Designing Science Curricula for Future Citizens

Science education must broaden its scope to address the issues and conflicting values that are affecting how we acquire and use scientific information.

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The impact of scientific knowledge and its application through technology has spread into almost every facet of contemporary life. Science and technology have moved from the less personal and controversial realms of communications, transportation, and manufacturing to such intimate human activities as sex and childbearing and to the very conceptualization of life and death. Science teaching in schools must recognize this fundamental change.

General education should provide students with enough information about science so they can keep abreast of developments throughout their lives. The average citizen will not keep up with nuclear physics, but he or she should be able to read *Time* and *Scientific American*. Science teaching that recognizes the importance of human needs stresses not only the importance of scientific inquiry but also the rational use of technology.

This brings into question science courses that focus exclusively on the "structure of a discipline," its theories and research processes, in which only problems internal to the discipline are discussed. The emerging paradigm of science acknowledges problems external to a specific discipline—problems related to human welfare and national interests—as a part of the scientific enterprise.

Science taught in a social context must, of course, be based on valid scientific information. An understanding of the processes, concepts, and interpretive principles of science is fundamental to the intellectual extension of science to social systems.

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However, there is a growing recognition that the measure of general education in the sciences is one's ability to apply knowledge wisely in the context of intelligent thought and action. This means that at least as much effort should be given to the use of knowledge as to its acquisition.

Human problems involve a condition and an action: a choice, a plan, a judgment, a decision. Simply marshalling facts, though necessary, is not sufficient. An answer to a human problem is not a by-product of information alone. There are nearly always related questions: What are the elements of probability, risk, uncertainty, cost, and benefit? Who wins and what do they win? Who loses and what do they lose? What will do the most good? What is plausible and what is probable? What is appropriate and what is acceptable? The decisions people make in the course of living have qualitative and judgmental aspects as well as quantitative ones.

Among the conceptual skills needed for the application of scientific and technological information are applied logic, deductive and inductive reasoning, scientific problem solving, and decision making. Students need to know how to locate sources of information and how to retrieve, organize, synthesize, and evaluate knowledge. Although experience in finding answers to discipline-based laboratory problems has its values, these skills are best developed and refined by confronting issues and solving problems in personal and social contexts.

Values and Ethics in Science and Technology

Teaching science and technology in a

social context invariably raises value and ethical questions. There are disagreements about how best to use, or even whether to use, newly available scientific information and technogical developments. For example, some people oppose prenatal detection of birth defects because it may increase the number of abortions.

Conflicts also arise from differing perceptions of individual well-being and social progress. New knowledge and new technological achievements alter the range of choices people have and this, in turn, brings into question personal and social values. Although technological innovations may be of great benefit to most of society, almost always there are negative consequences for a portion of the public. In a pluralistic society, we must respect the value judgments of each member. On the other hand, such decisions must reflect the greatest good for the greatest number.

Suppose, for example, that a group of high school science students were studying pollution. While some people place a very high value on absolutely pristine air, others are more concerned with costs. If I were their teacher, I would have the students look at statistics on how the death rate goes up and cost effectiveness goes down as pollution increases. I would want them to be aware that the problem for civilization is to determine where our society should be on each of these curves. The answer cannot be determined scientifically; it is a value judgment that can be resolved only by consensus of the populace.

The goal of instruction on such topics is not to instill a particular set of values, but to get students to recognize how values enter into decision making, and that several different decisions may be consistent with validated scientific information and within the capabilities of technology. Persons of good will who are equally well informed may not make the same value judgments.

A Future Perspective

Another requirement of science in general education is that it have a future perspective. The very essence of science is the seeking of new knowledge and insights. With advancements in science and technology come changes in society and the character of our culture. What these changes mean for life and living in the future is always uncertain; the fact of change is not.

Until now, the subject matter and teaching objectives of science education have been oriented almost entirely to the past and, at best, to the present. The tone of instruction is "this is what scientists have learned," as though science were a closed book. Seldom is instruction devoted to what is not known, what might be a future direction for research on a problem, or what new technologies are likely to be spawned from research information at hand. Nor do most students leave a science course with the notion that the world they are going into will be different from the one they have been studying.

A future perspective recognizes that many social problems related to science and technology are likely to persist but under conditions different from those of today. These problems will be influenced by new discoveries in science, new technologies, new human insights, and unexpected changes in the social system. These conditions, separately or together, will influence students' options as citizens and the decisions that must be made to resolve the continuing dynamics of science, technology, and society. Within limitations, the future can be planned and directed. It need not just happen.

The Organization of Science Courses

Shifting the rationale of science teaching toward a recognition of the interactions of science, technology, and society carries with it implications for organization of the science curriculum. Problems involving population growth, personal health care and health maintenance, management of natural resources and energy, and environmental quality have scientific, technological, economic, political, and ethical aspects. Analyzing and acting on these problems requires intellectual techniques and information from several sciences, as well as from other disciplines. This suggests that some courses may need to be organized on an interdisciplinary basis.

Current discipline-centered courses have served pre-professional preparation for science and engineering students effectively in the past. They have not successfully served the needs of citizens.

There is no need for courses to be organized the same way throughout the entire school year. To be effective, each section should be structured to support the type of learning desired. One phase of a course might be organized in terms of a problem or issue, another developed in a historical context, and a third could be discipline-based.

We need not be overly concerned that organizing courses this way might decrease the amount of material "covered." For 50 years precollege science courses, though limited to the disciplines, have presented selections from those disciplines; they have not "covered" all possible content. As knowledge has grown, more and more topics have been omitted. Selection of course content will become increasingly difficult in the future, no matter what organization we choose.

Moreover, it is neither necessary nor feasible that all students learn the same content. The common learnings need to focus on three key themes:

- The processes by which scientific knowledge are developed
- The limitations of that knowledge
- Specific relations of science, technology, and society in selected problem areas, such as energy, genetics, the environment, communications, nuclear technology, and nutrition.

Cutting across these selected content areas and inseparable from them should be instructional procedures that will enable students to develop abilities necessary for survival in a complex technological society:[1]

- Reading in the natural sciences and technology
- Writing about ideas in science and its relationship to technology and society
- Reasoning—inductive and deductive, distinguishing fact from opinion, drawing conclusions from a variety of data sources
- Speaking and listening to suit different situations, using appropriate scientific and technological information
- Studying for different purposes, setting goals, locating appropriate resources, organizing and synthesizing knowledge
- Decision making, considering alternatives, identifying them where necessary.

For the future citizen, achieving these common learnings is more important than surveying the life, physical, and earth sciences. Time does not permit accomplishing both. ■

[1] College Entrance Examination Board, *The Basic Academic Competencies and the Basic Academic Curriculum* (New York: College Entrance Examination Board, 1981).