Why We Must Transform Science Education

Integrated science curriculum must reflect modern content that teaches higher-order thinking, "learning to learn" skills, and the uses of science in human affairs.

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Integrating the Curriculum

When today's students complete their schooling, many of them will be functionally illiterate, unprepared to participate in or guide our science- and technology-oriented society. This situation, though bleak, is hardly surprising. More than 200 national reports on science education have described the current curriculum as obsolete. "In a great many cases, precollege education in the past decade has been literally perpetrating a fraud on the younger generation," observed D. Allan Bromley, science adviser to President Bush (Bromley 1989).

Perspectives for changing the science curriculum are taking shape. There is agreement that the present curriculum is indefensible; that science courses must reflect the ethos of modern science and technology; that instructional goals should focus upon the welfare of individuals and societal needs; and that reform is needed to prepare students for the 21st century. Here's what we must do.

Integrate the Disciplines

Science today is characterized by some 25,000 to 30,000 research fields. Findings from these fields are reported in 70,000 journals, 29,000 of which are new since 1978. Traditional disciplines have been hybridized into such new research areas as biochemistry, bio-physics, biogeochemistry, and genetic engineering.

Science has changed in other ways. In this century, science and technology have merged to become an integrated system. When physicists discovered the laser, for example, technologists soon used it to develop tools for bloodless surgery, to create a laser disc for recording music, and to invent a device for reading barcodes on items at check-out counters in markets. In the biological sciences, findings from research in biotechnology are likely to reshape social and economic forces throughout the world in the next century.

These changes in the way modern science is organized have yet to be reflected in science courses. There is little recognition that in recent years the boundaries between the various natural sciences have become more and more blurred and major concepts more unified (Neurath et al. 1955). Greater integration of school subjects can provide a partial solution to this problem (Henry 1958).

Modernaize the Content

Another problem with today's science curriculum is its outmoded content. Traditional courses reflect the theoretical structure and historical development of discrete disciplines, such as biology, chemistry, earth science, and physics. Each course seeks to convey the structure of an isolated discipline for the sake of understanding that discipline. Courses are not in close touch with human experience. As a result, the subject matter of traditional science courses is functionally inert outside of class.

One direction for reform, therefore, is to bring modern science into the curriculum. Recent social changes have brought new dimensions to the question of what knowledge is of most worth and what its cultural context should be. The authors of A Nation at Risk, for example, recommend that science courses give attention to the "application of scientific knowledge to everyday life and to the social and environmental implications of scientific and technological development" (Gardner 1983).

Compared with traditional notions of science, modern science is driven more by societal needs than by theory. Thus research is channeled largely to human and social ends, such as finding a cure for AIDS, developing new energy sources, improving food production, developing communication systems, or determining public policy. The result is a complex of interacting relationships among science, technology, society, education, and human affairs.

This tie between science and social concerns has led some to propose the concept of developing human resources as a theme for science teaching (Carey 1990). The implication for curriculum development is a selection of knowledge from the sciences and technology related to social concerns, personal development, and the common good.

Teach Higher-Order Thinking

An additional problem with the science curriculum is its emphasis on preparing students to practice science as researchers, a central goal of precollege science education throughout its history. This model persists because precollege teachers themselves have been taught this way for generations.
With a little training in something called "the scientific method," students—including those in elementary school—are expected to be able "to think like a scientist." Yet the method portrayed is largely unknown in the scientific community. Traditional science courses have taught thinking as a professional skill of scientists, with the assumption that there is a single "scientific" method of thinking. But the tens of thousands of research fields in modern science suggest there are multiple ways of thinking about science and technology problems. Patterns of thinking shown by researchers in physics, ecology, cognition, molecular biology, and computer science, for example, differ in style and vary with the investigator.

Students of science and technology clearly need higher-order thinking skills. These skills are qualitative and related to processing and using information in ways that suggest a path for effective action. In science, such skills are needed for dealing with a whole range of social and human problems—for example, fostering the environment to enhance human survival and the quality of life. By contrast, traditional science courses confine whatever problems are dealt with to those of specific research fields.

When science knowledge is applied to human affairs, many complex issues are raised: values, ethics, probability, policy, preference, limitations of the knowledge base, trade-offs. Alternatives must be weighed, risks assessed, and evidence confirmed or refuted. To channel knowledge from the sciences and technology to human experiences, students must be able to question the validity of knowledge from these sources. They must learn to distinguish theory from dogma, probability from certainty, fact from fiction, science from myth and folklore, and the limitations of science and technology in personal and social contexts. Higher-order thinking is critical to making such distinctions.

Use Better Texts, Less Jargon

Yet another problem with the science curriculum—closely connected with the "think like a scientist" criticism—is the overload of strange words students are required to learn. They are expected to grasp the technical terms, equations, formulas, and isolated facts that scientists use to communicate with fellow researchers. In a typical science course today, students encounter three to five new terms per day—words they have never seen before, never heard pronounced, and likely will never use again after Friday's test.

Science textbooks are among our most beautifully illustrated dictionaries. Some high school texts exceed a thousand pages of information, mostly facts. But, even if students were to know all the data ever discovered in the sciences, they would still be described as functionally illiterate. Scientific literacy is more than knowing a bag of facts.

Teach for Change

The rapid transformations occurring in the sciences and technology—and in all aspects of our lives—make recognizing and dealing with change a new goal of science teaching. Science and technology are the very bastions of change, offering "endless frontiers." The pace of change in the sciences doubles the amount of new knowledge every decade. Most technology becomes obsolete within five to seven years, faster in electronic fields.

Our culture, too, has changed in ways that must be considered in reforming science teaching. The socializing forces shaping the ideals, values, and lives of young people today are not the same as those of two decades ago (Feldman and Elliott 1990). Problems of health, early pregnancy, drugs, suicide, a rampant homicide rate, the breakdown of the traditional family, and an apparent decline in motivation to learn cannot be neglected in reshaping science education.

Economic changes also deserve consideration. Since mid-century, the health of our economy and that of other developed countries has rested on our capacity to generate new knowledge, especially in the sciences and technology. Knowledge has replaced brawn, land, and other natural resources as the leading factor in determining our gross national product. Hence, our students will need to know more and work smarter than any past generation. Not surprisingly, support for an economic goal for science teaching comes primarily from business and industry (Hurd 1989).

The sum of all these changes has made "learning to learn" an imperative in science education. This perspective seeks to provide students with the capabilities to renew and sustain their education throughout life. Developing learning skills alone will not accomplish this objective, however, without a science curriculum in which subject matter is selected for its generalizability in human experiences. Traditional discipline-bound, fact-laden science courses are too narrow in scope to do this.

To change the perspective of science instruction from a historical one to a focus on "learning to learn" projects a future context. The goal is not to predict the future, however, but to use what we have learned to plan and direct the future. For example, to achieve a high quality of life, a favorable environment for human survival, sustainable sources of energy, physical and mental well-being and longevity requires planning throughout one's lifetime.
Inventing the Integrated Curriculum

Despite the turmoil over the science curriculum during the past decades, not much has happened. The changes that have been made—higher graduation requirements in science, longer school days and school years, more hands-on activities, improved testing, and more rigor—are well intentioned but have little to do with modernizing the curriculum. In fact, changes have done more to stabilize an obsolete curriculum than to provide insight and guidance for realizing a new vision of science teaching (Hurd 1984).

What has stalled the curriculum reform movement is the lack of a coherent vision of what an education in science for effective citizenship should be about, and what every citizen should know. The reform movement of the 1990s calls for an integration of school subjects: a conceptual convergence of the natural sciences, mathematics, and technology with the social and behavioral sciences and the humanities into a coherent whole. A unity of knowledge will make it possible for students to take learning from different fields of study and use it to view human problems in their fullness from several perspectives.

Breaking out of the intellectual straitjacket and nostalgia that characterize traditional science courses will not be easy. We must start from scratch. Little will be gained by simply revising and updating old subject matter, tinkering with the instructional system, modifying assessment techniques, or reorganizing institutions.

Transforming science teaching so that students graduate with scientific literacy requires that the natural and social scientists, behavioral scientists, teachers and other educators—along with representatives from the humanities and the philosophy and sociology of science—sit down together, in a spirit of good will and mutual respect, to determine what citizens should know for living and participating in our science- and technology-oriented society.

References


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