Using Science, Technology, and Society Issues to Achieve Scientific Literacy

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The often-quoted reports of the 1980s describing the condition of schools and education in the United States have prompted proposals for change in many areas of the curriculum, including science. The proposals for changing the science curriculum and the way science is taught, while taking various forms, emphasize some common and defensible characteristics. Implementing these proposals is only beginning, and the actual classroom versions, as carried out by teachers and students, may not be totally predictable. Nevertheless, any group of individuals or company wishing to influence precollege students might benefit by understanding the nature of these proposals. I will describe only those proposals that have the potential for national impact, and even those descriptions will be incomplete. Even though the proposals discussed here have similar features, they have some potentially significant differences.

Project 2061: Science for all Americans

The American Association for the Advancement of Science's (AAAS) Project 2061: Science for all Americans (1989) stresses the importance of science for all students. The first phase of the project identifies, through the involvement of many individuals from a wide variety of science education backgrounds, science instruction outcomes that are essential for students in the next century. These outcomes encompass understanding major scientific concepts, developing skills and habits of scientific thinking, integrating the sciences and integrating science with other curricula, and realizing the consequences of science and technology's interrelationships with society. While this proposal identifies specific outcomes, it also stresses that current programs cover too much material and suggests that "less is more" should be characteristic of future science outcomes. Understanding more about a few concepts is more productive for students, in their view, than is covering a great deal of information. The proposal discourages memorizing vocabulary without providing meaning for the vocabulary through background experiences. The proposal also recommends that the teacher's role be consistent with the view that meaningful learning is the responsibility of the student. Instructional models that rely heavily on information imparted to the students by the teacher have little impact. Only by involving the learner in activities that structure his or her thinking about questions, events, or phenomena will meaningful learning occur. The proposal has as its underlying goal the scientific literacy of all citizens. Preparing future scientists and engineers is a secondary outcome and is accorded much less emphasis than might be expected.

Phase II has engaged a few schools across the country in curriculum development to implement these goals. Various curriculum organizations and teaching models are anticipated as product evaluation and revision occur. Phase III will seek support from diverse sources to extend successful approaches into schools.

Scope, sequence, and coordination of secondary school science (SSC)

SSC is the proposal advanced through the National Science Teachers Association (NSTA) (1990). While the impetus for this proposal originally came from the organization's executive director, many science educators and teachers have shown interest in the proposal. With input from many individuals at widely attended meetings, the proposal has gained considerable financial support. Implementation at five sites across the country, including more than 200 California schools, is already under way. Funding sources include the National Science Foundation and the U.S. Dept. of Education.

The NSTA proposal, based on approaches to science instruction

used in Russia and other countries, calls for teaching four sciences—physics, chemistry, biology, and earth/space science—over 6 years from grades 7 through 12. The rationale is that concepts are both learned and retained to a greater degree if they are spread over a longer period. This approach necessitates a concrete approach to physics and other sciences early (grades 7 and 8), leading to a more abstract and quantitative approach to the same science later (grades 11 and 12). Spreading the disciplines over 6 years also necessitates coordinating the content of each of the four sciences at each grade level. This coordination is handled in a variety of ways at the implementation sites. The SSC proposal also abandons tracking science students to accommodate individual student abilities and aspirations—at least through grade 10. All students would take the same science classes from grades 7 through 10. Both expanded scientific literacy for more students and more students choosing scientific and engineering careers are anticipated outcomes. The essential content in each of the science disciplines is being identified by teachers and subject area specialists. The SSC proposal also stresses the importance of knowing "how we know" and "why we believe" in addition to understanding specific discipline concepts. Within the broad framework of having students 1) encounter elements of each science discipline each year (possibly each week), 2) approach concepts from the concrete to the abstract, and 3) recognize how scientific ideas attain acceptance, teacher and school participants are encouraged to reorganize curricula to fit their teaching situation.

Curriculum and instruction frameworks

The National Center for Improving Science Education (NCISE), a joint effort of Network, Inc., and the Biological Sciences Curriculum Study, is formulating a series of recommendations for science curriculum and instruction frameworks at the elementary, middle, and secondary levels (NCISE, 1990).

The proposal also includes recommendations for assessing science achievement at these levels and for developing and supporting teachers involved in science education. This project is funded by the U.S. Office of Educational Research and Improvement.

NCISE proposals encourage a curriculum structure that supports learning the major integrating concepts of science, including cause and effect, change and conservation, diversity and variation, energy and matter, evolution and equilibrium, models and theories, probability and prediction, structure and function, systems and interaction, and time and scale. These concepts are not intended to be independent study units but should link subjects, topics, and disciplines. Emphasis on scientific reasoning, such as the willingness to modify explanations and to rely on data, also is encouraged. Most importantly, students should develop skills to answer questions, make decisions, and take action. The specific context in which science is studied should relate to the world of the student and provide motivation for attaining the knowledge, skills, and attitudes identified as outcomes. The NCISE proposal further states that the curriculum should focus on depth rather than breadth.

An equally important component of the NCISE recommendation is the prescription of a teaching-learning model. The model is designed to increase the likelihood that instruction will lead to the learner's greater understanding. The elements of the teaching-learning model proposed involve inviting the learner, through an activity or other procedure, to become involved in the study topic or theme. The learner then engages in several exploratory activities that provide first-hand experience with the topic's major ideas or concepts. Students, with the help of their teachers, propose explanations or solutions to the questions or problems identified. Finally, the learner participates in addi-

tional investigations to reinforce the concepts developed earlier.

The use of technological aids for instruction, outside resources, scheduling flexibility, hands-on activities, peer teaching, and cooperative learning is emphasized, especially at the middle level of instruction. Recommended assessment includes a broad range of measures carried out over extended periods. The major goals of science instruction as well as the broader goals of education that encompass other curricula should be assessed. Rather than a grade, parents should receive a profile that reflects what the student has accomplished during a specific period. Finally, the success of any educational reform depends ultimately on the teacher. Distinctive preparation for future teachers is necessary both at the pre- and in-service levels.

Common features of reform proposals

Substantial financial support from the National Science Foundation and the U.S. Dept. of Education and the prestige of major scientific and educational organizations ensure that these proposals have a reasonable chance to make a significant impact on science education in the years ahead. At the least, schools and teachers will have the opportunity to move in new directions. A review of these proposals suggests what those directions are likely to include.

It is clear that science education likely will move from being "elitist" to more mainstream. Implementing and encouraging access to science for everyone has many implications for both curriculum choice and instructional procedures. Science educators and teachers will need to look beyond the structure of the science disciplines for ways to make connections with the student's world and interests. Perception problems relating to the rigor of science courses cannot be avoided, and arguments for necessary curriculum changes will have to be articulated well and supported by members of the scientific research community.

Restructuring courses so that boundaries are blurred between the science disciplines and between science and other curricula also will require support from the scientific community. Retraining teachers who have been prepared as single-discipline teachers and training future teachers in varied disciplines and as members of a team will be critical in integrating curriculum.

There is almost universal agreement to reduce the amount of science learned at all levels. A better understanding of fewer concepts is acceptable to most authorities. University and examination requirements can be made more consistent with this goal. Again, the scientific community must become a strong advocate for implementing the "less is more" philosophy if it is to have an impact on precollege programs.

Implementing a constructive view of learning is also widely accepted, but the lack of good models, particularly at the college and university levels, will continue to impede progress toward this goal. Because a constructive view of learning involves a much different role for the teacher, a good training model is necessary. Simply telling future teachers how to adjust their teaching style is not enough. Focusing on the learning process rather than on the teaching process certainly makes good sense. Many modes of learning must be available to students. Requiring all students to use the same learning mode (take notes, solve problems, take quizzes, etc.) may make for efficient teaching but not for efficient learning. Often students simply find ways to cope with the requirements of the course rather than to pursue the higher road that leads to understanding and competence.

Scientific literacy has been an accepted but elusive goal of science education for at least several decades. Accepting scientific literacy as the primary goal of science education may be simple enough, but accomplishing this goal demands much more serious attention than it has been given in the past. Attainment of scientific literacy by even a small proportion of secondary school graduates would be quite an accomplishment, but a more difficult goal is to encourage continued scientific literacy after formal schooling is completed. Again, the scientific community needs to recognize its responsibility to inform and involve the public in scientific decisions that relate to societal issues.

To implement these changes, many tasks have to be completed,

including identifying the important science concepts/processes, understanding the learning process, recognizing the teacher's role, and training the teacher. However, the science curriculum must first be organized to achieve the important science outcomes for all students.

It is still clear that many would prefer to maintain the discipline approach to curriculum organization. This approach ensures that each discipline is included and is not compromised by containment within other organizational patterns. The AAAS recommendations seem to favor a curriculum organization that uses themes or major concepts. Themes such as change or scale or interaction cross discipline lines and provide an effective organizer. Some of the implementation schools are using specific phenomena as organizers. Sinking and Floating, Hot Stuff (study unit titles), and the environment constitute the framework for incorporating concepts from the earth/space sciences, biology, chemistry, and physics in one SSC trial set. Others retain the discipline structure and correlate teaching the separate disciplines. In some approaches, issues in science, technology, and society (STS) provide the organizing framework for realizing the outcomes of science instruction. The issues often arise from students' school, community, or even state, national, and global concerns. Consequently, these issues provide a connection with the student's world and the medium for realizing the outcomes of science instruction, including scientific literacy.

STS issues

Realizing science objectives through investigating STS issues is an alternative being explored by some teachers and projects. Scientific literacy continues to be the emphasis of science instruction. Educated citizens that are literate in science can participate in public debates involving science and technology concerns and issues. Encouraging students to participate in issue exploration and resolution and to develop confidence in their ability to learn related science, make decisions, and take action is the most logical way to proceed. This procedure would result in relevant scientific knowledge, practical process skills, and continued participation as citizen, making scientific literacy maintenance a real possibility for many participants in such a program. Indeed, STS issues provide a context for practicing scientific skills and reasoning and for understanding the relevance, potential, and limitations of science.

STS issues are introduced into the science classroom in at least three ways, depending on teacher preparation and confidence, students' interests and capabilities, and the nature of the issue or concern chosen. Probably the easiest approach is to infuse the issue into the science curriculum either at the *time* it is most relevant or within the *topic* in which it is most relevant. For example, a local issue such as whether to restrict the use of wood stoves would best be discussed when it is being debated in the community. In contrast, a long-term concern such as global warming might be introduced when interaction of radiation with the atmosphere is studied in a physics class. With this method, the students will have studied the relevant concepts, and discussing a concern will give them a chance to apply these concepts. The concepts take on more relevance as a consequence of their immediate application.

Some teachers believe that certain units normally covered in a discipline-specific class are suitable as STS units. For example, the issue of whether to build more nuclear power plants might be used to develop concepts related to nuclear reactions and structure. The issue becomes a vehicle to teach the students outcomes of the chemistry unit. Chemistry in the Community (CHEM-COM) attempts to incorporate all concepts usually encountered in a first-year chemistry course into the study of issues closely related to these concepts. The issues are selected specifically to accomplish content understanding and involve students in both decision-making and action-taking.

In courses where content objectives are not rigidly defined or specified, teachers might involve students to a greater extent in selecting issues to be studied. The content studied would be based more on the issues chosen than on discipline-designated outcomes. Middle school students might be more interested in local and school issues, while secondary school students might study both local and global issues. Emphasis would be on understanding the relevant science concepts, technological implications, and societal impact of

the issue being investigated. Some issues could very likely be anticipated, but others would be spontaneous—the result of student questions or a local event or controversy that developed quickly.

The teacher's role would be much different from that usually envisioned. Teacher decisions regarding the appropriateness and potential of certain issues or concerns are critical. Teacher guidance during the investigation of an issue or controversy requires excellent professional judgment, science skills, and knowledge of needed resources. Teachers would need to direct and manage student enthusiasm and energy.

Resources needed by teachers

Science-discipline lobbyists and professional societies could provide resources for teachers and students to support investigations of current issues. Textbook information is usually outdated since research proceeds so rapidly, particularly in certain areas. Newspapers and popular periodicals often provide misleading descriptions of current research findings. Such misinformation must be identified through reputable and reliable resources.

The resources provided could take many forms. Sample activities and investigations leading to relevant concepts that also incorporate process skills are always needed. Fact sheets or similar references that summarize current information needed in evaluating specific issues are valuable. Bibliographies and references are useful in accessing information and locating sources of relevant information. All types of teaching aids, including computer software and videodiscs, are useful to students. Issues can be approached and investigated through various learning modes and media.

Professional societies can provide resource support to teachers as a way to encourage students and acquaint them with the profession. Many groups recognize that it is beneficial to support educational activities of young learners. The potential of students choosing a career in the profession is certainly enhanced and, just as important, the students' perception of the profession is bound to be more positive. Not to be overlooked are the student gains in understanding significant concepts that are actually a part of the discipline represented by the professional society.

Issues related to horticulture

Specific issues for ASHS to consider include, on the global level, global warming, acidrain, pesticides, and possibly solid waste disposal. These issues could have local significance also.

The following concerns regarding global warming might be explored by secondary school students and could direct resource material development by groups such as ASHS.

- Origin of fossil fuels
- Climate descriptions and variations
- Plants as users of CO₂
- Effect of climate change on plants (agriculture?)
- Plant growth (increased CO₂)
- Plant improvement
- Irrigation and humidity
- Climatic requirements
- Climate (?)—influence on diseases (?) and pests
- Plant diseases and disease control
- Photoperiodic effects (clouds)

Horticulture in the classroom

Gardening is a popular elementary school activity. It provides a context for developing horticultural concepts and the opportunity for practicing scientific process skills and the basics of reading, writing, and arithmetic. K.L. Davis states in *School and Home Gardening*

(Davis, 1918) that “the *trial of these exercises will develop much thought in the young mind*, and a greater interest will be maintained.”

The following opinions from Davis's book are chiefly from rural teachers.

- “School gardening arouses interest and may be made the means of keeping boys and girls in school.”
- “It helps in all other branches of the work.”
- “It helps the children in all branches of study.”
- “The attendance is much better.”
- “It teaches growth of plants, and farming or gardening can be learned easily. Instead of being degrading, it is elevating.”
- “It gives children a means of understanding the life that surrounds them so that life means more to the student than to a child who never realizes his or her relation to nature and his or her dependence on plant and animal life.”
- “School gardening may be correlated with all other subjects taught in the school. It is therefore a good study to introduce early in order to enrich the other work.”
- “A school garden teaches the children to become interested in rural life, and it gives them a practical interest in their other studies.”

The following aspects of elementary school gardening projects could be supported with specific resources.

- Benefits of plants
- Plant identification
- Composting
- Propagation and planting
- Growth and growth regulators
- Soil-chemical properties and organisms
- Fertilization and fruit set
- Water properties
- Pesticides - environmental effects
- Marketing, storage, and preservation
- Pruning
- Greenhouse operation
- Vegetable-crops-uses
- Nutritive values of foods

Summary

Several national organizations, supported by funds from the National Science Foundation and the U.S. Dept. of Education, have proposed significant changes in precollege science instruction. The support and assistance of professional societies and the scientific community are critical to the success of these efforts. STS issues can be used to develop science understandings and attitudes in various curricula. Providing resource materials that incorporate current understandings of science and technology concepts and the societal implications of these concepts would give teachers and students valuable assistance in implementing these proposed changes.

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