The Evolution of a Biology Curriculum

Its Reflection of the Nature of Science

David H. Ost

David H. Ost's 25-year career in teaching includes experience at the elementary, junior high, senior high school, college and university levels. He served seven years as department chair of biology at California State Univ., Bakersfield before taking his current position as executive director of the Truman Pierce Institute, Auburn Univ., 1228 Haley Center, Auburn, AL 36849. Active in both scientific and science teacher organizations, he has just completed his second term as Council Delegate for AAAS and served as vice-president of NABT. Ost has been president of the National Association for the Education of Teachers in Science [AETS]. He holds degrees from Augsburg College [Minneapolis], the Univ. of Michigan and the Univ. of Iowa.

A major problem facing all science departments is the ambiguity of the structure of scientific knowledge. This problem tends to get lost in the day-to-day efforts of offering courses, developing specialty programs and staffing. In addition to ensuring that students develop analytic techniques, it is now expected that science programs should provide students opportunities to gain experience in applying principles to real-life situations and a chance to synthesize basic content into some type of structure reflective of personal needs.

These different expectations can conflict with the need to offer an undergraduate program that reflects the nature of science. Such conflicts are impediments to the design of biology curriculum and to offering philosophically sound instruction (Ost & George 1975). The biology faculty at California State College, Bakersfield (CSB) has been grappling with these issues for nearly two decades and offers a biology program that balances some of these issues.

Some Philosophical Issues

It is the nature of science to increase its body of knowledge and it is necessary for the undergraduate to have a sound basis of content. However, we at California State firmly believe that the student must develop the intellectual skills necessary to distinguish between data and information and to be able to process data and/or information. Our primary criterion for including content is its potential use to the student both in terms of some inherent value of the knowledge and/or as a tool for gaining additional knowledge.

In the early 1970s our response to this dichotomy of biology as process or product was to employ an inquiry approach to instruction throughout the department. We felt that students who went through our *entire* curriculum would learn most of the traditional content. The position taken was that the context in which the content and skills were learned justified the instructional approach. But, we quickly learned that specialty service courses, such as anatomy for the nursing student, were best off if taught in a traditional manner. These types of departments (nursing, etc.) believed that we ignored basic content that assuredly reappeared as questions on state board examinations. To them, the inquiry methodology seemed to shortchange their students; we didn't argue. The Department of Biology did not put up much of an argument since it is much more economical to teach a straight lecture/laboratory course.

To attain an accurate picture of some biologic phenomenon requires that each part be understood separately (analysis) and as part of the whole (synthesis).

To attain an accurate picture of some biologic phenomenon requires that each part be understood separately (analysis) and as part of the whole (synthesis). Synthesis is the combining of parts or ideas into a complex whole; it is the forming or building of something more complex from smaller parts. Peter Medawar (1977) writes

> Biology before Darwin was almost all facts . . . there is an epoch in the growth of a science during which facts accumulate faster than theories can accommodate them.

Unfortunately, much of biology is still taught as if Darwin never lived and theories have not been developed. Students, in introductory courses, frequently spend far more time learning a classification system rather than learning to classify.

The CSB biology faculty recognized that despite efforts to the contrary, the biology student still had to

do the synthesis without any significant guidance. That is, it was still the responsibility of the student to integrate the discrete concepts and the various skills (observation, data gathering, analysis, hypothesis formulation, etc.) into a working body of knowledge.

For a short time, we went to group projects. The environmental issues of the 1970s and the emphasis on environmental impact reports (EIRs) were good instructional vehicles. The comprehensiveness of the problems fostered student-faculty interaction, required students to integrate knowledge and skill, and even required a good deal of writing and formal communication. In addition, using a commonly defined problem reduced the staffing and supervision difficulties.

Unfortunately, environmental issues appealed to only a few faculty members and a select group of students. And, in a real sense, environmental problems go beyond science, involving politics and economics. Although we could, and did, justify this approach on the basis that science operates in a culture, it is not the kind of biologic problem reflected on Graduate Record Exams, entry exams for professional schools, or even for basic employment.

Biologic knowledge is tentative and all science is subject to retesting and revision. There are no immutable facts. Just as old track and athletic records are made to be broken, scientific "facts" are constantly being modified. High school biology students of the 1950s learned that the human cell contained 48 chromosomes. Several years later in their college classes they were surprised to learn that the number was "changed" to 46 and even that number may vary, depending on various circumstances. The point is that even the smallest unit of knowledge, the fact, is not immutable.

Science is never complete in its process of seeking out truth. The competitive nature of scientists and theories force a constant self-criticism within science as a whole. In every effort to validate prediction, science undergoes self-examination (Szent-Gygorgi 1964). The current work in sociobiology and the dialog concerning evolutionary theory illustrate this point. The tentative nature of science in general and biology in specific is ambiguous for most people.

Static curricula and unchanging course content mislead students and lock faculty into old ideas and ways of thinking. The challenge is to provide a stable curriculum that has the flexibility to change as the emphases in biology change.

A Modern Small College Biology Curriculum

Small college departments of biology do not have the flexibility that comes with large budgets and large staffs. Instead, more must be done by fewer and with less. Such departments cannot afford to have anyone not carrying their share of the teaching, advising, recruitment or curriculum development. The curriculum described below is the current state of more than 15 years of continuing efforts to deal with the issues described above within the constraints of a small college budget and faculty. The realities of the need for articulation with community colleges and other institutions from which students tend to transfer mandates that our introductory courses represent, somewhat, the standard of the profession. However, even at the lower division we tend to demand something different from our students.

Unfortunately, much of biology is still taught as if Darwin never lived and theories have not been developed.

Our introductory (200 level) courses focus on the basic principles of biology. These courses are designed to provide the student with a working vocabulary and some understanding of appropriate principles. Laboratory studies are generally investigative; students must write up the investigations using a format similar to scientific papers (eg. introduction, materials and methods, results, discussion and conclusion). Near the end of each course, the student must design and carry out an investigation from scratch (usually testing a hypothesis). Generally, we require a formal proposal prior to the study to ensure that the investigation is within the capability of the student as well as within the limits of our space and equipment.

The 300 level courses emphasize concepts in various subdisciplines of biology. It is at this point that the curriculum can be tailored to fit the expertise of the faculty and the needs of the student population and the geographic area served by the institution. The courses must stress concepts rather than factual content. There is no hope of covering the traditional as well as emerging content in a one-quarter course. For example, the facts and basic content of an introductory genetics course easily could result in a three-course sequence. Covering just major genetic concepts demands some selection.

The real uniqueness of our program is found in the four fourth-year biology courses. The current requirements for the major mandate that the student take one course of the 410, 411 or 412 sequence.* Although we would like to require each of the three courses, we cannot at this time, primarily because the department does not have the consistent staffing flexibility to offer all the courses regularly more than

* The reader familiar with learning theory will note the similarity of the course titles and the higher order thinking skills discussed by Bloom and others.

Biologic knowledge is tentative and all science is subject to retesting and revision. There are no immutable facts. Even the smallest unit of knowledge, the fact, is not immutable.

once a year.

Analysis of Biologic Problems (410) is offered at least twice a year with different content emphases related to faculty expertise. Areas that have served as focal points for the course include advanced ecology, renewable resources, physiologic assessment and soil ecosystems. Emphasis is placed on developing methods of analysis. Specific attention is given to the description and measurement of measuring variables, understanding the interaction of the variables and determining their relative value. An underlying theme has been the assessment of the interaction between organisms and their environment. The course offers two hours of lecture and nine hours of laboratory. This includes field investigations and use of computer assisted methods of analysis. Biology 301 is a prerequisite and prior experience with computers is highly recommended. It must be underscored that the focus of this course is *analysis.*

Application of Biologic Principles to Contemporary Problems (411) is a course designed to provide students with experience in applying basic content and concepts to solving real problems. Problem definition and delimitation are basic skills fostered in the course. The "application" of biologic principles to the solution includes an assessment of cost-benefit data, short-term and long-term consequences and general trade-offs. Courses have been offered that focused on plant pest management, virology, environmental stress on plants and insect biology. The function of this course is to provide the student insight into and experience with the *application* of known biologic principles in new problem settings.

Modeling of Biologic Systems (412) provides the student experience with both computer and noncomputer modeling techniques. Students develop skills in the formulation, development, use and testing of models describing biologic phenomena. Although the techniques are used to obtain realistic explanations of biologic problems, it is equally important that the student gain an understanding of the limitations of models. Sensitivity analysis is an important activity, in this regard, for students to use on the models. The focus of the course is the skill of modeling and not the models themselves. We believed that such a course requires considerable ability in the *synthesis* of information, data and concepts in applied situations.

A Senior Seminar course (490) serves as a capstone to the program, which provides an opportunity to develop *synthesis* skills applied to formal operational concepts in biology. The unifying theme in the course is evolutionary theory. Readings, discussions and student presentations cover topics such as evolutionary mechanisms, evolutionary theory and sociobiology, and perhaps more importantly, issues and conflicts that surround modern evolution such as punctuation, determinism and creationism.

It is important to note that each of the fourth-year courses is *not* content bound. Each can be offered with different topics or with an alternative focus to fit student interest and individual career needs as well as faculty expertise. Faculty enjoy using their scientific skills rather than spending an inordinate amount of time preparing content lectures. The students benefit from faculty who are enthusiastic and excited about their teaching!

Service Courses

The department continues to provide a good number of courses for use by students majoring in other areas (Table 2). In general these courses are designed and taught in a manner reflecting the needs of the various programs. It is somewhat ironic that the faculties of the other programs do not really care about the students' perspective of biology as a science. They prefer straight lecture courses. The ad-

Table 1. Courses in the Biology Major California State College, Bakersfield

All courses carry 5 quarter hours of credit.
200 level courses—3 hours lecture and 6 hours lab per week
300 & 400 level courses—2 hours lecture & 9 hours lab per week

210—Principles of Animal Biology*
211—Principles of Plant Biology*
212—Principles of Cellular Biology*

301—Design of Biologic Investigations*

302—Concepts of Cell Physiology
303—Concepts of Developmental Biology
304—Concepts of Genetics*
321—Concepts of Plant Diversity
322—Concepts of Animal Diversity

351—Comparative Anatomy of Vertebrates
353—Comparative Physiology of Animals
362—Plant Physiology
377—Special Topics in Biology

410—Analysis of Biologic Problems
411—Application of Biologic Principles to Contemporary Problems
412—Modeling of Biologic Systems
490—Senior Seminar*

480—Research
489—Experiential Prior Learning
496—Internship in Biology
497—Cooperative Education

(* denotes required courses)

Table 2. Service Courses Offered by the Department of Biology

All courses carry 5 quarter hours of credit unless otherwise indicated

General Education Course Offerings

100—Perspectives in Biology
110—Natural History of Plants & Animals
203—Principles of Ecology

S310—The Nature of Science and Technology and Implications for Modern Society

Service Courses for other Majors

250—Human Anatomy (lect./lab)
255—Human Physiology (lect. only)
256—Laboratory in Human Physiology
258—Biologic Aspects of Child Development (lect. only)

314—Medical Microbiology (lect./lab)
355—Human Pathophysiology (lect. only)
370—Nutrition (lect. only, 3 credits)
371—Problems in Nutrition (2 credits)
S314—Science for Elementary Teachers (disc./lab)

vantage to the biology department is that the faculty time invested in such courses is reduced because laboratory investigations are not required. More time can be devoted to the biology major.

Student Reaction

A comment needs to be made about the students. Approximately one out of six of the graduates from our program go on to graduate or professional school. These students report being very well prepared for their studies. In fact, many have written to express appreciation to individual faculty members for the inquiry-based instruction and the flexible curriculum. The remaining five-sixths of our graduates generally move into career-oriented positions with local or regional industry and government agencies. This student group reports being well trained to handle the responsibilities given them. Such information supports our belief that the curriculum and instruction fit the needs of the student population we serve.

Summary

We have found that the curriculum provides important staffing and scheduling flexibility for a relatively small department with heavy responsibilities to provide general education and specialized courses for other majors (Table 2) in addition to offering the biology major courses (Table 1). The biggest barrier to implementing the program was the work that the faculty had to do to ensure that the nature of science was reflected in the curriculum. At first, even though a course was to focus on "analysis," there was the tendency to want to stress content and to cover the material in the book. We now believe that both the curriculum and instruction fit, or at least better reflect, the nature of science.

References

Medawar, P.B. (1977). *The life science: Current ideas in biology*. London: Wildwood House.

Ost, D.H. & George, D. (1975). The contradictory faces of science. *The Science Teacher, 42*(1), 14-16.

Szent-Gygorgi, A. (1964). Teaching and the expanding knowledge. *Science, 146*, 1278-1279.