Joseph D. McInerney

Curriculum Development at the Biological Sciences Curriculum Study

By placing enduring scientific principles in a context useful to teachers and sympathetic to the prevailing educational culture, BSCS textbooks have transformed the way many students learn biology. But new challenges lie ahead.

The Biological Sciences Curriculum Study (BSCS), a nonprofit corporation, was established in 1958 to rejuvenate and restructure the tenth-grade biology curriculum. BSCS accomplished this task by first updating what Bentley Glass (1970) called "the antiquated content of the biology courses in the high schools" with more experimental, quantitative content, and second, by designing materials that promoted "the teaching of science as a

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process of investigation and inquiry, rather than simply and wholly as a body of knowledge" (Glass 1970).[1]

Those two principles of curriculum reform were reinforced by a decision to avoid a single representation of biology (Glass 1970). The result was the development of three separate textbooks: *Biological Science: A Molecular Approach* (blue version, originally published as *Biological Science: Molecules to Man*); *Biological Science: An Ecological Approach* (green version); and *Biological Science: An Inquiry Into Life* (yellow version). The books have sold more than 5.5 million copies since their commercial release in 1963. A fourth program, *Biological Science: Patterns and Processes*, developed for high school students who are unsuccessful learners, has sold more than 750,000 copies since its development in the mid-1970s. BSCS textbooks have been adapted for use in over 60 countries.

Independent analysis has shown that when compared to traditional textbooks, the BSCS basal textbooks resulted in improved student achievement, improved process and analytic skills, and improved attitudes toward science (Shymansky 1984).[2] Furthermore, BSCS programs were more effective in improving achievement, process and analytic skills, and attitudes toward science than were other major curriculumdevelopment projects of the 1960s, such as PSSC Physics, Project Physics, CHEM Study, and the Chemical Bond Approach. The BSCS has had a secondary impact on biology education in that many other high school biology textbooks follow the BSCS model.

William Mayer (1978 in press), Arnold Grobman (1969, 1984), and Glass (1970) have analyzed in detail the process used to develop the three BSCS versions. As important as the process itself, however, was the decision to make the BSCS a permanent enterprise, rather than to apply its curriculum development process only as an ephemeral palliative for the deep-seated problems in biology education.

Determining What Is Worth Knowing

The rate at which new knowledge accumulates in biology is daunting. One may, perhaps, quantify this expansion of knowledge in terms of new research articles, new journals, or new pieces of information. No one person, however, can truly comprehend the impact of the steady accumulation of information on the conceptual framework of the discipline.

Yet, curriculum developers in biology (and other disciplines, as well) must synthesize and interpret tremendous quantities of information. They must choose from an enormous body of knowledge information that conveys to students a cogent answer to Ernst Mayr's (1982) seductively simple question: "If one wanted to say a few words about modern biology, what would one say?" To attempt to answer that question in isolation from those who generate the information, or from the context of general education, guarantees the development of irrelevant materials. The objective for the curriculum developer, then, is to answer a question that parallels Mayr's, first raised by Herbert Spencer in the mid-nineteenth century, to wit: "What knowledge is of most worth?" (Spencer [1854] 1966).

In arriving at an answer to that question we consider several critical criteria.

Criterion 1: How well does the information in question illustrate the basic, enduring principles of biology? Attention to that question helps avoid what Paul Doty and Dorothy Zinberg (1972) called the "temptation of being current," that is, to incorporate into curriculum new information simply because it is new, absent of any justification for how it helps students understand major concepts. One might, in a chapter on genetics, list the human genes that have been mapped most recently to highly localized regions of specific chromosomes. For the average student, however, that is useless information unless it is discussed in the broader context of a major unifying concept such as genetic continuity (see note 1), or applied to a particular problem that has personal and social utility such as the use of gene mapping in the prenatal diagnosis of genetic disorders.

This guideline, which is important for curriculum development at the national or local level, helps developers avoid the growing tendency toward producing encyclopedic, vocabulary-laden textbooks, a trend that will likely accelerate as a result of new information and newly developed state science requirements (McInerney in press). It also requires that the developers understand thoroughly the major organizing principles of the discipline, and that they involve advisors and writers who do, as well. Although that seems obvious, biology and other disciplines are saddled with textbooks whose concentration on minutia demonstrates that the developers did not sufficiently comprehend the major precepts of the discip1ine, or consciously subordinated major principles in favor of information for its own sake.

Many well-conceptualized curriculums quickly attain state-of-the-shelf status because they fail to attend to the realities of the classroom and the backgrounds of the teachers for whom the materials are developed.

Criterion 2: Do teachers and administrators perceive the proposed materials as useful and important? Curriculum development at the national or local level is generally based on an assessment of what the target population needs. The distinction between wants and needs is critical. What science teachers want—for example, "how to" activities—may not be what they need, which may be a clearly-articulated, comprehensive biology program.

In our experience, teachers often determine utility and importance by assessing whether new materials can occupy a well-established niche in the current curriculum. BSCS, for example, has had little trouble with the implementation of *Basic Genetics: A Human Approach*, because virtually all high school biology courses devote substantial time to genetics. The major problem has been to convince teachers to abandon their traditional concentration on plant and animal genetics in favor of human examples, and to embrace pedagogical techniques such as role-playing and group discussion of ethical dilemmas, techniques foreign to the average science teacher.

Conversely, new BSCS modules from the program *Innovations: The Social Consequences of Science and Technology*, have not been as successful, despite excellent reviews in the literature (*S-STS Reporter* 1985). The modules have a sound scientific base, but they do not have an obvious curricular home because they concentrate on the political, ethical, and economic implications of rapid scientific and technological progress. The secondary science teacher must create a new niche for the materials, thereby excluding other topics, or must use this program to illustrate traditional material in new ways. The developer, therefore, must overcome the compound problem of resistance to new content and to learning new teaching strategies.

The problems of assessing the perceived utility of new materials may not be quite as severe in the case of local curriculum development, where teachers and administrators may articulate needs more clearly and the curriculum into which the materials will fit is more familiar to the developers. Nonetheless, local developers must assess carefully the teachers' perceptions of the proposed materials. That is especially important in light of research on implementation, which shows that educational innovation must have support from within the system, not be imposed from the top down (Komoski 1985).

The issue of perceived utility and importance raises the critical question of the extent to which curriculum development can promote innovation. Curriculum developers do not seek to maintain the status quo; they desire instead to promote change in the conceptualization of a discipline or in the teaching strategies used to convey a particular conceptualization. Developers must, therefore, be willing to take some risks. They live with the continuous tension between promoting innovation through new materials, and keeping those materials sufficiently recognizable to teachers to ensure their use. If BSCS, for example, were to forsake innovation in its materials, there would be no reason to maintain the organization. Conversely, if new materials were so different as to ignore the realities of the classroom, there would be no market for them. The extent to which innovation is accepted depends on the educational climate. Some BSCS programs, the versions, for example, were developed during periods of strong support for educational reform; those programs resulted in wholesale revisions in the biology curriculum. Other programs, developed during less active periods, acknowledged the need for incremental change. We believe that the educational community is on the verge of a more active period where substantive change is again possible.

Criterion 3: What is the relationship between the proposed curriculum materials and the prevailing context of general education? Just as a host of environments—from the cellular level to the level of the biosphere—influences the expression of individual genes, the framework of general education influences the development of curriculum and its ultimate expression in any given classroom. Curriculums must adapt to reflect the prevailing perceptions of the purpose of education (Boyer 1983, Goodlad 1984, Sizer 1984).

Notwithstanding the many and varied opinions on what the American educational enterprise is intended to

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accomplish, the curriculum developer must ensure that new materials reflect the broad goal of preparing students for effective citizenship in a democracy. With respect to science education, that means preparing students to comprehend the components of a rapidly changing society that depends heavily in both intellectual and practical terms on science and technology.

Early BSCS materials responded to a prevailing perception that science education should be organized on the knowledge base of the discipline and that inquiry-oriented instruction should help students to think and solve problems the way scientists do. The organizational structure for the biology curriculum was derived from the structure of the discipline itself and from the processes by which biologists conduct research. There was little concentration on the personal and societal implications of the biological sciences.

Beginning in the early 1970s, however, BSCS materials began to reflect the emerging opinion that science education should acquaint students with the ways in which rapid progress in science and technology challenge long-standing values and traditions and raise new questions of ethics. That opinion is now a working assumption for science education and for general education as well (Hurd 1986, Hickman and Kahle 1982, Graubard 1983, Bybee 1985).

The strong support for including science, technology, and society themes indicates how the perception of biology education has changed since the inception of the BSCS. This trend has also expanded the BSCS perception of inquiry. Formerly, inquiry referred exclusively to an investigation of the scientific method. New BSCS programs include in the process of inquiry an emphasis on decision making that results from the personal and societal implications of science and technology.

Lessons from 28 Years of Curriculum Development

The three criteria described above—ability of new curriculum to illustrate basic concepts, utility and importance of the information, and the relationship of the material to the goals of general education—help the BSCS staff and board of directors plan, conduct, and implement new projects. The BSCS board and staff strive to anticipate sound trends in biology and in science education and to bring these trends into the educational mainstream, often against considerable inertia. The following brief discussion presents four enduring problems that contribute to that inertia, and suggests how these problems might be resolved.

1. *Implementation.* The best curriculum material is worthless unless it is used effectively by teachers and students. Many well-conceptualized curriculums quickly attain state-of-the-shelf status because they fail to attend to the realities of the classroom and the backgrounds of the teachers for whom the materials are developed.

The intensive teacher-education institutes conducted with federal monies in the 1960s and 1970s are unlikely to occur again, particularly under the current administration. Curriculum developers must, therefore, depend on various cooperative mechanisms to introduce new materials and new teaching strategies. Among those are workshops supported by local school districts and publishers. One publisher of BSCS materials—Kendall/Hunt Publishing Company—has trained ten consultants (identified by the BSCS) to present workshops ranging from one hour to a full day on the content, philosophy, and instructional strategies of BSCS materials. A newly funded BSCS project trains leaders from school districts in the Pikes Peak region to conduct inservice seminars on the use of the microcomputer in the science classroom. New BSCS materials will include computer software and print materials to allow for districtwide coordination of implementation efforts.

2. *Funding.* Curriculum development at the national level is costly. Consultants in biology and education, writers and artists, nationwide field testing, and formative and summative evaluation of field test materials require substantial funding. Government support for curriculum development has decreased, and the Gramm-Rudman-Hollings Act ensures that the decline will continue. Yet the federal government itself calls for new curriculums in science to meet the needs of a changing society (National Science Board 1983, National Commission on Excellence 1983) as the amount of scientific knowledge continues to increase, and the implications of that knowledge for citizens in a democratic society grow more troublesome and complex.

During the last half dozen years, the BSCS has expanded its funding base to supplement funds available through competitive grants from organizations such as the National Science Foundation (NSF). Indeed, many BSCS projects are now supported by a consortium of funding organizations including government agencies, private foundations, corporations, and research societies. For example, the development and distribution of *Immunology and Human Health* was supported by NSF, the American Association of Immunologists, and the National Association of Biology Teachers. The development of a new module on genetic technology is supported by grants from the Monsanto Corporation, E. I. du Pont de Nemours & Company, Ward's Natural Science Establishment, and NSF. BSCS is currently conducting a design study for a K-6 science and health program in cooperation with the Educational Systems Business Unit of International Business Machines. A proposal to develop K-6 materials based on the design study includes support from the Gates Foundation, the Adolph Coors Foundation, NSF, and School District No. 11 in Colorado Springs.

Those developing materials for local use should attempt to establish similar funding consortia. Contributions need not be in the form of cash; many businesses will donate staff time and equipment to improve the curriculum in local schools.

3. ***Publication.*** Publishers have not supported curriculum innovation. The BSCS depends on the commercial sector to publish its materials. Increasingly, however, major publishers (many of whom are owned by conglomerates whose central concern is not education, but profit) are unwilling to risk publishing innovative programs. They prefer instead to produce books that promote the status quo and offend no one (Apple 1985, Mayer in press, McInerney in press), least of all single-issue groups such as those that oppose the teaching of evolution or anything related to sexual reproduction (Benetta 1986, Moyer 1985). These single-issue groups have convinced major publishers that innovation can be dangerous to corporate health. BSCS has, therefore, turned increasingly to smaller publishers whose commitment to educational innovation and corporate risk taking are more consistent with the BSCS mission. We hope that more such publishers will emerge.

4. *Teacher preparation.* Teachers need to be trained in the major principles of biology and must understand the process of teaching by the inquiry method. Substantial evidence (National Science Board 1983, Moore 1984, the Holmes Group 1986) reveals that most prospective secondary science teachers are not, in fact, provided that background during their undergraduate education. The BSCS, therefore, is cooperating with the American Institute of Biological Sciences, the National Association of Biology Teachers, and the American Society of Zoologists to improve the preparation of teachers.

A Process of Refinement

There are many aspects to the development of a workable curriculum. This article has addressed some of the more important components of the curriculum development process that we have evolved at the BSCS over a period of almost 30 years. We refine the process continuously through our annual interaction with numerous biologists, science educators, classroom teachers, and students.□

Author's note: I am grateful to my colleagues on the BSCS staff for their valuable assistance in the preparation of this article.

1. The BSCS steering committee identified the following themes which, taken together, became the conceptual framework for the three BSCS versions: (1) change of living things through time—evolution; (2) diversity of type and unity of pattern in living things; (3) the genetic continuity of life; (4) growth and development in the individual's life; (5) the complementarity of organism and environment; (6) the biological roots of behavior; (7) the complementarity of structure and function; (8) regulation and homeostasis—the preservation of life in the face of change; (9) science as inquiry; and (10) the intellectual history of biological concepts. An eleventh theme, the relationship between science and society, was added in 1970.

2. For purposes of analysis, Shymansky and his colleagues distinguished between "new" and "traditional" curriculums as follows: "New science curricula were defined as programs which (1) were developed after 1955; (2) emphasized the nature, structure, and processes of science; (3) integrated laboratory activities into course discussions; and (4) emphasized higher cognitive skills and an appreciation and understanding of the nature of science. Traditional science curricula were defined as courses which (1) were developed, or patterned after a program developed prior to 1955; (2) emphasized knowledge of scientific facts, laws, theories, and applications; and (3) used laboratory activities as verification exercises or secondary applications of concepts previously covered in class."□

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Joseph D. McInerney is Director, Biological Sciences Curriculum Study, The Colorado College, Colorado Springs, CO 80903.