PACE

POLICY ANALYSIS FOR CALIFORNIA EDUCATION

Policy Forum No. PF85-7-3

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This paper is adapted from an address delivered at the PACE Seminar on Education Policy for a Changing California Economy, Sacramento, California, June 14, 1984.

This paper was sponsored and published by Policy Analysis for California Education, PACE. PACE is funded by the William and Flora Hewlett Foundation and directed jointly by James W. Guthrie and Michael W. Kirst. The analyses and conclusions in this paper are those of the author and are not necessarily endorsed by the Hewlett Foundation, PACE, or its directors.

EXECUTIVE SUMMARY

Recent national reports on school reform refer to science education as a critical factor in our economy and the nation's future. The need and call to reform science education are clear. However, the problem is complicated by the necessity of relating the curriculum to a changing society at the same time that science itself is undergoing a transformation.

Growth in scientific knowledge alone has been tremendous. The sheer amount of knowledge complicates efforts to keep school curriculum current with research. Science courses currently are organized to reflect the knowledge and strategies of individual scientific disciplines, and the growth in knowledge and curricular materials has become unwieldly. One widely-used, seventh grade life science textbook, for example, contains 2,500 technical terms and unfamiliar words.

Moreover, since the 1940s, the classical image and ethos of science have been changing radically. Science has become an integral part of our social, economic, and political decisionmaking processes. Furthermore, science and technology have become broadly integrated. It is no longer possible to draw clear lines between science and technology and their influences on our everyday lives.

These changes have implications for science education in the schools. School courses obtain their knowledge base and the interpretation of that base from parent disciplines. The educational justification for teaching any school subject is that it contributes to the personal development of individuals, fosters social responsibility, and benefits the quality of life. In other words, an acceptable science curriculum has cultural as well as scientific validity. Today's science curriculum falls short of this measure.

A fair degree of consensus now exists about directions for science education reform, and the national reports recognize this: (1) regard science as a core discipline, (2) teach it in a social context, (3) balance science and technology while emphasizing their relationship to society and human affairs, (4) concentrate on critical thinking skills and responsible decisionmaking, and (5) frame courses around persistent social problems like energy, the environment, and health. College courses have done this since 1970. Science education in elementary and secondary schools, however, has not followed suit.

Raising the level of scientific and technological literacy depends more on the subject matter of science curriculum than any other factor. Yet, most of the actions currently being taken to improve science education or increase the rigor of science courses serve only to reinforce a curriculum and teaching practices that gave rise to the urgent calls for reform in the first place.

What is missing in efforts to transform science education in the United States is a conceptual framework, with associated policies, that justifies the need for change and provides a map for the direction that should be taken. Such a framework would be consistent with the changing culture of science and technology, it would be likely to promote social progress and to improve the quality of life, and it would have meaning for the work and leisure lives of individuals. The work to establish a consensus around such a framework is still to be done. We need a vision to move us beyond the solutions of the national reform reports and to begin the necessary transformation of science education.

POLICY ANALYSIS FOR CALIFORNIA EDUCATION

Policy Analysis for California Education, PACE, is a university-based research center focusing on issues of state education policy and practice. PACE is located in the Schools of Education at the University of California, Berkeley and Stanford University. It is funded by the William and Flora Hewlett Foundation and directed jointly by James W. Guthrie and Michael W. Kirst.

PACE efforts center on four tasks: (1) collecting and distributing objective information about the conditions of education in California, (2) analyzing state education policy issues and the policy environment, (3) evaluating school reform implementation efforts and state education practices, and (4) facilitating communication among policymakers, researchers, and others.

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A CHANGING SOCIETY: NEW PERSPECTIVES FOR SCIENCE EDUCATION

There are periods in history when events and conditions require that we reconceptualize our institutions and determine anew their legitimacy in human and social affairs. The ideas and arguments of the past are no longer adequate for answering the questions that now bother us. Economic, political, and social events have brought about shifts in the culture and have recast the questions. Fortunately, the continuing growth of knowledge provides us with the potential for finding answers for these questions, if we do not reject the questions.

Within the last two years more than twenty national reports have been published questioning the condition of education in the United States. All the reports state that the schools of America are in need of reform and it is time for them again to justify their purposes in terms of current economic and social conditions and the foreseeable future.

Rather than taking a broadside approach to overall issues of elementary and secondary curricula, I shall use science education as an example of what must be done in a reform. Nearly all the national reports have made special reference to science education as a critical factor in the economy and the nation's future progress. The reconstruction of science education has been argued since 1970 within the scientific community. The problem is complicated by the necessity of relating the curriculum to a changing society at the same time that the culture of science itself is undergoing a transformation.

The Growth of Scientific Knowledge and the Discipline-Bound Curriculum

Science in its modern form was introduced into Western cultures about 400 years ago. Technology has been a part of man's history since the first primative used a stick to kill a rabbit and threw rocks at his enemies. Science in contrast to technology is a way of thinking that leads to the generation and validation of new knowledge through experimentation and intellectual synthesis.

The success of the enterprise, measured by the number of research reports published each year, has reached the point where 120,000 technical journals in regular print are insufficient to describe all that is new each year. Someone has calculated that a person would have to read at the rate of four million words per hour to keep up-to-date with all of science. Scientists get around this problem by specializing in ever smaller sub-fields of a discipline, by working in teams, and by using microcomputers for information retrieval and data processing. The sheer amount of knowledge is one of the problems that complicates attempts to keep school science current with research.

The original purpose of scientific research was simply to understand better the biological and physical worlds. Botanists, zoologists, chemists, physicists, and geologists among others went about this task each in their own special way. Scientists were content to live their lives in the laboratory and field, coming out on occasion only to report to their peers, through print or at professional meetings, what they had been doing and to seek verification of their findings by others. In due time, usually several decades, a selection of some of the new findings would find their way into school textbooks along with "experiments" presumed to illustrate how a discovery was made or some of its characteristics. Typically, these experiments are preprogramed to produce a "right" answer in 45 minutes or less time.

The context of the school science curriculum for the past 200 years has been discipline-bound. Courses are organized to portray the structure of an individual discipline and demonstrate its strategies of scientific inquiry. The subject matter of these courses has consisted of professional knowledge, information deemed important to know if one should ever choose a career in a scientific or engineering field. As the amount of what is known in science has increased, textbooks have become thicker and the number of technical terms students must learn has increased. One widely used seventh grade life science textbook contains 2,500 technical terms and unfamiliar words.

The Transformation of Science and Science Education

But the classical image and ethos of science have been changing radically since World War II. Science has become an integral part of our social, economic, and political decision-making processes. Science and public policy are no longer separate entities. Furthermore, in recent years science and technology have become broadly integrated into a complementary system, each dependent upon the other for new knowledge or innovation. Advances in science today are determined as much by new instrumentation, for example microcomputers, laser technology, and genetic engineering, as they are by theories and models. An overall result of these changes has led to a scientific-technological driven economy with global dimensions. It is no longer possible to draw so clear a line between what is science, what is technology, and what is economics and how each influences social progress and human affairs.

What do these changes in the nature of science mean for science education in the schools? Any school science subject obtains its knowledge base from corresponding parent disciplines. The culture of these disciplines determines how the knowledge should be interpreted. The educational justification for teaching any school subject is that it contributes to the personal development of individuals, fosters social responsibility, and benefits the quality of life. In other words, an acceptable science curriculum has cultural as well as scientific and technological validity. The science curriculum now in schools falls far short of meeting these criteria.

A number of the national reports on education recognize the importance of reconceptualizing school science programs. The National Commission on Excellence in Education refers to science as a "new basic" in schooling. The report stresses the teaching of "the social and environmental implications of scientific and technological development," "the application of scientific knowledge to everyday life," and methods of inquiry and reasoning. The report to the National Science Board entitled Educating Americans for the 21st Century states that every student should acquire the "scientific and technological knowledge needed to fulfill civic responsibilities, improve the student's own health and life and ability to cope with an increasingly technological world." The report also emphasizes the importance of developing "facility with problem-solving strategies needed" to cope adequately "as decision makers in our technological democracy." The report of the Committee on Economic Development stresses the importance of an education for "change" emphasizing life-long learning skills. The Task Force on Education for Economic Growth emphasized the need to clarify the "blurred goals" of education and to modernize the curriculum, especially in science. In America's Competitive Challenge by the Business-Higher Education Forum, the major curriculum imperatives were identified as "knowledge for action" and "information-processing skills." The Conference Board in its comprehensive report on Information Technology points out:

> There is a shift in emphasis away from learning what is known toward learning the means of finding out what one has to know when the need arises. This means learning to use information processes.

These statements are backed with the threat that if we do not modify the present curriculum to increase the intellectual level of workers, our living standard will be jeopardized and we will lose our "competitive edge" in science and technology.

Of the twenty or so reports on the condition of schooling in the United States, there is a fair degree of consensus about directions for the reform of science education.

1. Science should be regarded as a basic in the common core of elementary and secondary education, taught daily at every grade level from kindergarten through grade 10, and required of all students. The last two years of high school would be reserved for specialized science courses for students who wish to test their career interests or simply learn more science. (Thirty-five states now require two or more years of science for high school graduation.)

2. Science courses in the core should be taught in a <u>social</u> context rather than that of the special disciplines. The implementation of this recommendation would break a 200-year-old tradition of discipline-organized science courses.

3. The subject matter of science courses should include an appropriate balance of science and technology emphasizing their interrelations with each other, with society, and with human affairs. This is not a particularly new idea. In 1620 Francis Bacon wrote "...the ideal of human service is the ultimate goal of scientific effort." This is the perspective that portrays the thrust of the curriculum reform movement in science education today.

4. The intellectual skills to be emphasized in science courses should lead to the optimal utilization of knowledge. These are skills related to information processing, responsible decision making, determining the quality of knowledge, and locating sources of valid information. There would be as much attention given to skills in utilizing information as there is to learning skills. The ability to use knowledge would become the primary focus of testing programs.

5. The organization of the science curriculum should be future directed by framing courses more in terms of current and likely persistent socio-economic problems

such as creating new energy sources, preserving the natural environment, achieving optimal health and vigor for individuals, managing new technologies, among other problems. Most of these problems are national in scope and this implies that much of the science curriculum should emphasize a fund of common knowledge and shared values important to carry forward the next phase of America's social and economic evolution. If science education is to serve the common good it must have national perspective. This is in contrast to the present overemphasis on localism, individualism, and cultural diversity; after all, we are a people bound together by a concept of democracy.

The question of whether such a curriculum is possible to organize has been answered. Since 1970 nearly 1,000 colleges and universities in the United States have developed courses or programs along these lines, usually titled science/technology/society and emphasizing human values.

Shortcomings of School Reform

What then has been the response to the demands for a reform of science education in schools? By mid-1984 nearly 300 state and national task forces, commissions, and blue-ribbon panels had been formed to explore ways to foster "excellence" and "quality" in American education. There has been no lack of actions to obtain these goals. Typical of such actions have been an increase in science requirements for graduation and the development of "exit tests" to determine whether more science has been learned, the lengthening of the school day and the school year, the assignment of more homework, a demand for "tougher" textbooks and more rigorous courses, increases in college entrance science requirements, demands for better trained teachers and more computers in schools, and the rating of schools on the basis of student rank on standardized achievement tests. Just about everything that can be mandated, regulated, measured, coerced, or established by fiat has been done. But there is no way that lawmakers through legislative acts or regulations can effect a reform of science education, though they help pave the way. Raising the level of scientific and technological literacy depends more on the specific subject matter of the science curriculum than any other factor.

What has been the result of these actions for the improvement of science education? Essentially nothing; there has been no reform. Students are being taught what they have always been taught, for the same reasons, and in the same manner. The only change is that they are required to spend more time doing so and the learning is being made more difficult. Every time efforts in the past have been made to increase the rigor of science courses, the result has been that teachers simply increased the technical vocabulary to be memorized, failed more students, and were more careful to teach for the test on which their performance would be judged. Most of the actions currently being taken to improve science education serve only to reinforce a science curriculum and teaching practices that gave rise to urgent pleas for a reform in the first place, such as "more time on task," and the use of outdated achievement tests to measure gains in learning. The majority of actions taken to improve science education serve only to provide an illusion of reform.

The Missing Conceptual Framework and Policies

What is missing in efforts to transform science education in the U.S.? Certainly the many national reports have offered sufficient evidence justifying a need to improve the quality of education. There is even a respectable consensus about what needs to be done. The public press, radio, and television have been highly effective in bringing the issue to the attention of parents and other concerned persons. Today education may rank only at a secondary level on the national political agenda, but this is higher than it has been for several decades. Yet efforts to effect a curriculum reform movement have stalled.

The missing part is a conceptual framework, with associated policies, that justifies the need for change and provides a map for the direction that should be taken. This would be a framework that is consistent with the culture of science and technology, that is likely to promote social progress and improve the quality of life, and that has meaning for the work-life and leisure-life of the individual. To accomplish these results will require that we approach the problem with a forward look at our culture and the developing social scene. Little will be gained by attempting to revise yesterday's science curriculum. It would be desirable to examine its goals and subject matter if for no other reason than to answer the question: What went wrong?

Strategic plans for educational reform are of limited value unless preceded by strategic policies. The collaborative, integrative, and productive efforts needed to establish a degree of consensus on what ought to be the framework and guiding policies of science education have not yet been made. There is no lack of conference reports and recommendations on the issues, but missing are a vision and the policy conceptualizations that go beyond the meaningless collections of cliches, slogans, and opinions displayed in these reports. If our goal is an educational reform by the beginning of the 21st Century we should be aware that the senior class for that year will soon begin the first grade.