# The Crisis in Biology Education

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## Redaktionele verantwoording

*Bijgaand artikel uit 'The American Biology Teacher', volume 44, september 1982, werd door de redaktie belangrijk genoeg gevonden om in verkorte vorm in dit tijdschrift te worden opgenomen. Daarvoor golden de volgende overwegingen:*

- *Het onderwijs in natuurwetenschappen is in Nederland sterk beïnvloed door Amerikaanse curricula.*
- *Het artikel geeft een samenvatting van zeer omvangrijk evaluatie-onderzoek omtrent Amerikaanse leerplanontwikkelingsprojekten.*
- *Het artikel wijst op de grote problemen die met de innovatie van nieuwe curricula samenhangen en waarschuwt daarmee tegen al te groot optimisme dienaangaande.*
- *Alhoewel geschreven voor het biologieonderwijs is het artikel ook grotendeels van toepassing op natuur- en scheikundeonderwijs.*
- *Het lijkt nuttig en interessant ons af te vragen in hoeverre de beschreven problemen ook gelden voor de situatie in ons land.*

## 1. Introduction

Each historical period is unique, but some are more significant than others in affecting the future. The current time for biology education is indeed unique and appears to be one of those significant points where the future of the discipline is endangered. There is urgency in the problems that confront us - urgency that causes many to describe the current situation as one of crisis. But, a crisis can be a turning point. Action can be taken to use this turning point to benefit the profession. Or, lack of action can result in a downward spiral and further deterioration. A greater understanding of our problems - perhaps the reasons for them - can assist us in controlling change and revitalizing biological education.

This article is divided into three major sections. The first is a review of biology education for the past 32 years. The 1950 starting point is not an arbitrary one; the changes that followed were far more significant than any that occurred during the preceding three decades. During these three decades (1920-50) biology became a common offering in American secondary schools. The second section of the article deals with the results of one of the most costly and elaborate educational assessment programs ever undertaken in the U.S. The assessment began in 1976 as a response to major criticism and concern for the great public support of science education which followed the launching of the Sovjet Sputnik in 1957. The third section is an attempt to identify solutions to problems and to plan for the year 2000. The historical perspective from the first part and the data provided by the assessments in the second part are used in seeking solutions for the remaining years of this century.

## 2. Recent history of biology education

*Pre-Sputnik, 1950-56.* By 1950, biology was well established as a standard course in the curriculum of almost every American high school. It had become the 'tenth year' science course and was commonly used by students to complete graduation requirements. In some schools, it became a required course. In most schools biology was taught with few laboratories and as a recitation-type course where the textbook found extensive use. Like other courses during the war years (1940s and early '50s), biology began to focus on applications of basic science - often in areas such as health, disease, nutrition, safety, substance abuse, and human systems. Such emphasis tended to increase the gap between the biology known by researchers and the biology students were experiencing in schools. This dichotomy was often identified as a problem by professional biologists. Both high school and beginning college courses focused upon the taxonomy of plants and animals; in addition, major attention centered on the cell-tissue-organ levels. Course content, textbook, and teaching style were all quite consistent within schools and class sections.

*The 'Golden' Years, 1956-70.* In 1957 the Soviets launched a satellite into space, an event that was to affect science education dramatically. Sputnik was perceived as an indication of Soviet scientific-technological superiority. The public suddenly demanded improved science education to soothe a wounded national pride. 'Inferior' science education in America was acknowledged and funds for improving the situation were appropriated.

In the case of biology education, major funding occurred after the formation of the

Biological Sciences Curriculum Study (BSCS) in 1959 by the American Institute of Biological Sciences, a scientific society with a total membership of 85,000 biologists. The first BSCS educational materials were prepared during the summer of 1960 and field tested in schools during the 1960-61 academic year.

The BSCS organization, activities, and materials represent well the tenor of the so-called Golden Years. The public was supportive; the scientific community directed the improvement efforts and the production, field testing, and publication of materials became a standard sequence of events. BSCS became a non-profit corporation complete with building, permanent staff, and a Board of Directors. BSCS materials were disseminated and are used throughout the world. BSCS programs were the most successful of all the national science curriculum efforts - at its zenith BSCS materials were in use in over one-half of the biology classrooms in the U.S.

*Time of Disillusionment, 1970-76.* The 1970s ushered in a new set of problems. We had apparently 'caught up to the Russians' with several spectacular space exploits, including landing the first man on the moon, though we found ourselves in a very unpopular war in Vietnam. Further, there were serious societal problems around us, most with no apparent solution and many with apparent ties to science and technology. Social unrest, conflict, a war in a faraway corner of the globe, political problems, environmental concerns, and a loss of faith in science, education, and other central institutions of our society created a climate of protest, questioning, and retrenchment - called for the return to former times, traditional values, earlier priorities.

Science education was attacked on several fronts. At the national level, there was a serious challenge to the appropriateness of NSF science curriculum projects. Funds for all active curriculum development projects were delayed while national commissions studied their aims, quality, appropriateness, and importance. After some reduction in funding and change of direction, the active curriculum projects of the 1970s were allowed to continue. However, none has achieved the recognition, the use, the support of major publishers, and the successes of the earlier science curriculum efforts (Ross 1979; Knott 1980; Hughes 1976; Burkman 1981).

There was great public concern about inclusion of such sensitive areas as sex, reproduction, social issues, and evolution in the last national curriculum efforts in science; there were suggestions that the curriculum efforts departed from traditional science topics and even that they included pornography. What a shift in public support! In the late 1950s support for science education was unquestioned; it was even related to patriotism. In the 1970s science curriculum efforts were being criticized as a cause of breakdown of the family, lower morals, youthful 'liberalism'.

The 'Time of Disillusionment' resulted both in curtailment of curriculum development and suspension of teacher education programs.

*Time of Assessment, 1976-82.* Serious challenges often result in calls for more information to meet such challenges. With the suspension of teacher training activities and a decline in support for further curriculum developments in 1976, it was a propitious time for initiating major studies to discern the impact of past efforts and to identify present needs. Three major status studies were funded by NSF. One, by Helgeson et al, at Ohio State University, was designed to review all the 1955-75 research literature in the areas of science, mathematics, and social studies education (Helgeson, Blosser, and Howe 1977). A second study surveyed teachers, supervisors, administrators, and others to identify their perceptions of K-12 programs in the same three curriculum areas. This study was conducted by Iris Weiss, Research Triangle Institute (Weiss 1978). A third study was conducted by Stake and Easly, University of Illinois (Stake and Easley 1978). It consisted of eleven case studies of school systems representing different sizes, emphases, and geographic areas. These three large studies used different methodologies, but they all were attempts at determining the current condition of American science education.

In 1977 Norris Harms, University of Colorado, proposed Project Synthesis (Harms 1977). Harms had been a central staff member with the Third Assessment of Science for the National Assessment of Educational Progress (NAEP 1977). The Third Assessment included an extensive battery of affective test items which provided rich information concerning the general effects of teachers, programs, and schools upon student learning in science. Harms proposed using the NAEP information as well as that from the three NSF status studies to synthesize a model of the actual state of science teaching in five focal areas: biology, physical science, inquiry, science/technology/society, and elementary science. Harms, an evaluation expert, also proposed developing a 'Desired State' model for science education based upon another set of reports and literature. Once such a desired state condition was developed and the actual state conditions verified, it was possible to identify specific discrepancies between the two conditions. An analysis of these discrepancies resulted in specific recommendations for future action - action designed to reduce the differences between what is and what should be the condition of science education.

The information about science education, amassed during the past five years has kwown no equal, at least in terms of numbers researchers involved and the public support to accomplish the effort. Unfortunately 1982 appears to be another turning point for assessment activities. The Reagan administration has placed a very low priority on science education.

## 3. Results of 1977-82 assessments

*The NSF Status Studies*. Although there have been over 5,000 pages of data produced during the past few years focusing on the current assessment of American science education, the most extensive reports have been the three status studies which cost several million dollars and produced over 2,000 pages of information. With such thorough studies and with so much information, it is dangerous to generalize, but the following are suggested as major outcomes of these studies: Biology in the school program can be characterized by one word - textbooks. The biology textbook not only determines the content, but the order, the examples, and the applications of that content. These, in turn, directly control the teaching strategy. Nearly 90% of teachers use a textbook 90% of the time. Teachers make few curricular decisions about their classroom biology programs. The teacher's major involvement is in the initial choice of the textbook - apparently the most important decision made in establishing the content and activities for a given course. Teachers appear to have 'faith' in a textbook; they lament, 'if only the right one could be found' (Stake and Easley 1978, p. 13-2). They also feel that selecting a new text is a significant curriculum reform. Interestingly, there are relatively few titles in use in most biology classrooms in the U.S., regardless of the pride in local control and the choice of textbook. Helgeson, Blosser and Howe (1977) report that over 80% of all biology courses can be described by the content of three textbooks; over 40% use holt's Modern Biology with about another 40% evenly divided between the BSCS 'Yellow' and 'Green' version.

A closer look at biology textbooks reveals some important generalizations. Typical textbooks emphasize new words or concepts, often as many as 30 on a single page. Such words are frequently italicized or set apart; often they are included in questions at the end of chapters; they are the favorite focus for quizzes and examinations. Hurd et al.(1981) reveal that a typical middle/junior high school science textbook includes 2,500 new words, nearly double the number required for a person at the same age attempting to learn a foreign language.

NSF studies reveal that classical didactic teaching characterizes most classrooms. Teaching science as inquiry, a goal stated often during the 1960s, is rarely observed. High school biology is usually a survey of the discipline of biology wherein teachers tend to emphasize the textbook information with corresponding emphasis on terminology and definitions. When laboratories are used, they tend to be demonstrations of information already presented or exercises used merely to break the monotomy of recitation/discussion (Yager and Stodghill 1979).

The NSF Status Studies also revealed great dependence upon defining all science in terms of the specific disciplines per se. Biology is presented in a way known to biologists. Sureley the structure of BSCS courses was developed around the unifying themes of the discipline. There have been some attempts to develop new courses, often minicourses, in the area of environmental problems, societal issues, marine biology, and other biological specialities. Nonetheless, biology is presented in the elementary school as topics characteristic to the discipline; in the middle/junior high school the life science course taken by one-third all students includes the traditional topics which characterize biology; the same basis topics of biology appear in virtually every textbook for the tenth-grade course (the course that as many as 80% of high school graduates complete). Biology, as it appears in the school program, is pure in the sense that there are few applications, little attention to current issues, no focus on personal needs of students, and little attention to career awareness (Harms and Yager 1981; Yager, Hofstein and Lunetta 1981).

*Project Synthesis.* Several means of organization were used in the Project Synthesis research effort (Harms and Kahle 1981; Harms and Yager 1981). One was a set of Goal Clusters - the four areas where agreement had been reached concerning important functions for a science program. The Goal Clusters used throughout the study included:

1. *Personal Needs.* Science education should prepare individuals to use science to improve their own lives and to cope with an increasingly technological world.
2. *Societal Issues.* Science education should produce informed citizens prepared to deal responsibly with science-related societal issues.
3. *Academic Preparation.* Science education should allow students likely to pursue science academically as well as professionally to acquire the academic knowledge appropriate for their needs.
4. *Career Education/Awareness.* Science education should give all students an awareness of the nature and scope of a wide variety of science and technology-related careers open to students of varying aptitudes and interests.

It is apparent that the only goal area that received attention by teachers and by the curriculum is in the area of academic preparation. Science teachers seem concerned only with teaching biology as something important for future studies. Biology too often seems important because teachers emphasize its importance in an academic sense - as a means for advancing up the academic ladder. Project Synthesis also employed 'Critical Elements' as another set of organizers (Harms and Yager 1981; Yager 1982a). Major Critical Elements included goals, curriculum, instruction, evaluation, and teachers. It was possible to examine the data used in the prospective synthesis - that designed to describe a Desired State for biology education. It was possible to use the NSF status studies and the NAEP data to define an Actual State condition. This analysis produced notable differences in each of the five Critical Element categories in the area of biology (table 1).

*Accomplishments and Needs.* The NSTA effort (NSTA 1978) paralleled the NSF assessments which resulted in the Status Studies, the review of the studies by nine professional groups, the Project Synthesis effort, and similar ones in mathematics and social science. The 309-page analysis of the Accomplishments and Needs study was completed at the end of 1980 (Yager 1980a). Some of the specific accomplishments in science education during the preceding two decades were identified as:

1. Major involvement of the scientific community in defining the disciplines of science, in interpreting discoveries that are important as preparation for future living, and in participating as a part of curriculum development teams;
2. New views of science education that include philosophical, historical, sociological, technological and humanistic dimensions; recognition that these new views are as valid as organizers for learning experiences as are content and process schemes;
3. National concern for and interest in better science experiences for America's youth; renewed interest in science for all people;
4. Devèlopment of new materials which can be adapted to local situations; new instructional strategies with model materials to implement them;
5 Massive efforts to affect science curricula and teacher inservice programs;
6. Excellent preparatory sequences to enable students to prepare for advanced careers in science and technology;
7. Improved materials and facilities for appropriate science instruction.

The science education leadership (including elementary teachers, secondary teachers, supervisors, teacher educators, and researchers) also identified major needs for future years. After gathering information from 500 leaders in science education, seven general needs were identified:

1. A new conceptualization of science education as a discipline;
2. Inservice programs to assist professionals with implementing programs consistent with new goals;
3. Continued curriculum development to assure models for implementing new philosophy and new teaching strategies;
4. New programs for assessing all aspects of instruction and learning to provide information for planned changes and improvements;

Table 1: Project Synthesis Comparison of 'Critical Elements' in Biology Education

| Desired state | Actual state |
|---|---|
| *Goals* | |
| 1. Human adaptation and alternative futures emphasized. | 1. Minimal consideration given to human adaptive capacities. |
| 2. Biosocial problems and issues as goals | 2. Marginal emphasis on biosocial goals. |
| 3. Inquiry processes unique to biological disciplines. | 3. Inquiry skills characteristic of a generalized model of science. |
| 4. Decisionmaking involving biological knowledge in biosocial contexts. | 4. Uncovering a correct answer to discipline-bound problems. |
| 5. Career awareness an integral part of learning. | 5. Minimal attention to careers; historical personages highlighted. |
| 6. Value, ethical and moral consideration of biosocial problems and issues | 6. Value-free interpretations of discipline-bound problems. |
| *Curriculum* | |
| 7. Curriculum is problem-centered, flexible, and culturally as well as biologically valid. | 7. Curriculum is textbook-centered, inflexible; only biological validity is considered. |
| 8. Humankind central. | 8. Humankind incidental. |
| 9. Multifaceted including local and community relevance. | 9. Textbook controlled, local relevance fortuitous. |
| 10. Use of the natural environment, community resources, and the students themselves as foci of study. | 10. Contrived materials, kits, and classroom-bound resources; use of sub-human species as foci of study. |
| 11. Biological information is in the context of the student as a biological organism in a cultural/social environment. | 11. Biological information is in the context of the logic and structure of the discipline. |
| *Instruction* | |
| 12. Individualized and personalized recognizing student diversity. | 12. Group instruction geared for the average student and directed by the organization of the texthook. |
| 13. Cooperative work on problems or issues. | 13. Some group work, primarily in laboratory. |
| 14. Methodology based on current information and research in developmental psychology involving cognitive, affective, experiential and maturational studies. | 14. Weak psychological basis for instruction in the sciences, behavioristic orientation. |
| *Evaluation* | |
| 15. Testing and evaluation stress the use of biological knowledge to interpret personal and social problems and issues. | 15. Replication of assigned information. |
| 16. Student evaluation is based on growth in rational decisionmaking. | 16. Stating 'correct' solutions to preplanned problems. |
| *Teachers* | |
| 17. Requires a change in perceptions (philosophy, rationale belief system) of biology teaching to include a commitment to human welfare and progress. | 17. Philosophical perceptions not evident in practice, beyond a commitment to biology as a science. |
| 18. Philosophical position influences all aspects of curriculum and teaching practices. | 18. Curriculum and teaching practices largely atheoretical and routine. |

5. New cooperative enterprises involving all segments of government, industry and community groups as well as persons from all levels of the professional science education community;
6. New support systems, including personnel, learning centers and communication links, to encourage change and professional growth;
7. New philosophical bases for research in order to test the validity of new conceptualizations and new directions.

The analysis concludes with a discussion of areas of agreement that indicate results of our years of assessment in science education. These include:

1. Emphasis upon science for academic preparation has been a major focus of the past. However major concern for science as a means of encouraging and resolving current societal problems, as a means for attending to the personal needs of students and as a means of approaching greater awareness of career potential in science, technology, and related fields suggest goals that may be far more important than the traditional goal of academic preparation for future courses.
2. Teachers are central in realizing past accomplishments, in planning local programs, and in making the difference with learners. Curriculum is seen as a form of support for teachers - not something that will constrict and/or direct them. The necessity for improving teacher education programs (both preservice and inservice) is viewed as a critical need and one where there is greatest agreement concerning the need across the profession.
3. Some of the past assumptions regarding science teaching are being questioned. These include:
   a. the importance of the laboratory - (a redefinition of laboratory in terms of position in the program is occurring);
   b. the appropriateness of inquiry as a focus;
   c. the 'discipline' organization for secondary courses;
   d. a two-dimensional view of science (i.e. content, and process) as accurate and/or complete;
   e. a focus upon science that is at the 'cutting edge' of researchers (science that is useful in the lives of learners is in evidence);
   f. the necessity of science as a precursor for study at the next academic level;
   g. the appropriateness of all learners learning the major ideas and the unique processes that professional scientists know and use; and
   h. the more science content preparation that a teacher experiences, the better the teacher.

4. Continued questioning assessment, evaluation and specific new attempts with goals, curriculum, teaching strategies and support materials and personnel are important as a means for stimulating improvements and for solving many immediate problems. This basic 'spirit of science' must be used to a greater degree in science education.
5. There is an urgency concerning the current status of science education in the United States. There is general agreement that science education must act in a concerned fashion in order that educational and social problems might be confronted and resolved.

*Other Analysis*. The volume 'What Research Says to the Science Teacher (Yager 1982b) includes a review of problem solving and its importance in teaching, a review of our knowledge of the effects of instruction on learning, a review of developmental psychology (Piaget) and science teaching, and a review of research concerning creativity. The volume identifies several dimensions of science education - many not often considered in school programs and by teachers currently.

One important section of Volume 4 deals with attentiveness to science. Persons defined as 'attentive' to science have three characteristics: 1) they express interest in science; 2) they possess knowledge about science; and 3) they pursue information to maintain both interest and knowledge. Some very interesting findings emerge:

1. There is no growth in interest in science across the years students are enrolled in the secondary school;
2. Fewer than half of high school graduates express any interest in science (only 30% of non-college students);
3. Interest in technology is significantly greater for all students than in science per se;
4. Knowledge of basic science concepts (four examples used) is very low: 40% have knowledge of amoeba and DNA, 25% molecules; and 20% organic chemistry;
5. There is no growth in knowledge of basic science concepts studied across the four years students spend in a secondary school;
6. Very few high school students pursue additional information concerning science (10% of non-college students and 25% of college-bound students);
7. Fewer than 10% of the students enrolled in secondary schools can be considered 'attentive' in science;
8. Presence in school and participation in science does little to promote attentiveness.

There is little evidence that school science prepares students for college and/or for life.

## 4. Seeking Solutions, 1982-2000

The remaining years of the 20th century must be spent seeking solutions to the problems in biology education. Never have we known so much nor have the solutions seemed more obvious. Nonetheless, there are *major forces* that would lead us to ignore what we have learned from the assessments of the past five years. Conceptualizing a new framework, a new rationale for science education, is much more difficult and time consuming than merely using conventional correctives and tried procedures from the past.

There are some who would have us begin with the same correctives we tried in 1957. The National Research Council Report, for example, calls for just such action (NSF 1979). Many are content to call for more financial support, presumably to do again many of the things we did during the '60s (Renner and Yager 1980). There are those who would blame our current crisis upon a decline in standards, a relaxation of graduation requirements, changes in college entrance requirements, antagonism for science on the part of school administrators and counselors, and less public commitment to science and the funds required for a truly effective program. Too few take time to analyze and question the appropriateness of current programs, materials, goals, and instruction. They demand instead that someone should declare traditional programs and practices as good, important and required. With such pronouncements they assume that the current crisis would be ameliorated. Too many biology teachers remain enamored with the professional biologist. The scientific community is assumed to be in the best position to define biology, to provide information regarding the most recent research results, to establish the legitimacy of the biology being taught.

Recommendations of the 'back-to-biologists-as-Messiah' group are cosmetic and designed to preserve the science that was developed two decades ago. Clearly, solutions that do not go beyond support for past practices are not solutions at all and only result in further deterioration of biology teaching.

At the national level, others are calling for changes in national, policies as a solution to our current crisis. Such policies would be advanced by major professional societies or by NSF. Such policy statements would outline new approaches to science, new curriculum efforts, new teacher education models. However, during the past 25 years, outside groups, national leaders, and prestigious persons have 'handed down' new policies and programs for the masses to follow. Such actions and such solutions may have been appropriate in the past, but now ignore the vast amount of information available from our years of assessment.

Still, the calls for new policy statements about the importance of school science are many and loud. Some national leaders have returned to the tactics used in the late 1950s to proclaim the inferiority of U.S. schools and curricula when compared with those in the Soviet Union, Japan, and West Germany. Many of those reports are popular for meetings of science educators and for articles in education journals (Burdman 1980). Many proclaim loudly about the importance of science in schools; they want national policies established to force uptodate and 'pure' science on more students. These leaders are remembering fondly the Golden Years. But, times have changed and society has turned its attention to 'the basics', and a weakening economy.

Science educators concerned that science is frequently omitted from public calls for a return to the basicsfeel that science *is* basic to our current society. However, they fail to note that most of the science that is being taught is not related to the problems that exist in today's society. There is a mismatch between the science taught and that needed. One major finding from Project Synthesis and the Analysis of Current Accomplishment and Needs in Science Education is the need for a new rationale - a new purpose. Such a statement of purpose could affect policies as well as practices in schools. Instead of beginning at the practice or the policy level, we need to begin at the purpose level. We need not wait for the government to act or for any agency such as NSF to make a pronouncement concerning new goals for science education. Some indicators of new directions have already been described (Bybee, 1979a, 1979b; Hurd et al., 1981; Harms and Yager 1981). Indeed, the prospective synthesis which produced the Desired State condition for biology may be a significant starting point. At this point it is important to take a scholarly look at information that has been amassed and to take the next step - action.

As we work toward solutions for a new century, we must remember that such a search is a part of the solution. Science education, like science, must be everchanging. All solutions must be viewed as tentative ones - exemplifying the self-correcting feature of the scientific enterprise. The immediate future for biology education is full of challenges as we emerge with solutions for the current crisis. It is important to remember, however, that real solutions must begin with a re-definition of the major goals of our discipline. Such a redefinition is the first vital step in easing the current crisis in biology and preventing future crises before they occur.

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