Biology Education: What Next?

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Futurists concern themselves with predicting the future and with creating the future. As biology educators we can also engage in predicting and creating our futures. In this presentation we will first examine some trends to help us predict likely future possibilities. We will also make use of some techniques of futurists to create future possibilities.

Trends

In most high schools across the nation, biology is taught in the tenth grade to fifteen-and sixteen-year-old students. Census Bureau demographers are predicting a continuous decline in the numbers of students in this age group from 4.3 million in 1976 to 3.6 million in 1984. In a short period of eight years, we will have only four students for every five we had in 1976.

College enrollments are expected to peak around 1982 at about 13.6 million students and to decline throughout the remainder of that decade. The number of students enrolled for degree credit in all types of colleges will reach a maximum of 11 million in 1980, and the subsequent modest growth will be due to increases in the numbers of students not in degree programs.

In the two-year colleges, enrollment will increase through 1985 when it will account for 31% of the students in degree programs and an even larger percentage of the non-degree enrollment. Public colleges will enroll increasing proportions of students at the expense of the private colleges. In 1960, only 60% of degree students attended public colleges; by 1985, 80% will attend public institutions.

The reasons students go to college are also changing. First, improved earning capacity no longer provides a strong incentive for attending college. Based on a 1970 report of the Carnegie Commission (Hecht and Traub 1974), lifetime earnings of a college graduate exceed those of a high school graduate by approximately $60,000—about the equivalent of the cost of college and the foregone earnings. Second, by 1980, a college education will offer less assurance of getting a job commensurate with one's educational attainment. By that time college graduates will comprise 20% of the civilian labor force; but only 15% of the jobs will require a college degree (Best 1978).

We need not limit this discussion to students pursuing degrees, for all of our educational institutions abound with students who have what *Washington Post* columnist, William Raspberry (1978b) calls "great and unrealistic expectations." He asserts that we teach skills but fail to teach young people what those skills are likely to produce in income. Many students expect to finish a vocational program and quickly land a $25,000-a-year job. A few even prefer to remain on welfare rather than to work for less than the salary they expected.

Changes in life plans will have far-reaching effects on what parts of one's life are spent in school. Some futurists believe that the linear life plan—childhood, education, and employment—is becoming obsolete. The cyclic life plan (Best 1978) suggests that people might enter the work force in the teen years, work for several years, return to school for a year or two, and continue to alternate work and school throughout a lifetime.

These trends seem to indicate that the student population will become increasingly diverse in interests and needs at the same time it is decreasing in size. We will be confronted with greater competition for a smaller number of faculty positions. Those of us who remain in teaching will be challenged by the task of serving this diverse population of students.

Curriculum Trends

As the diversity of the student population increases, so will the diversity of the curriculum. However, instead of serving up a kind of potpourri for students who want to make choices but don't know what they want as we did in the 1960s, we will be called upon to respond to the needs and interests of students many of whom *do* know what they want—or to parents who know what they want for their youngsters. "Proposition 13," "back to the basics," "open admissions," "equal opportunities for women," "the new Harvard core"—these phrases capture some of the essence of curricu-

lar trends today and set some broad limits on what may be possible in the future. Let's take a brief look at each of these trends.

Proposition 13, initiated in California, has made its way into the thinking of people in every state. The issue for educators seems to be to attempt to avoid the "meat ax" approach to budgets by looking carefully at how we use our resources and suggesting ways to increase efficiency without sacrificing quality.

"Back to the basics" may someday be remembered as the battle cry of the late 1970s. Parents are concerned that their youngster will be passed through the school system and even graduated from high school without learning to read well enough to use a newspaper or to do arithmetic well enough to balance a checkbook. Only a few small voices are suggesting that improving reasoning skills might be an important part of basic education. If the basics are to be specified, as biologists we need to be involved in that process. We need to explain that the study of biology can help students to learn how scientists reason to solve problems. We need to teach so that we do help students develop scientific reasoning abilities—even if this means we may transmit fewer facts.

The new Harvard core (*Chronicle of Higher Education,* March 6, 1978) specifies substantive course requirements in five areas, one of which is science and mathematics. It specifically excludes survey courses, possibly because they offer a smattering of facts over a broad area without delving into any aspect of the subject in sufficient depth to achieve understanding. The Harvard core also requires the study of moral and ethical problems as a part of social and philosophical analysis but fails to mention the study of ethical issues as a part of the science requirements. One would hope that such studies might be included.

Open admissions, not at Harvard, but in many other colleges, has been touted as a new opportunity for those students who dropped out or were passed through the high school. As an ideal it cannot be criticized; as a practical solution to an educational problem, it has been less than ideal. Whoever said what we call open-door really means revolving-door identified the problem. Allowing students to register for courses they are ill-prepared for results, not in providing a new opportunity for success, but in setting the students up for the most magnificent failures they have ever experienced.

Equal opportunities for women is an issue at every level of our educational system. Schools spread sexism, as NABT's past president Carter said in an editorial in *American Biology Teacher* (1978). From the stereotypes of little girls who aren't expected to do well in math to the second-class citizenship offered many women enrolled in colleges, the academic reward system is overwhelmingly biased toward male students. Futurists (Coates 1978, Fields 1977) who have concerned themselves with the problems of women assert that female college students need to prepare to enter the work force and often require child care facilities. They expect to be taken seriously and to be treated with the same respect as their male counterparts. To respond to these needs and legitimate expectations, all schools will be forced to create more equitable conditions for women faculty members and to provide situations in which these women can serve as role models for their students.

Though the quality of biological education in the future will be influenced by budget cuts, demands for developing basic competencies, and pressures from each of the many different kinds of students enrolled in our schools, I believe the major changes will come from our efforts to foster intellectual development and to deal with bioethical issues. Chickering (1975) demonstrated relationships between intellectual and moral development and made several recommendations for changes in educational processes. Most significant among these recommendations was the suggestion that educational institutions consider the intellectual and moral developmental stages of their students in determining teaching practices.

Intellectual Development

Piaget (1971), who was trained as a biologist before he began studying intellectual development, hypothesizes that experience is stored in what he calls mental structures. By the process of assimilation, new experience is integrated with what is already known. When an experience is encountered that does not fit within the existing mental structures, the learner must, through the process of accommodation, rearrange the mental structures to make the new experience meaningful. Intellectual development, then, is the result of assimilation and accommodation. As teachers, we may often want to create situations that require accommodation to facilitate development. Piaget says these situations create a disequilibrium in which the learner is forced to experience intellectual development (Gruber and Voneche 1977).

Piaget also studied the natural chronological stages of intellectual development; and, of these stages, the concrete and formal reasoning stages are of concern to us. Many students of college age have not developed the ability to engage in formal abstract reasoning, particularly in unfamiliar subject areas. For students who are at the concrete reasoning level, we could easily introduce objects to manipulate in the laboratory before we deal with abstract concepts about those objects. Even those students fully capable of formal reasoning might experience some of the excitement of investigation if they were given the opportunity to make some laboratory studies before they have received an explanation of abstract concepts. For example, we might ask our students to determine some factors that affect the growth of a plant before we overwhelm them

with an abstract discourse on photosynthesis.

Ausubel (1968), and more recently, Novak (1977), assert that meaningful learning occurs when new information is assimilated into an existing relevant aspect of an individual's knowledge structure. Furthermore, they contend that the most important single factor influencing learning is what the learners already know. Ascertain this and teach them accordingly.

Ausubel and Novak are particularly concerned with reception learning, that is learning presented to the learner rather than being independently discovered by the learner. Because so much of formal learning is reception learning, their efforts to make it meaningful are worthy of our attention. If reception learning is to be meaningful it must be internalized by the learner. The process of internalization includes the following events: (1) cataloging of information, (2) reconciling that information with existing knowledge, (3) translating the new information into a personal frame of reference, and (4) reorganizing it toward the development of more inclusive concepts. To assist the learners in this process, Novak recommends developing a cognitive hierarchy—a kind of map of concepts arranged from most inclusive to most specific. Instruction then proceeds from what the learners already know to the introduction of the broadest and most general concept. By working up the hierarchy concepts are integrated.

These brief summaries of some of the contemporary theories about learning, of course, fall far short of providing enough information for a teacher to use them in designing instruction. I have presented them to illustrate that sufficient theoretical basis now exists for us to begin to base our teaching methods on what we understand about how people learn.

One might wonder why individualization and the defining of minimum competencies have not been emphasized. These might be thought of as the methodological trends of the 60s and 70s. They will certainly continue to be used in the future but are unlikely to serve as a source of significant new directions. Furthermore, though these methods do reduce the competitiveness of the learning situation, they may also help to create the pedagogical plains that Dael Wolfle (1978) warns against in a recent *Science* editorial. He feels that a certain amount of competition and rewards for high quality performance are needed to maintain and improve the quality of educational programs. The pedagogical plainsmen are so concerned about averages that they shovel off the peaks of excellence to make plains of uniformity. What the plainsmen do not realize according to Wolfle is that "although their plains are sometimes shadowed, they are also nourished by the peaks."

Bioethics

Ethical issues permeate almost every facet of biology. Biologists can no longer afford to teach biology, do research, and train researchers and teachers in a "science-for-its-own-sake" fashion. A quick listing of some of the important research areas will illustrate this point: recombinant DNA, energy alternatives, behavior modification and psychopharmacology, nutrition and world population, prevention of cancer and circulatory diseases, genetic engineering, and the development of medical resources so costly they can be available to only a few.

The ethical questions raised by research in these areas are overwhelming. Requiring a course in ethics in the philosophy department is not sufficient; to do that might instead create to false sense of having considered the ethical issues. Biology teachers must accept the responsibility for leading their students to consider the ethical implications of biology as they consider the principles of biology.

Nevitt Sanford, in a panel discussion at the April 1978 meeting of the American Association of Higher Education, asserted that "the university has lost its standing as a moral force. It just does what anybody pays it to do." He went on to explain that after World War II, many professors became amoral consultants. Their acceptance of the notion of value-free science and ethical neutrality allowed university scholars to accept money without thinking too seriously about the implications of what they were doing. Sanford concluded by predicting that we will have to endure "a period of rampant vocationalism before we get back to looking at education as something we do for people because they are people." Perhaps Sanford is right, but I hope we will be able to help students to meet vocational needs and at the same time help them to understand the social and ethical implications of science to their vocations and to their lives.

To present bioethical issues as we teach biology, we need to know something about the pedagogical techniques that are available and the rationale behind their use. Two approaches to be considered here are Kohlberg's cognitive development approach (Kohlberg 1971, Mattox 1975, Bereiter 1978), and the values clarification process (Raths, Harmin, and Simon 1966; Bereiter 1978).

Kohlberg's methods are based on extensive research on the way moral thought develops in children. Kohlberg found that children, regardless of their culture, go through the same stages of development of moral thought. The sequence of the stages is fixed, but the time to go from one stage to the next is variable. The stages proceed from obedience based on fear of punishment (stage 1) to a pragmatic level of "I'll do something for you, and you'll do something for me" (stage 2), to conventional behavior for social approval (stage 3), and to moral behavior based on the need for social order (stage 4). Reasoning above stage 4 is rarely seen before adulthood. Stage 5 involves reasoning based on rights and responsibilities as might be used

in a court of law, and stage 6 is moral reasoning based on self-imposed ethical principles.

Instructional stategies based on Kohlberg's theory make use of discussion of ethical dilemmas with opportunities for students to consider examples of moral reasoning beyond their own level. See Mattox (1975) for examples of such dilemmas.

Values clarification is a process by which students are led to consider their beliefs in three steps. First, was a belief freely chosen after thoughtful consideration of alternatives? Second, is the individual happy with the choice and willing to affirm it publicly? Third, are the individual's actions consistent with the professed belief? (Raths, Harmin, and Simon 1966).

These techniques can be extended to deal with ethical decision-making. Kieffer (1978) describes the following steps: (1) stating the problem, (2) determining possible courses of action and the consequences of each, (3) stating the values or moral judgments involved in each course of action, (4) rank ordering the values, (5) deciding on a course of action most consistent with the values given the highest priority.

Predicting Future Possibilities

The most significant ways in which education in the future will differ from education today are: (1) that much greater emphasis will be placed on fostering intellectual development; (2) that emphasis will also be placed on using techniques for encouraging moral development and applying them to bioethical decisions; and (3) that the level of intellectual and moral development of the students will be considered in the design of instruction.

Let me conclude this discussion of trends in education with a summary of Barnes (1978) article "An Educator Looks Back From 1966." We have put behind us the belief that we can control information and have developed an open system of education that negates the prevailing view of the 1970s that we were successful if we taught our young people what our culture already knew. The high interest in training of the 1970s succumbed to renewed interest in learning as discovery in the 1980s—a good thing in Barnes's view because training deals with the known and learning with the unknown. We began to see the need to equip people to become generalists—to understand relationships and connections and to synthesize information in holistic ways. Lifelong learning has become estabished and schools have become community learning centers serving all ages on a year-round basis. The educational approach has changed from cognitive to cognitive-affective, from fragmentation of knowledge to integration of knowledge, from book-centered to multi-resource. Textbooks fell into disuse in the 1980s. We have moved from schooling to education, and as Barnes says, "education is what each of us will have when we draw our last breath."

Creating Future Possibilities

Now that we have considered some trends and made some predictions, we are ready to begin generating ideas about the future. One word of caution is in order. Too often when we begin wrestling with big problems we are inclined to succumb to "big picture paralysis" (Raspberry 1978a). If we paint the picture big enough we can paint ourselves right out of it. We are going to paint big pictures, but we will use techniques for creating a future that keep us very much in the picture.

Collea (1975) describes a process of brainstorming to stimulate creativity and encourage the formulation of alternatives. The steps in the process are as follows: (1) create an image of the future; (2) select a goal; (3) identify forces that will help or hinder achieving the goals; (4) consider alternative actions to alter forces; (5) initiate action.

Working in groups of no more than seven, the group takes an imaginary leap one-to-five years into the future. Group members will describe what they see happening and tell why it pleases them to see the progress that has been made since the present. All imaginary observation will be stated in the present tense and the group recorder lists them without the group taking time to discuss them or judge their quality.

Now the group chooses one image of the future that they agree is important to realize. They then restate the image as a goal to be achieved. Next the group lists all of the forces that will help them to reach their goal and all of the forces that will hinder them. They assess the strength of each of the forces and may use a graphic representation—long lines for strong forces, short lines for weak forces and arrows pointing toward or away from the goal.

Next the group uses brainstorming to search for alternatives. They try to strengthen the strong positive forces and weaken the strong negative forces. Collea indicates that the greatest effect usually comes from diminishing the strongest negative force that the group can do anything about.

After determining what kinds of actions are possible, the group selects one or more actions to pursue. They ask themselves: Who besides ourselves do we need to work on this? Where do we begin? How do we begin? Who will do what to get us started?

In selecting which of the images of the future is most important to achieve, a feasibility-desirability matrix (Evans 1977) might be used. The matrix consists of a 5 x 5 grid with feasibility on one axis and desirability along the other. Highly feasible and desirable goals would be plotted in the top right corner; unfeasible and undesirable goals would be plotted in the lower left corner of the grid.

Summary

As biology educators we can make

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Advisory Board, a surprising omission given the significance of environmental matters, particularly at the time the project was initiated.

Given its uniqueness as a single comprehensive reference source on bioethics, the excellent readability of the essays (the mark of a decidedly firm editorial hand), the authoritative quality of the articles, and its pedagogical richness owing to the various resource aids, this set of volumes should not be absent from any college or university library, from any high school worth its salt, and from any public library deserving of that appellation. It should remain vital and viable for some years to come.

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predictions about the future by using our knowledge of general trends, our understanding of curriculum issues, and our expertise in applying appropriate teaching methods to educational problems. We can participate in creating our own futures by applying the techniques of futurists to situations that affect us. The future is ours—how nearly it satisfies our expectations is at least partly to be determined by our own efforts.

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