thinking. Only then is it possible to introduce science of real relevance to the learner in Botswana and for the teachers to help the students in their conceptual development.

There was no pilot study for this project, which involved not only curriculum change but also a massive school building program and implementation of Integrated Science in all junior secondary schools. Pressure of the time-scale for implementation, which was politically derived, as well as the shortage of personnel meant an immediate and full-scale implementation, a situation not uncommon in developing countries (Kahn, 1990). Since there was no pilot study, there was no evaluation before implementation.

Curriculum evaluation is still at a very early stage in Botswana. For the former junior science syllabus, the results in the Cambridge O-level examination were used as an indicator of success as the syllabus aim was to meet the needs of the pupils proceeding to the Cambridge Overseas School Certificate (Botswana Government, 1981). It is far more difficult to evaluate the impact of a science syllabus, for which the aim is to provide pupils with knowledge, skills, and attitudes needed for understanding and responsible participation in our society (Botswana Government, 1985).

There are some aspects though of curriculum change that can be more easily evaluated and researched. These include environmental factors, some of which could be external and some of which are of the type that can be controlled by the education system. This would include such factors as class size, available funding, supply of equipment, availability of teachers, teaching aids, and textbooks. In Botswana these controllable factors are fairly uniform across the country, so it would be difficult to find a control group.

Of more importance is the need for classroom based research on the teaching process and the methods used. The only data available are those by Prophet (1990) which involved classroom observations in five junior secondary schools in Botswana in 1987-88. He observed considerable discrepancies between curriculum intent and actual practice. For example, teachers are often too willing to give the "correct" answer instead of allowing the students to investigate and find out for themselves. Students are not given sufficient opportunity to practice manipulative skills.

Prophet's observations are correct. However they must be seen in the context of the situation. The "discrepancy" at this early state of implementation is hardly surprising considering the hasty implementation schedule. Although pupil workbooks and teacher guides have been produced and distributed, the textbook had not yet been written, inservice personnel had not yet been recruited, and the imported equipment was still being shipped to Botswana. However, the study does bring to attention the importance of teacher inservice. The Ministry of Education has since introduced a nationwide in-school inservice scheme, where professional officers assist teachers with lesson preparation, management of practical lessons, new teaching approaches and improvisation. A more extensive classroom interaction research is now needed to find out how the teachers are coping with the new curriculum, its content, and methods.

Prophet does not expose the nationality of the teachers used for his case studies. This is unfortunate as such information could help in taking corrective action. It should be noted that in Botswana 70% of the teaching force in science is made up of foreigners serving the country on two- year contracts, representing about 20 different nationalities and education systems. In the short term this is a good arrangement as it reduces the number of unqualified teachers in the system. In the long term the problems are many. The high turn-over of teachers makes inservice over a period of time ineffective. The cost is, of course, astronomical for a developing country.

However, a more important reason for speeding up the training of local teachers for science is to have teachers who are familiar with the society, its culture, its tradition and technologies, and its way of thinking. Only then is it possible to introduce science of real relevance to the learner in Botswana and for the teachers to help the students in their conceptual development

Scieoce-Technology-Society Initiatives in Israel

Pinchas Tamir School of Education and Israel Science Teaching Center Hebrew University, Jerusalem

STS oriented education attempts to make the study of science relevant to every day life, to the needs and interests of individual students, as well as to the needs of the society. The roots of STS may be found in two educational movements: First, the student-centered education in Europe, featuring educators such as Rouseau and Montesory, followed by the progressive education in the United States of America and the open education all over the world; and, second, the technological- vocational education system which has emphasized the application of knowledge and its use in solving problems in agriculture and in industry. The curriculum reform of the 1960's has claimed to build on developmental psychology with special emphasis on Piaget's ideas and has attempted to take account of individual differences by developing various methods of individualized learning such as programmed instruction and audio tutorial courses. However, the dominating characteristic of the curricula developed in the 1960's has been their strong reliance on the structure of the disciplines and on various modes of discovery learning which were designed to permit students to discover the principles and laws of science. Application of knowledge has been down played and the courses were developed so that they meet the needs of students who intend to continue to study science in college and aspire for science related careers. The STS movement in education has evolved as a reaction to the curriculum reform movement of the 1960's. However, rather than returning to past orientations, it has been developing its own style, using some of the positive attributes and ideas of the 1960's (e.g., experiential-active learning, developing inquiry skills, providing opportunities for individual projects) but paying special attention to selection of topics of generic interest to students and relevant to their lives, thereby helping to produce citizens capable of applying science in service of social interest and improved standard and quality of life.

A Nation Returns to its Homeland

The STS education in Israel has been influenced by world trends (as described above), and by their interaction with the unique conditions of the country and its inhabitants.

Zionism, the recent movement of Jews to return to their Homeland (Zion), began more than hundred years ago in Eastern Europe and later on spread into all European countries. Most of the people who left Europe with its comforts of life to start hard life in an undeveloped country characterized by deserts, marshes, and poverty, were idealists. In addition to the hardships just mentioned, they were confronted with an enormous cultural problem. Jews came from many different countries differing in language, values, and habits. The Hebrew language had been used for praying and remained unchanged since biblical times. The educational system that had been developed during the first half of the twentieth century was a reflection of the needs, means, and ideals of a society of new immigrants, multi-cultural and multi-lingual, with very limited financial support. No wonder that a number of different educational streams have been developed under these circumstances. However, in all the schools there was a strong emphasis on studies which would help in the process of building an autonomous nation in its old-new Homeland. How has all this affected science education? One of the central values associated with the Zionist movement has been "love for the Country of Israel." No wonder that when science had been considered as a school subject, it was decided to focus, in the elementary school, on the scientific characteristics of the country and the subject was designated "Nature and Homeland." It emphasized learning about local plants and animals, frequent field trips, and the keeping of a vegetable garden with two periods weekly assigned to work in this garden.

Agriculture was very important not only because of the general importance of agriculture in all the countries in that era, but also for special reasons concerning the newcomers returning to Israel. For hundreds of years Jews, in the diaspora, had been forbidden from owning land, thereby forced to engage mainly in commerce. The value of "working the land with one's own hands" had become very important and served as a symbol of the new free life. Thus the educational system had incorporated manual work in agriculture as a core subject. Moreover, between the mid-thirties and the mid-fifties agricultural secondary schools were very prestigious and admission to such schools was considered an honor. The science curriculum developed and taught in these schools was, naturally, oriented to agriculture and emphasized application and preparation for rural life. As an example, the courses of biology and chemistry in the 1940's in one of the prestigious secondary agricultural schools are briefly described. Biology and chemistry were among the most important subjects. Each had a well equipped laboratory and all the lessons were taught in the laboratory (very unusual and non-existing in many schools). The course of study in biology included unique topics, such as: a) Meteorology, which provided opportunities to actually measure rainfall, dew, and wind; b) A study of insects with special emphasis on life cycles of pests (e.g., locust, the Mediterranean fruit fly); c) A study of fungi with special emphasis on plant diseases (e.g., mildew); d) A study of mushrooms distinguishing between poisonous and edible species; e) A study of the digestive system of cows and the implications for feeding. In addition, students were expected to identify wild plants by their names and to carry out as homework biweekly field trips on which a written report was handed-in and assessed.

The course of study in chemistry also included special topics, such as a) Soil chemistry; and b) Laboratory methods to identify substances in farm products and to determine their freshness (e.g., milk tests). The science teaching was not confined to biology and chemistry but, rather constituted an important component of the various agricultural subjects. For instance, in Fruit Growing the use of hormones for various purposes was discussed, or in Chicken Raising the use of artificial light to monitor the time of laying of eggs was explained.

Although the term STS had yet to be invented, undoubtedly science taught as just described fits well the STS approach.

Vocational schools had become very important in the mid-fifties as the role of agriculture in the economy of the country was diminishing and the role of industry had been increasing. However, the study of science in these schools had not been developed like that described above in agricultural schools. The reason was that the majority of students enrolled in vocational schools were the less talented who were not admitted to the academic schools. Consequently their science courses consisted of watered-down general science topics. Only recently, during the last decade, special physics modules integrating science and technology, which can be regarded as fitting an STS approach, were developed. These modules were developed by Professor Menachem Finegold and his colleagues in the Technion in Haifa and have been used successfully not only in Israel but in South Africa as well. It is interesting to note that many professors of engineering prefer to teach students who have studied in academic schools. One reason may be that for many topics in engineering the production of new knowledge is so rapid that high school teachers cannot keep up with it so that much of what they teach soon becomes obsolete. This issue is open to research and one of the questions would be: Can a high school science course of study be designed with an STS approach which would provide an adequate preparation for everyday life but will also take advantage of special formal conditions of a technological high school? Or, alternatively, is it time to close the vocational schools and offer STS-oriented courses which would serve equally well the needs of all students?

STS Education in Elementary Schools

The school vegetable garden is by now just a memory in most elementary schools. In the 1970s a new elementary science program designated as MATAL was introduced to Israeli schools. This program was modeled after United States programs such as SCIS and SAPA and had significantly upgraded the teaching of science in many schools which adopted In 1990 a new program designated as MABAT was introduced with an aim to replace MATAL. This new program heavily emphasizes technology and integrates the use of microcomputers. Some teachers feel that there is too much technology and too little science in the materials which have been released so far. A survey of opinions of science educators carried out several years ago (Silberstein & Tamir, 1979) indicated that the majority would have liked to see a it.

program for elementary school children which would be based on their curiosity and interest in nature, in organisms and their life cycles, in the human body and how it functions, and in similar topics which they can see as relevant to their lives. Elementary school teachers are somewhat suspicious whether the new program MABAT is what they would like to teach and whether it is the best for their students. A general implication from all this is that just using an STS approach means very little. STS means different things to different people and one must examine each program for its own merits.

STS In Junior High School

The science curriculum which dominated schools since the 1970s may be characterized as consisting of separate units in the physical sciences and in the life sciences, both taught with no special reference to STS. However, in many junior high schools a program entitled "Agriculture as an Environmental Science" is taught as well. This course certainly fits attributes of STS. It includes, for example, outdoor experiments dealing with photoperiodism, which show students how flowering time can be monitored. Another example is a game called "The Hunger Game" which students play and thereby become cognizant of various factors related to the interactions among science-agriculture and economy. The problem with this STS course is that it is not regarded by most students as science and when they make their choices for further study, the image they have of science is that of their physical and life science courses which have very little STS flavor.

A recent study of science teaching in Israel has shown that grades 6 to 9 are crucial in terms of deciding to study or not to study science in the senior high school. Further, it is very rare for a student who has not studied science in grades 11 and 12 to elect to study science at the university. This recent study also shows positive correlations between success in science in early years and both choosing science and achievement in science in later years (Tamir, et. 1988).

It would appear that in light of research which revealed a strong correlation between an STS approach and the development of positive attitudes toward science (Yager et al, 1991), that encouraging teachers to use STS strategies may increase the number of students who become science prone.

STS in Senior High School

has only recently become an optional subject for the matriculation examinations and only a few students have taken the course so far. The course may be described as STS-oriented, with a strong slant towards problems of the environment such as pollutions, land use, ecology, and nature preservation. Issues such as biotechnology are not included.

In the regular , which is currently elected by about one-third of the matriculating students, there are several spots especially amenable to an STS approach. Following are some of these activities:

* Every study is required to carry out an individual project beginning in grade 11 and ending in grade 12. The project should be ecological and typically involves a study of particular biotop.
* The new national curriculum in biology does n££ include any compulsory topic. It contains a list of topics with detailed outlines. However, any teacher can choose from the menu what he/she likes and believes to be most relevant to his/her students. This opportunity to choose is one of the cornerstones of an STS approach.
* In the matriculation examination students are required to write either one or two essays. The topics for these essays often have a significant STS component. For example: "What are the differences between biological and chemical control of pests? Under what conditions will you prefer the use of biological control? Explain."
* Authors of new units as well as teachers are encouraged to include STS components. For example, aspects of biotechnology related to the teaching of genetics have been included in a recently published genetics textbook.
* A unit entitled Biotechnology is being prepared. This will be one of six topics that teachers may choose to teach.

* Various steps are taken to incorporate microcomputers in teaching biology. For example, a practical matriculation examination was tried last year in which half of the investigation is actually preformed in the laboratory, whereas the other half is carried out with the microcomputer.
* Finally about 10% of grade 12 students who take a matriculation examination in biology follow a special course of study which is aimed at students in agricultural schools. That course integrates science and technology (biology and agriculture) and the students take a special matriculation examination, particularly matched to the agricultural emphases of the program.

In the regular curriculum which is elected by about one-sixth of the matriculating students, there is a special section devoted to the chemical industry in Israel. Special units have been developed to cover this topic, the most popular has been "Chemistry of the Dead Sea." Some attempts have been made to include STS materials in as well. A unit on the of medical instruments has been developed and tried in a Nurses training school, where it appears to be successful.

In addition to what has been done in regular science courses, special courses each focusing on a particular STS-related topic have been designed and used in various schools. For example, a unit on "Smoking" was developed and taught in several schools. Similarly, a unit on AIDS was developed and is now being tried as part of a Ph.D. dissertation. There are many science teacher education programs, both in universities and in teacher colleges, which deal with and provide examples of STS orientations.

Conclusions

Although there is a general recognition and appreciation of the STS approach among science educators in Israel, the dissemination of this approach has been slow. So far very little research is available regarding the implementation and outcomes of this approach. However, as described in this article Israel has had a long tradition of integrating ideologies and social issues in its educational system. Instead of promoting the "ideal of manual work" and the "love of Nature and the Homeland," new issues such as conservation of the environment, nutrition, health, and biotechnology, which constitute STS topics, are included in current curricula and an STS approach is advocated as one of the major instructional components. Only at the elementary school, however, the STS approach has been pushed to become the dominating instructional mode. Judging from experience of other countries, reaching a desired level of instruction using an STS approach, requires much longer and deeper preparation of teachers compared with what has so far been done. A second requirement for upgrading STS instruction is continuous evaluation and feedback. Finally, it should be recognized that STS is one desirable approach but not the only one. There is room in our schools for diversity of approaches.

References

Silberstein, M., & Tamir, P. (1979). Questionnaire data as a source for curriculum planning. ^ 5, 109-214.

Science, Tech oology and Society: Initiatives in Australian Schooling

Geoffrey J. Giddings Curtin University of Technology, Western Australia

During the early and mid 1980s, Australia participated in the Second International Science Study (SISS) conducted by the International Association for the Evaluation of Educational Achievement (IEA), which assessed science achievement across 17 countries. The international coordinator for the study was an Australian, Dr. Malcolm Rosier of the Australian Council for Educational Research (ACER). Another Australian, Dr. John Keeves, former Director of ACER, was the chairman of the international policy committee for the study. The IEA tested the achievement of children aged 10, 14, and 17 in 10,000 schools throughout these countries and concluded that, in comparison to the other countries in the sample, Australia had slipped dramatically since the last tests were carried out in 1970 (Jacobson & Doran, 1988). In 1970 Australia ranked third in the 17 country sample; in the most recent testing the nation slipped to tenth place (Rosier, 1988).

Unfortunately, science education at primary, secondary, and tertiary levels in Australia is beset with several serious problems in addition to these declining standards (Rosier, 1988). Evidence of the declining participation rates in science and technology disciplines at the secondary and tertiary levels is irrefutable. In the traditional secondary science courses such as physics, and chemistry, the proportion of Year 12 students taking such courses has declined nationally over the past ten years (Dekkers, de Laeter & Malone, 1986). The situation is mirrored at the tertiary level: whereas total tertiary enrollments have almost doubled over the past decade, enrollments in the physical and geological sciences have not kept pace with this overall increase. The Commonwealth Schools Commission's *National Policy for the Education of Girls in Australian Schools* (Australian Federal Government, 1987) highlights the concern that, of all school subjects, perhaps the greatest inequity between the sexes in enrollment, achievement, and attitude occurs for the physical sciences (Fraser & Giddings, 1987). The time is ripe in science education to redress these low enrollment numbers and disappointing achievement levels for all students. Such an exercise is more likely to become a reality if there are strong and clear national guidelines for both science and technology education.

Science and Technology Education in Australia

Setting and achieving a national agenda for science and technology in education is a top priority for Australia's policy makers in this, the last decade of the twentieth century. Teachers and schools are constantly being told through the media and other sources, that scientific discovery should be related to technology and that as the resulting effects of the technology on society has such an important impact on peoples lives, schools should be including Science, Technology, and Society (STS) courses in the school curriculum. In addition, many Australian educators believe the key to facing many of the challenges presented by the technological change associated with contemporary Australian society involve introducing effective science education programs from the earliest stages of schooling.

Hence much interest has been generated in STS courses in Australia. Cross (1990) alerts us to the range of meanings attached to the STS label that have become apparent at international conferences and through a variety of publications and programs in many different countries. Indeed, it is clear that there are several identifiable agendas underpinning the different values inherent in STS courses. It would seem the STS movement has been interpreted differently by different groups in different countries. For instance, there are clearly science teachers in many countries who are greatly concerned about the problem of ensuring that students connect science with the social, technological, and political forces that shape science, and that STS courses appear to offer an excellent vehicle for achieving these ends.

Before discussing some of the initiatives on the Australian scene, it should be stated that Australian educators, science and others, have been carefully formulating and evaluating their views in this area, in order to achieve the goals they wish to achieve, in the most effective manner possible. The Australian approach to STS could therefore be described as very positive, but questioning. Perhaps Cross (1990) sums up the reticence faced by many Australian science educators in wholeheartedly embracing STS by stating that "there are potential conflicts of interest between a socially responsible science education and an education for technological imperatives and that particular STS curriculum materials may or may not promote the values we would wish for a future society based, for example, on a sustainable life on the planet for all people" (p. 33).

Science teachers in this country are alert to the need for a questioning approach to STS in order to ensure compatibility with their own educational objectives. The role and nature of the "technology" in the STS equation is a crucial one. For instance, much of the STS material appears to promote teaching for and about technology in a language which expresses a most optimistic viewpoint about technology. Such an approach has been promoted in this country by the national government, although there have been words of caution. For instance, in 1982, Barry Jones the national Minister responsible for Science and Technology at the time, claimed that "every technological change has an equal capacity for the enhancement or degradation of the quality of life, depending on how it was used..." (p. 231). On the other hand, a more socially responsible approach as advocated by Cross (1990) may be to adopt a neutral stance towards technology by utilizing an evaluative approach.

Certainly there has been a changing view of technology. There has been a shift from considering technology as merely the application or use of science, to one which portrays technology as involving problem-solving, drawing on knowledge and skills from several disciplines and hence developing the capacity to apply knowledge for some human purpose (Kings, 1990). Technology curricula in this country have tended to grow out of science (e.g., STS), industrial arts (Craft-Design- Technology [CDT]), or be developed independently.

No single approach dominates at the present moment—the different states are busy developing and designing their curricula along statewide guidelines, given that there is currently no single national imperative formulated on this issue. That is not to say, however, that this situation will remain static. There are strong moves towards a core national curriculum statement from the national government. It has also been important for the various states to consider carefully the amount of time that can be devoted to technology and/or the technology component of science education and whether teachers have the full range of skills required to teach this area. This chapter outlines some of the directions and the accompanying rationale for STS and related approaches in three Australian states--Victoria, New South Wales, and Western Australia.

Kings (1990) reports that in Victoria there have been at least two relevant concurrent developments. The Blackburn Report (Ministerial Paper, 1985) on post-compulsory schooling (Years 11 and 12) and the Curriculum Frameworks P-12 Report (Education Department of Victoria, 1985). Both had implications for the science and technology curriculum. Based on the recommendations of the Blackburn Report, science courses have been structured to include STS-type themes. Based on the Curriculum Frameworks document, the purposes for science as stated in the curriculum guidelines include the following: science as knowledge, science as technology, science and society, and science and personal development. Within the boundaries of these purposes, teachers are developing programs which give greater emphasis to what is termed the "social context of science and technology." This phrase or theme would seem to encapsulate the main common denominator of STS Australian-style.

It should be pointed out, however, that within the Australian context, all curricula (except at Years 11 and 12) are currently broadly-based and individual schools decide on the details of what is to be covered in any given curriculum. In Victoria again, new curriculum initiatives in information technology studies have evolved quite independently of other studies (including science) and appear to conform to acceptable definitions of technology.

The argument that technology education has little, if anything to do with science, has a degree of support in Victoria. Its proponents are developing technology education in such a way as to have its own curriculum, its own knowledge and skills, its own equipment, its own space, and its own new breed of teachers (Fensham, 1990).

One the other hand, many new science courses in Victorian schools have included units of study which clearly fall under the STS approach, but which for various reasons, are not specifically designated as such. These new courses include units with such titles as: Transforming Raw Materials and Meeting Human Needs, Transforming and Reshaping Products and Meeting Society's Needs, Extending our Capabilities and Creating New Hazards, and Science and the Development of World Views. It should be mentioned that a number of overseas curriculum innovations, such as the British Science and Technology in Society (SATIS) materials, are fairly well known in Australia (Holman, 1986) and extensively used as "add-on" applications for traditional science courses. As Fensham (1990) points out, these add on approaches are easier for teachers and do not disturb the overall course structure too much. It also means that teachers can control how much technology they do, and allows the needs and constraints in their own particular school, their own background knowledge, and the availability of relevant equipment and materials to be highly influential in the nature of the course they construct and teach.
In the Western Australian state context, one of the outcomes of the desire to implement technology education in schools was the decision in 1987 by the state Ministry of Education to designate and fund six pilot secondary schools to be designated Technology High Schools. The way each school proposed to integrate technology into their school, depended on their definition of technology as well as the knowledge and skills of the teachers in the school. This section is a summary of this particular initiative from the perspective of one of these schools, derived from an early review of the innovation (Treagust & Mather, 1990).

The desired outcomes for technology education chosen at the particular pilot school after much debate were basically those identified by the Commission on Technology Education for the State of New Jersey (Fricke, 1987). Using these as a starting point, the school developed and implemented an across-the-school technology education curriculum model. This curriculum model integrated technology objectives across aU subjects in the compulsory Years 8-10.

Each subject area rewrote the objectives in their units incorporating the four technology areas selected, i.e., technological literacy, technological awareness, technological capability, and information technology (see Table 1).

Specifically, the science curriculum for Years 8-10 at the pilot school now has a range of technology objectives integrated within it. Interestingly, the science staff decided that not all units would have technology objectives integrated within them. Their preference was to include them initially in all the "core" science subjects which all students would study. Student reactions to the technology aspect of their curriculum were whole-heartedly positive. The manufacture of clothes in the Home Economic unit Technology and Fashion illustrated an increased understanding of the role of technology in all aspects of clothes making and manufacture. In the science area students met their community and commercial oriented project with interest, commitment, and enthusiasm. One such course in Robotics, utilizing sets, involved prototype building and ultimately an exploration of the marketing and commercial potential of products of the course.

the teaching staff ensuring they are implementing the desired technology education at the school" (Treagust & Mather, 1990, p. 59).

The state of New South Wales has many good examples of what we may call a more conventional STS approach to science teaching. One such example is the Science, Technology, and Society Curriculum designed for the Department of Education (North West Region) by Paterson, Boggs, and Patterson (19SS). The course has been written to meet a perceived gap observed in the senior school curriculum offerings in science. The course has been specifically written to link the three strands of science, technology, and society together. The course has been designed as a set of independent modules.

Teachers are free to choose any combination to satisfy the number of units required as set out below.

Year 11	1 unit	- 4 modules
	2 unit	- 8 modules
Year 12	1 unit	- 3 modules
	2 unit	- 6 modules

Following traditional STS-style objectives, the main aim of the course is to provide students with an understanding of the impact of science and technology on the individual's quality of life, within a changing Australian society. Specifically, the course aims to:

1. Provide students with a knowledge and understanding of the inter-relationships between science, technology, and society;
2. Provide students with a variety of practical experiences involving experimental work, information processing (including computer operation), modelling, games, and simulations;
3. Enhance the problem-solving, reasoning, and communication skills of the students so that they may develop competent and confident self-images; and
4. Promote in students a positive attitude towards Australia's future, and a capacity to critically evaluate technological developments in terms of their impact on Australian society and the Australian environment.

The course consists of 15 modules. Within each module the set of content ideas is not meant to be of equal time duration or prescriptive. The modules consist of: Introductory Core Unit— Technology, Science, and Society; Legal Drug Use; Living with Natural Materials; Clean Living; Food and Agriculture; Moving People; Information Technology; Energy and the Future; Science and Technology for the Consumer; Medicines and Diseases; Environmental Hazards to the Human Body; Modern Materials Technology; The Exploration and the Colonization of Space; Electronics; and Biotechnology and the Future of Humans.

All the evidence at this point in time suggests that this type of course is popular with both teachers and pupils. Although clearly putting additional strain on the mental, physical, and material resources of the schools.

Summary

Science and technology will continue to pervade and interact with our economic, cultural, and social life. It is our responsibility as teachers, educators, and decision-makers to present science in its real-life societal contexts. Students must be exposed to the skills and knowledge about science and its related technologies, about the successes and failures of these endeavors, and about the criteria one can apply to evaluate the ideas and products of this union. All citizens need to be party to, and in charge of, the decision-making processes that are shaping their lives. For science teachers there should be little debate about the place of technology in their curricula—what is not as clear is whether technology is sufficiently interdisciplinary to warrant an across-the-school approach to its teaching and whether the teachers are trained appropriately in the skills to teach it.

References

Australian Federal Government. (1987). . Canberra, Australia: Australian Government Publishing Service.

Cross, R. T. (1990). Science, technology, and society: Social responsibility versus technological imperatives. . 36(3). 33-38.

Dekkers, J. de Laeter, J., & Malone J. (1986). . Perth, Australia: Western Australian Institute of Technology.

Education Department of Victoria. (1985). . Melbourne, Australia: Curriculum Branch.

Fensham, P. J. (1990). What will science education do about technology? . 2£(3), 8-21.

Fraser, B., & Giddings, G. (Eds.). (1987). . Perth, Australia: Curtin University of Technology.

Fricke, G. L. (1987). (Report to the Commission on Technology Education for the State of New Jersey). Trenton, NJ: Commission on Technology Education.

Holman, J. (Ed.). (1987). Special issue on science and technology in society. . 10(4).

Kings, C. (1990). Developments in science and technology education: Some cross-cultural comparisons. . 36(3). 39-45.

Jacobson, W., & Doran, R. (1988). . New York, NY: Columbia University, Teachers College Press.

Jones, B. J. (1982). . Melbourne, Australia: Oxford University Press.

Ministerial Paper. (1985). (The Blackburn Report). Melbourne, Australia: Victorian Government Printer.

Paterson, M., Boggs, D., & Patterson, G. (1988). . Sydney, New South Wales: Department of Education, North West Education Region.

Rosier, M. (1988). International comparisons of science achievement. 62. 1 - 3.

Treagust, D. F., & Mather, S. H. (1990). One school's approach to technology education: Integration across the curriculum. . ¿6(3), 50-60.

AFTERWORD

If Science-Technology-Society is to be a major international reform in science education across the world, it can not be a special form of education (like environmental education, health education, energy education, and the more than 300 other subdivisions or foci for K-12 science). The term which has crept into common usage— STS education—may promote STS as a misfire for real reform. STS themes, lessons, or perspectives may help curriculum developers and textbook authors/publishers. Again, however, STS can not be reform if it is merely a curriculum component or organizer.

If STS becomes the reform that many authors in this volume see it to be, the broad definition of STS offered by NSTA will have to be used and more universally accepted. Reform means major change; this means more than the addition of material or the inclusion of a new perspective.

Reform is needed in science classrooms everywhere. STS can be that reform: However, it means sharing information, careful assessment, and making correctives based upon actual evidence and not preference and intuition. If STS is to achieve its potential, everyone must attend to certain resolutions, namely:

1. Ask for real evidence for the effectiveness of all modules and all instructional strategies proposed and tried. Without such evidence our efforts are little more than creations of art!
2. Take the best materials and model the best instructional strategies we can find. We don't have to reinvent every wheel, wagon, and energy source to help with reform efforts!
3. Accept and understand the engineer metaphor. We need to know the problem, propose solutions, and test the solutions we propose. Such is science and technology—as well as good science education!
4. Collaborate with others freely and frequently. No one knows all the answers; there is no perfect way; no one need to wait for directions—i.e., someone telling someone else what to do and how to do it! Individual actions and experiences represent power that can be shared with others; such shared experience is motivating and a way to grow!
5. Welcome failures; they represent powerful experiences that can help find real correctives sooner. Fear of failing often prevents action, reform, and improvement!

John E. Penick Coordinator
Science Education Center
789 Van Allen Hall
The University of Iowa
Iowa City, Iowa 52242-1478 USA

Alan G. Ryan
Department of Curriculum Studies College of Education University of Saskatchewan Saskatoon, Saskatchewan Canada S7N 0W0

Joan Solomon
DISS Project
University of Oxford
Department of Educational Studies
15, Nor ham Gardens
Oxford, 0X2 6PY
Great Britain

Gary F. Varrella
Science Education Center
759 Van Allen Hall
The University of Iowa
Iowa City, Iowa 52242-1478 USA

Robert E. Yager Professor
Science Education Center
769 Van Allen Hall
The University of Iowa
Iowa City, Iowa 52242-1478 USA

Eric Zehr

ICASE

AIMS

The Internationa] Council of Associations for Science Education (ICASE) was established in 1973 to extend and improve education in science and technology for all children and youth throughout the world by assisting member associations and institutions. It is particularly concerned to provide a means of communication among individual science teachers associations and to foster co-operative efforts to improve science and technology education.

ACTIVITIES

ICASE activities include:

- Publishing a journal *Science Education International* and other publications
- Issuing a Directory of Science Teacher Associations Worldwide
- Disseminating information about activities of national and regional groups
- Arranging regional activities in association with other organisations such as UNESCO
- Promoting exchanges of science teaching personnel
- Using its endeavours to promote research in science education

MEMBERSHIP

Full Membership is available to

- National associations for the promotion of science education
- National associations for the promotion of education through separate disciplines
- Science education sections of national scientific associations or national educational associations

Associate Membership is available to

- Sub-national groups concerned with science education
- Multi-national associations concerned with regional or international activities in science education Institutional

Membership is available to

- Science centres, science museums, science societies, or other centres interested in science education
- Faculties embracing science education in universities or colleges

Foundation Membership is available to

- Foundations or support groups with an interest in science education and science teacher associations Company

Membership is available to

•

- Companies & business endeavours with an interest in science education & science teacher associations

CONSTITUTION

The governing body of ICASE is the General Assembly consisting of one delegate from each member association together with any members of the Executive Committee who are not delegates.

The Executive Committee comprises the President, Past President, President Elect, and up to eight members elected on a geographical basis. The Executive Secretary, Treasurer and Journal Editor are appointed by the Executive Committee.

ICASE is closely linked with the Committee on Science Teaching of the International Council of Scientific Unions (ICSU) and thereby enjoys full recognition by UNESCO and other international and national organisations.

ICASE - supporting science teachers around the world

SUBSCRIBE NOW

and find out what's happening in science education around the world

Science Education International is the new quarterly journal of ICASE, the International Council of Associations for Science Education

Feature articles on science education

Science education around the world - news of projects and events

Research on teaching and learning - bringing significant research to the attention of science teachers

Science teacher education - communicating ideas and strategies to assist science teacher educators

Primary science - classroom ideas for primary and elementary teachers

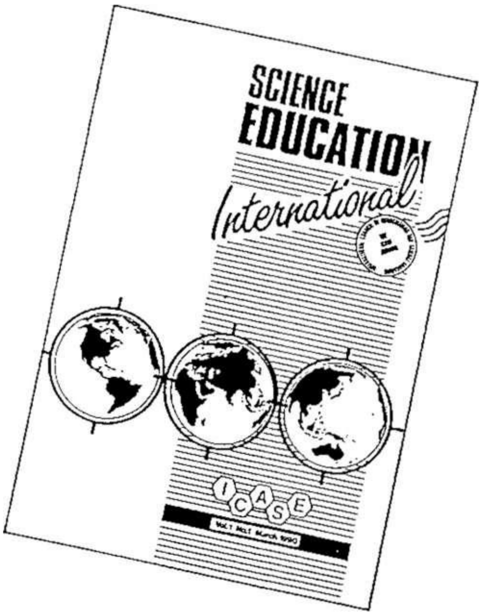
Science technology society - classroom ideas for primary and secondary classrooms

Resources for teachers

Calendar - international and regional conferences and meetings

ICASE news - keeping member associations informed around the globe

And more!



DETACH BELOW AND SEND WITH PAYMENT TO Dennis Chisman, ICASE Hon Treasurer, Knapp Hill South Harting, Petersfield GU31 5LR, UK

OR A SUBSCRIPTION CENTRE BELOW

SCIENCE