# Biology, STS & the Next Steps in Program Design & Curriculum Development

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In all science programs that have been identified as "exemplary" in the National Science Teachers Association (NSTA) Search for Excellence program there was an overt effort by science teachers to help students develop into scientifically literate citizens. (i.e. persons who have the skills of critical thinking, who can make reasoned judgments and who understand that the society of the future will be increasingly technological in function and driven by science.) Perhaps this is not unexpected since the Project Synthesis goal clusters were accepted by NSTA as appropriate when criteria were developed for its Search for Excellence effort. In all, 30 biology programs were selected in the various searches conducted during the 1982–89 interval. The NSTA goal clusters (from Project Synthesis) include:

1. **Science for Meeting Personal Needs.** Science education should prepare individuals to use science for improving their own lives and for coping with an increasingly technological world.
2. **Science for Resolving Current Societal Issues.** Science education should produce informed citizens prepared to deal responsibly with science-related societal issues.
3. **Science for Assisting with Career Choices.** 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.
4. **Science for Preparing for Further Study.** Science education should allow students who are likely to pursue science academically as well as professionally to acquire the academic knowledge appropriate for their needs (Harms & Yager 1981).

The Project Synthesis research team found that typical courses, textbooks and teachers ignored the first three goal areas while focusing exclusively on the fourth. Science/Technology/Society (STS) efforts in the U.S. have become more common since emphasis was placed on such programs developed as a result of Project Synthesis and two national searches for exemplary STS programs by NSTA.

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NSTA has offered the following definition of STS:

> *STS is the term applied to the latest effort to provide a real world context for the study of science and for the pursuit of science itself. It is a term that elevates science education rhetoric to a position beyond curriculum and the ensuing debate about scope and sequence of basic concepts and process skills. STS includes the whole spectrum of critical incidents in the education process, including goals, curriculum, instructional strategies, evaluation and teacher preparation/performance. One can not "do" STS by adding certain topics and lessons to the curriculum, course outline or textbook. Students must be involved with goal setting, with planning procedures, with locating information and with evaluating them all. Basic to STS efforts is the production of an informed citizenry capable of making crucial decisions about current problems and taking personal actions as a result of these decisions. STS means focusing upon current issues and attempts at their resolution as the best way of preparing people for current and future citizenship roles. This means identifying local, regional, national and international problems with students; planning for individual and group activities which address them; and moving to actions designed to resolve the issues investigated. Students are involved in the total process; they are not recipients of whatever a pre-determined curriculum or the teacher dictates. There are no concepts and/or processes unique to STS. Instead, STS provides a setting and a reason for considering basic science and technology concepts and processes. It means determining ways that these basic ideas and skills can be seen as useful. STS means focusing on real-world problems instead of starting with concepts and processes which teachers and curriculum developers argue in terms of usefulness to students (NSTA in press).*

Degenaar (1988) has argued that it is the responsibility of the school to teach skills that will enable students to access information on any subject that is intellectually engaging. In the broadest sense, the exemplary STS programs reflect the approach advocated by Degenaar. In fact, the programs appear to be most successful where traditional curricula fall short—that is in providing students opportunities to *synthesize* discrete bits of information and to *generalize* isolated concepts into a meaningful personal experience. The next step in the evolution of such curricula is to project as well as explore issues that can be integrated into curricula which are typically identified as "biology." To this end school programs should be more interdisciplinary, and teachers should have the license and be encouraged to extend instruction and curricula beyond the boundaries and constraints imposed by academic disciplines. A strategy for using comprehensive problems is suggested as an instructional device to address general topics under the renewed rubric of life science.

## The Nature of Science & Biology

A fundamental quality of science is "free inquiry," i.e. the freedom of science to study whatever is of interest, to question any authority or to follow any line of scholarship. In a free society it is believed that ideas and concepts should be judged by reason and rationality. Barber points out, "The modern world thinks the rule of reason more important than the rule of custom or ritual" (1952, p. 96). However, the typical high school biology curriculum is more custom and ritual than reason and rationality. Although the majority of students are *not* destined to become future biologists, biology programs are designed as if all students needed classical biological content rather than an understanding of life science concepts gained through rational problem solving and reasoning.

It may be a natural rule that all authority figures, whether they are politicians, religious experts, curricular experts or professional biologists, should be questioned. Biology teachers who question what typical teachers and standard textbooks include as course guides for courses called biology soon see the fallacy of such boundaries for where they lead their students and for most overt reasons. Emphasis on critical thinking and questioning by some of the most creative biology teachers reflects the recognition that there are values at the very heart of science which in turn may well be a major value of society which supports science. J. D. Bernal suggests, "The full social use of science comes only when the proletariat, the class that had been called into existence by industry, itself (controls the system)" (1952, p. 33). Once a public is free of question, a society will change. In such an environment rigid political conditions are forced open and rational thought can become the basis for establishing individual equality.

Few of the major questions concerning modern society, current scholarship or ongoing science fit neatly into compartmentalized academic disciplines. Efforts to address questions generated from issues such as poverty, economic growth, energy or something as important as the meaning of life are constrained by definition of an academic discipline. Nowhere is this more true than in biology. Hunger, kinship, life, society, substance abuse, application of ethics and values and the definition of life are but a few areas which students should be able to study through biological perspective but because the topics do not fit neatly into the nature of traditional biology and associated curricula, the student is generally deprived of the opportunity.

For many persons, their memory of biology includes dissecting frogs, memorizing vocabulary and a frustration that came with trying to understand complex diagrams. Such perceptions are the result of the student's (and frequently the teacher's) confusion of the symbols used in science and with the knowledge of science. "Parts" courses—parts of the cell, parts of the microscope, parts of the leaf, parts of the brain, parts of whatever—neither do justice to the nature of biology nor do they benefit the student.

## The Constraints of Biology Curricula

The origin and growth of science are a function of the human mind; they do not exist outside the realm of the mind. Therefore, the factors that influence the mind—teaching, curriculum, choice of content—have a direct effect on *how* science is sensed and perceived. The culture of teaching influences the student's lifelong perception of science and this in turn influences the culture at large. The *type* of knowledge that is part of the educational process and *how* it is transmitted to the next generation determine the direction of the culture and the future of science.

In a modern society, the rapid specialization in science, the advance of technology and the influence of industry contribute to the widening of the gap between the nature of knowledge in educational curricula and the ability of the individual to access and use the knowledge. Subdisciplines of biochemistry, biophysics, biotechnology, sociobiology, biostatistics, psychobiology and the like, reflect the increasing trend towards specialization in terms of content, in technical skills and in modes or forms of inquiry. General knowledge, data and information that can serve as the basis for socially-oriented decision making are exponentially increasing. However, the potential to develop skills and knowledge necessary to access specialized knowledge and information remain external to the structures of classical biology and other school subjects/disciplines. A short example will illustrate the point.

> Worldwide population dynamics have been a target of science and technology for some time, probably since Malthus. On the one hand, science and technology foster the growth of populations by improving agricultural techniques and food preservation. Yet, famine and hunger have not been reduced. As a result of science and technology unrelated to the study of population dynamics, the impact of epidemics and disease has been reduced through improved public health treatment.
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> In an effort to control the resulting population growth, science and technology have been encouraged, with

considerable success, to research the control of birth rates. However, the resulting knowledge has been challenged by individuals who reflect value systems that are far more provincial than the broader problems of worldwide overpopulation, hunger and famine.

Science operates within the context of a culture, but as a cultural tool it directly or indirectly has impact on all individuals. Current members of the public may identify science with the quality of life (usually measured in the accumulation of materials), or as a threat to their ways of life (when morals and values are challenged). These trite levels of understanding should have been unacceptable to us for our children, but maybe we can do something for our grandchildren. Unless curricula are changed, the adult citizens of the future will not fully appreciate the interrelatedness of science, technology and society. Neither will the individual citizen have the ability to define problems and gain decision-making skills to help them address issues such as biodiversity, global warming, problems of waste disposal and others.

A large hiatus exists between the kind of science typical in instructional settings and the type of science value to the individual and to the broader society. Curricula designed to transmit a knowledge base of the traditional discipline are constraining. The student does not learn how to transfer the principles of biology to problems external to the discipline. Furthermore, it is difficult to recognize a modern philosophy of science or of life which is part and parcel of traditional biology courses limited to discipline-based knowledge. The primary reason is that science, as a driving force of modern industrialized nations, is no longer a strong philosophy of life. The strength of a philosophy or ideology is measured by the extent to which it is found in the people. Monod suggests that science is the only viable constitutive norm for society (1972), and, if there is *not* to be social darkness, science must become *dominant* philosophy (1971).

It can be argued, however, that biology courses do teach a limiting form of ideology by implying that all science must take place in the laboratory, by stressing singular *correct* answers and by emphasizing that a prerequisite to doing anything with science is the mastery of a highly complex body. Furthermore, it is through rationality and the rule of reason that the equality of the individual is established. Fostering science as a habit of mind requires the reduction of authority and the removal of curricular constraints if the freedom to question is to be nurtured and the individual equality is to be fostered.

It is well known that schools are vehicles for maintaining a dependent public and preparing individuals to adhere to a specific way of life. Persons who cannot solve problems require a service-providing workforce, so specialized that their skills have little generalizability. Such a population is easily regulated. Through this philosophy of life, it is easy to perpetuate the illusion that materialism and the accumulation of things are the measure of happiness.

## Life Science Goals

The crux of the argument is that courses labeled "biology" have both implicit and explicit constraints forced upon them. The constraints take two different forms:

A. Educational constraints include:
   1. Artificially prescribed content required by formally adopted curricular frameworks
   2. Questionable content known to be included in standardized tests mandated for students
   3. The archaic content standards of formal teacher training programs which usually require preparation in the standard academic disciplines.

B. Professional & personal constraints include:
   1. The proclamations of concerned professional biologists who, in defending the integrity of formal biology, prescribe limits to what can be included in a course "ordained" as biology
   2. The self-concept of teachers assigned to teaching biology including:
      a. Their personal understanding of the nature of biology as science
      b. The extent to which each teacher views him/herself as biologists and defenders of their beliefs about what biology should include
      c. The dependence upon textbooks, curriculum guides and the like as definitions of biology.

An underlying goal of biology instruction must be to prepare the students to be active citizens who have the correct values, appropriate knowledge and necessary skills to make decisions that would benefit both man and environment. If citizens are expected to make decisions on matters that cross the boundaries of the knowledge base of biology, then it behooves educators (not just biologists) to prepare the individuals.

However, if class time is to be used to foster the processes of science, to provide practice with appropriate skills and to nurture the correct values, then the number and kinds of facts will have to be reduced. Almost all facts have an intrinsic interest to someone; however, not all facts have generalized value to society. In a recent report on biological health sciences of the American Association for the Advancement of Science, this issue is addressed:

*From the multiple biological facts known to scientists and the images of reality they convey, it is necessary to select those that best serve society's needs, as well as the needs of the average individual* (Clark 1989, p. 1).

Facts that are included in high school curricula should serve society's needs and not simply be used to reinforce the classically accepted knowledge of the discipline. At the risk of being criticized for being too general and chastised for proposing a model that cannot be quantitatively evaluated, it is suggested that one strategy would be to approach science instruction in general, and biology teaching specifically, through a coherent "worldview." There are a number of worldviews that are worthy of being included in the school curricula. Table 1 provides a brief description of four. They are provided in the most encompassing language to illustrate their conceptual power in terms of the interrelationship of biological knowledge with society.

It should be obvious to the reader that the content, intellectual processes and experiences reflected in a worldview approach to biology range beyond the typical boundaries of the discipline. This is the very reason that the rubric "life science" should be used in place of "biology." Some of the material inherent in the worldview may not be entirely appropriate for lesser sophisticated students or conservative communities. Nevertheless, it should be apparent that a program structured in this manner provides the teacher a broad choice of topics deemed appropriate for his/her students and provides the student a much more comprehensive range of experiences.

Students deserve the opportunities to analyze and synthesize information concerning the relationship of biological concepts to society. Instead of studying only the mechanics and physiology of reproduction, values and behavior could be appropriately included. Instead of trying to master only the biochemistry of DNA and genetic engineering techniques, the future design of the human species could be approached. Further, it is argued that individuals who are provided an education of this type will be able to integrate typically isolated biological content into meaningful conceptual relationships.

Unfortunately, when a course is listed as "life science" the typical teacher conceives of it as little more than a less rigorous, or "watered-down biology" offering; without some special assistance, a life science teacher will think only biology and to some extent health! How then is it possible to address the substance and processes associated with the interaction of biology with society through a "life science" format? One proven way is the use of real comprehensive problem-solving (RCPS). The strategy emphasizes the development of intellectual skills, construction of personal cross-disciplinary knowledge,

Table 1. Selected worldviews appropriate for life science.

A. **Evolution, based on geologic, morphologic, biochemical and other scientific evidence, is the single unifying conceptual scheme of life science.** Among the major interdisciplinary principles that can be addressed through this worldview are:

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| 1. Structure/function | 5. Nature/environment |
| 2. Time/change | 6. Brain/mind |
| 3. Diversity/similarity | 7. Variability/stability |
| 4. Nature/nurture | 8. Culture/population. |

B. **The human as a biologic organism consists of a complex of systems, is responsive to population dynamics and has the knowledge and skills that can affect its own destiny.** Among the life science concepts that relate to this worldview are:
   1. The classical biologic areas of cells, organs, systems, of physical environments, genetics and reproduction
   2. Knowledge of physical, mental and public health, and technologies related to each
   3. Alternative ways of knowing, thinking and affecting change.

C. **The dynamics of social change include conflict and competition, and unless checked include the potential for humans to cause irreversible harm.** Dilemmas that are addressed through this worldview include the:
   1. Intertwining of political and economic organizations with belief systems and power structures
   2. Role of governments in directing and moderating change while competing in world social and economic systems
   3. Effects of technologies and technologic competition in shaping human behavior, social values and the quality of life.

D. **No species, including our own, possesses a purpose beyond the imperative created by its genetic history.** Among the major concepts addressed through this view include awareness of the:
   1. Human organism as a biological, social/cultural and technological species with a unique capacity for learning
   2. Interactive elements of the environment at all stages of the human life cycle from conception to death
   3. Relationships of the development of human potential and free will to knowledge of biologic controls
   4. Role of values, belief and cultural structures as enabling mechanisms for the brain and subsequent social behavior.

and the application of scientific and technologic inquiry processes.

## Real Comprehensive Problem-Solving

Problem solving and related skills have long been of concern to education planners and curriculum specialists. In recent times, this concern is being paralleled by a sincere desire by many members of the educational community to come to grips with problems that face humanity. Twenty years ago it was argued that society is a very primitive problem solver:

> *Our capacity to create new problems as rapidly as we solve the old has implications for the kind of society we shall have to design. We need a society . . . ready to improvise solutions to problems it won't recognize until tomorrow* (Gardner 1969, p. 30).

It is doubtful that anyone ever improves problem-solving abilities without engaging in problem solving. Problem solving is a search for real alternative solutions. The experience nurtures willingness on the part of the student to accept decisions based on the *best* available data. Sensing a problem is a natural intellectual activity, but students need practice in delimiting, clarifying and refining problems. Skills such as critical thinking, question development and recognizing personal limitations in dealing with issues can be developed through practice. Given time, problem-solving experiences will result in a unique self-confidence, as students begin to believe that they can solve, resolve or otherwise optimize solutions to real problems. Such optimism would be healthy in the 21st century citizenry.

Classical science laboratory activities are generally designed to have only one acceptable or correct solution. It is doubtful that students in such classes explore alternative solutions to problems or develop an appreciation of optimization when they are consistently taught to seek the "right answer." An exemplary learning environment must nurture the student's capability to generalize what they learn in the classroom to real problems in life. Optimization and other social skills are easy to foster in RCPS curricula.

Real problems do exist in specialized discipline-based science but they are not truly comprehensive. For example, the determination of the molecular weight of a compound could be a "real" problem for a student of chemistry. Such a problem would not normally be confronted in the day-to-day activities of the typical citizen or even the student of biology who is required to take a course in chemistry. For our purposes, a problem is considered *real* when the individual is able to identify it as a problem. A problem is considered *comprehensive* when its solution requires more than simple knowledge from within the discipline. The problem must be of a nature and scope for which a solution can be developed within the students' abilities. Addressing problems that transcend the limiting scope of traditional disciplines is a prime educational opportunity.

If a problem is real to students, a solution as well as the educational process will have meaning. If the problem is real and comprehensive, the learning experiences will provide opportunities to use skills, concepts and processes from a variety of knowledge and experiences in interdisciplinary settings. In addition to the integration of separate bases of knowledge, the integration of the cognitive, affective and even psychomotor domains can occur in ways that are not normally possible in traditional instruction. This, then, is real comprehensive problem solving (Ost 1975).

Real problems must have a basis in the environment of the student in terms of geography, experience or knowledge (Webb & Ost 1978). Only such problems and solutions are authentic and likely to be of type and interest to the student. Problems are real if the individual "feels" the problem, has the motivation to pursue a solution and fits the level of sophistication of most students. These starter ques-

Table 2. Starter questions for real comprehensive problem-solving activities.

**A. Primary/Elementary Grades**
1. How can we:
   a. Improve the traffic flow pattern of our school?
   b. Increase the safety of a crosswalk?
   c. Improve the appearance of our school?
   d. Better store our ___ (supplies, books, etc.) to increase the efficient use of our classroom?
   e. Determine the best product (for a purpose) to purchase?
2. Given a specific situation or condition such as:
   a. John has contracted ___ (measles, chicken pox, etc.); How can we best protect ourselves from getting ___?
   b. Having small animals in the classroom; "How could we construct a classroom zoo?"
   c. Doing something for a parent or member of the family; "How can we decide on growing a plant that we could give as a present?"

**B. Secondary Grades**
1. How can we:
   a. Improve the facilities of ___ (lunch, counseling, recreational, etc.) ___ (area, school, etc.)?
   b. Determine the best product (for a specific purpose) to purchase?
   c. Determine public (school, community, etc.) opinion regarding ___ (local issue)?
2. Given a specific situation or condition such as:
   a. An excessive amount of food is found in the garbage (i.e. school lunch room); "What is the basis of the problem?"
   b. A proposed plan for ___ (roads, parks, zoning, etc.); "What are implications for the area and are the assumptions valid?"
   c. The release of a major study, article (i.e. world health, ecology, population, etc.); "How does ___ (community, area, etc.) compare (student gathered statistics or other data)?"

**C. Post-Secondary Courses**
1. What are the issues surrounding ___ (hunger, population, environments, etc.) and what is the level of understanding held by members of ___ (community, university, public-at-large, etc.)?
2. Given a particular situation (proposed road, construction, or other development project, etc.), develop an environmental impact/analysis report.

tions are examples of what teachers have used. Teachers must develop challenges or questions that are responsive to their respective student needs and community context. Delimiting or refining the scope of the problem in terms of the abilities of the students and available resources is critical.

The response to the sample questions will necessitate the collection and analysis of data. It is a primary goal of real comprehensive problem-solving to stimulate decision-making strategies that use a data base constructed by the students. The framework within which the data are assembled must reflect the level of sophistication of the student.

Instructional challenges, placed in the context of "life science," will generate or raise issues related to society's values and beliefs. As students wrestle with real life science problems, it is not unusual to have to examine their personal beliefs. Healthy confrontations concerning beliefs are in themselves real problems and can be dealt with through RCPS. For example, Robinson has used real problems to stir "the consciences of the entire school community, and from here to try to reach out more widely" (1989, p. 16). In all of the NSTA STS Exemplary Programs, a concern for values, beliefs and associated ethics is expressed (Penick & Meinhard-Pellens 1984).

Belief systems affect the sensitivity students have for problems. Since such problems are *not* of a type which lend themselves to simple empirical analyses and conclusions, the solutions proposed by students must be optimized. Students who have developed an awareness of their beliefs as they optimize solutions are on better intellectual ground to support what they conclude. Further, they are aware of the extent to which the solution is based on subjective rather than objective data.

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