Joseph R. Karpinski

A middle school class studies marine life during a field trip to a wildlife preserve maintained by an electric service company.

The K-12 curriculum should develop understanding of the interrelatedness of science, technology, and society.

Toward New Meaning for School Science

ROBERT E. YAGER

There has been a complete turn-around of support for science education since 1976. New demands for excellence appear everywhere; new funds are available from the National Science Foundation, industry, the states, the National Institute of Education, the Department of Education, and a variety of other government agencies and private foundations. Few question the need for excellence; few doubt that achieving excellence will require major funding.

The times are exciting yet caution is warranted. The problems that have captured the attention of politicians and the public may only be symptoms of more serious problems that are not being addressed. If that is the case, there may be little financial support for resolving the major factors of the current crisis and too much for masking the symptoms. A review of specific studies conducted during the past few years suggests the depth of the problem.

Recent Assessments of School Science

In 1976 the National Science Foundation (NSF) funded three massive status studies in response to public demands for halting support for curriculum development and teacher education projects. When these studies became available two years later (Helgeson and others, 1977; Stake and Easley, 1978; Weiss, 1978), NSF awarded separate contracts to nine professional organizations to read the 2,000 pages of information and report their significance (NSF, 1979). NSF also awarded three large research grants to conduct synthesis studies in mathematics (Osborne, 1977), social studies (SPAN, 1980), and science (Harms and Kahl, 1981). In addition, it created a new program called Research in Science Education (RISE), which marked NSF's first move into research in the discipline of science education *per se*. Several RISE studies were reported in NSTA's "What Research Says to the Science Teacher" monograph series (Yager, 1982). Another RISE project (Hurd and others, 1981) focused on middle and junior high school science.

The National Science Teachers Association (NSTA), the largest society in the world dedicated to science education, also initiated a major status study. In 1978 it published a working paper on the accomplishments and needs during the preceding two decades of public support; in 1980 its research committee completed a major analysis of the 1978 paper (NSTA, 1978; Yager, 1980).

P.F. Brandwein (1981), a respected teacher, researcher, lecturer, author, and editor, published his own assessment of the current situation and analysis of the immediate past. His report adds insights and suggests new directions.

Collectively, these studies provide a rich information base—one that should be used as new paths are charted. The following is a summary of their findings in five areas.

Curriculum. The existing science curriculum focuses on the traditional disciplines of biology, chemistry, physics, and earth science, and is controlled by the textbook. Relatively few science texts are used across the K–12 spectrum: three at each grade level cover all the science that over two–thirds of all students learn in school. These textbooks emphasize content in a discipline context, stressing the concepts and words unique to science. The vocabulary of science at a given grade level is often greater than the vocabulary students must learn when taking a foreign language. In general, school science closely mirrors the science that teachers experienced in their own college courses, and is appropriate only for the few students who aspire to (and even fewer who attain) careers as professional scientists and engineers.

Instruction. Teachers tend to follow the textbook closely and use it as their primary tool of instruction. There is no evidence that students ever learn science by direct experience. They rarely experiment on their own; most so–called "laboratories" are verification exercises. Students seldom carry out an experiment without the text, teacher, or both having already related "what is supposed to happen." Teachers tend to present science via lectures with question–and–answer techniques; few are aware of any instructional strategies other than direct teaching. And most instruction is whole–group, geared to the average student.

Evaluation. Evaluation centers on recall of specific information that students encounter in textbooks, lectures, or other class activities. Typical questions emphasize the meaning of words and concepts; some activities at the higher grade levels require mathematical problem solving. In such instances, emphasis is invariably on stating "correct" solutions to pre–planned problems. There is little evidence that students are ever tested for their ability to use information or do anything other than acquire knowledge.

Teachers. Many teachers once aspired to careers in science and engineering, not teaching. Few are aware of research into learning, yet most want to improve their subject matter preparation. Fewer have been involved with inservice programs, largely because of the decline in NSF funds for such activities. In addition, science teachers as a group are aging swiftly.

Elementary School Science. Science at the elementary level has special problems:

> The typical elementary science experience of most students is at best very limited. Science is usually taught at the end of the day, if there is time, by a teacher who has little interest, experience, or training to teach science. Although some limited equipment is available, it usually remains unused. The lesson will probably come from a textbook selected by a committee of teachers at the school or from teacher–prepared worksheets. It will consist of reading and memorizing some science facts related to a concept too abstract to be well understood by the student but selected because it is "in the book" (Harms and Yager, 1981).

Science Education and Its Results on Students

If college entrance examinations are accurate indicators of learning, students are learning less. Scores have continued to decline as public concerns have intensified, but the reason for this is not clear. After all, the basic content of science, the curriculum sequence, teaching styles, and modes of evaluation have been extremely uniform across the years.

Studies of secondary school (and college) students and their science experiences have been most revealing (Miller, Suchner, and Voelker, 1980; Voelker, 1982). Although the investigators studied only four basic concepts, they found no growth in concept mastery over the secondary school years and, further, that many factors other than school science were affecting learning.

Miller and Voelker were interested in what makes students attentive to science and technology—that is, why some students are interested in and informed about science and technology and know how to further that knowledge. Ninety percent of high school graduates in the U.S. are not attentive to science and technology, nor is there any evidence to suggest that requiring more science (as currently conceived) would make them more attentive.

The affective items in the Third Assessment of Science by the National Assessment of Educational Progress (NAEP, 1978) provide other information about the results of science instruction in schools. This information has been updated by recent investigators (Hueftle and others, 1983; Rakow, 1983; Yager and Bonnstetter, 1983;

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"The place of science and technology in affecting society—and of society affecting the progress of science and technology—provides a context for science and an important vehicle for approaching goal areas."

Yager and Penick, 1983; Yager and Yager, 1983). Generally, science teachers, especially at the secondary level, are perceived as "knowing" science and as "answer-givers." Students like science less and regard it as less exciting the longer they are in school. Only 10 percent are scientifically literate ("attentive" to science) by the time they graduate.

When the results of standard curricula and traditional instruction are so unsuccessful, it seems especially inappropriate for public leaders to call for greater requirements in science and to demand more rigor in the classroom.

The Rationale for School Science

The NSF-supported Project Synthesis research may be the most definitive of the assessments made in the past seven years (Harms and Kahl, 1981). One important aspect of this study was the identification of four goal areas for school science:

1. Science for meeting the personal needs of students in their everyday lives.
2. Science for helping students resolve current societal issues.
3. Science for assisting students in becoming aware of potential careers in today's world.
4. Science for preparing students for further study.

Although some teachers give lip service to a variety of goals (Yager and Stodghill, 1979), in practice most consider only academic goals (Stake and Easley, 1978; Harms and Yager, 1981). The almost uniform focus (and justification) for science instruction is its value as preparation for further formal study of science—which reduces the importance of the study of science for most people. Fewer students will elect to continue taking science courses if the sole purpose is additional study. Most students do not continue with college study; most will not graduate from college; and the majority of those who do will not complete a major in science or technology. The existing focus for school science is self-defeating. It seems to be a means of disillusioning the majority—the majority that is the citizenry of the future.

There is also a major problem with the definition of science education. Many science teachers and others define science as that content which is traditionally studied in a class called "science." Such a view ignores the essential ingredients of science as a basic enterprise of the human species. The science traditionally studied in schools tends to be the content that scientists have discovered/developed/discerned. It is regarded as a given—much like spelling, or arithmetic, or rules of grammar.

In reality, science has three ingredients. It is, first of all, an *exploration* of the universe. Unfortunately, the typical school discourages curiosity and exploration of the natural world and, hence, the first feature of real science—the of developing the ability to improve one's skills for exploring nature.

The second ingredient of science is the attempt to explain events and objects encountered during exploration. The formation of such *explanations* is essential, yet it too is discouraged in most school curricula, especially in traditional science programs. Because teachers simply do not ask for student explanations, students have no chance to improve themselves by offering better explanations. Again, it seems that science education is alien to the basic nature of science.

The third feature of science is the *testing of explanations*. Students must be encouraged to develop increasingly better skills while devising and carrying out tests on their own ideas. But, alas, the school rarely encourages or even allows students to devise their own experiments.

Resolving the current crisis in science education will mean focusing on goals other than academic preparation. It will require a constant reminder of these basic ingredients of science.

Science/Technology/Society: A New Curriculum Focus

The National Science Teachers Association has proclaimed that the primary focus of school science for the 1980s should be on the relationship between science and society (NSTA, 1982):

> The goal of science education during the 1980s is to develop scientifically literate individuals who understand how science, technology, and society influence one another and who are able to use this knowledge in their everyday decision-making. The scientifically literate person has a substantial knowledge base of facts, concepts, conceptual networks, and process skills which enable the individual to continue to learn and think logically. This individual both appreciates the value of science and technology in society and understands their limitations.

The place of science and technology in affecting society—and of society affecting the progress of science and technology—provides a context for science and an important vehicle for approaching goal areas. Technology was eliminated from the science programs of the 60s as national curriculum developers concentrated on identifying unifying themes (that is, the conceptual frameworks, big ideas, and basic structure) of the various disciplines to use as course and curriculum organizers. They spent much time building strong lines of delineation between science and technology. By deepening this line and broadening the gap between science and technology, they robbed relevance and real meaning from the school science program.

In many respects, technology remains the unknown in a science/technology/society perspective—one of the major organizers within Project Synthesis, and NSF-supported effort for identifying the ideal state of science education and contrasting it with actual conditions. Project Synthesis accepted a rather broad definition of technology, which includes both "hard" and "soft" technology. Hard technology encompasses all hardware, ranging from the first crude weapons and tools of primitive man to the most sophisticated computer. Soft technology includes the systems involved in the development and use of technological devices, as well as the systems involved in solving problems in industry and society at large, including behavior modification. Low-level tech-

nology is the work of semi-skilled technicians: wiring a lamp, changing a tire, or changing a washer in a faucet.

The traffic control system in a community, for instance, involves all three technologies. The lights, timing mechanisms, machines that stripe the roads, and signs and surfaces are all hard technologies. The system designed to control the traffic—laws, timing sequences, maintenance schedules, procedures for analyzing and evaluating the system—are all soft technologies. And changing burned-out lights, installing traffic lights, or striping roads are all low-level technologies. The impact of the entire traffic control system on individuals and society is an example of the science/technology/society interface.

Project Synthesis identified eight areas of concern within that interface. They include energy, population, human engineering, environmental quality, use of natural resources, national defense and space, sociology of science, and the effects of technological development.

In 1982, NSTA initiated a program called Search for Excellence in Science Education (SESE), which used the ideal conditions developed in Project Synthesis as its criteria for excellence. These criteria (curricular and instructional goals) were consistent with NSTA's position and are categorized according to the four major divisions of school science programs. These goals focus on science in a social setting, science for application in students' daily lives, science affecting contemporary issues, and science and potential careers. The science/technology/society (S/T/S) focus in all standard disciplines of science and across the K–12 curriculum suggests the extent of this new approach to science education.

NSTA's Search for Excellence in Science Education selected 175 programs for special recognition. The Project Synthesis teams then narrowed this number to 50 national exemplars, about ten in each of the four science divisions. Thirteen programs were identified as exemplars of the science/technology/society focus. These programs do more than meet academic requirements for science; they involve all students in real science.

The Science/Technology/Society Domain

Project Synthesis, a major NSF-supported effort for identifying the ideal in science instruction and contrasting it with actual conditions, identified science/technology/society as a major new organizer. Science education programs, which prepare individuals to use science to improve their own lives and cope with an increasingly technological world, should provide students with:

- **An understanding of energy problems from a personal perspective**
- **An understanding of their role in population dynamics**
- **An understanding of the emerging problems in the field of human engineering**
- **An understanding of the various aspects of environmental quality and that those aspects may differ in priority from person to person**
- **An understanding of the various aspects of using the earth's natural resources**
- **An understanding of the various accomplishments of space research and national defense programs**
- **An understanding of the sociology of science**
- **An understanding of the effects of hard and soft technology on individuals and society in general**
- **The background necessary for taking responsible action on energy-related issues confronting society**
- **The background necessary to understand and react to problems associated with population dynamics**
- **The background necessary to develop insight into the emerging work field of human engineering and its impact on society**
- **The background necessary to recognize the variations in acceptable environmental quality in their communities, states, and nation, as well as to maintain or improve them**
- **The background necessary to recognize the societal problems involved in finding, using, and conserving natural resources**
- **The background necessary to react to the problems and potential benefits to society of the national defense and space programs**
- **An understanding of the sociological effects of science and technology**
- **An understanding of the impact of technological developments on society, in order to make reasonable and responsible decisions.**

Features of Exemplary Science Programs

Study of the NSTA exemplary programs suggests new directions and provide new meaning. These include:

1. *A focus on social problems and issues.* Science cannot be separated from the society that spawns it. It was a mistake trying to make science into an enterprise free of humans, free of societal issues, and free of the real environment of life. For many, science has meaning only when it is presented in a real setting.

2. *Practice with decision-making strategies.* Everyone uses information as evidence to reach decisions—making decisions about daily living as well as decisions about the future of society. Without practice in using information for making decisions, students are left with the feeling that science is unimportant and without use.

3. *Concern for career awareness.* In a technological/scientific society, the careers related to science and technology are central. A good science education for all must create awareness of such opportunities for a lifetime of work. This does not mean a focus on careers only as top-rate scientists and engineers.

4. *Local and community relevance.* Science must be community-based; it must have meaning for students in their own environments. Science study must be concerned with events and objects that can be seen, considered, and studied locally. Meaningful science cannot be textbook science.

5. *Application of science.* Applications of technology can lead to a consideration of pure science. Technology has more relevance and is more easily seen and understood than the unifying ideas of pure science. Once motivated, once involved, once interested, students can be encouraged to consider meanings and ideas. A consideration of basic science can be an outcome—a result—as opposed to a major goal or an organizational scheme.

6. *Focus on cooperative work on real problems.* Contrived experiences, individual work on verification activities, and textbook problems do not help students grow as cooperative citizens ready to tackle the social problems of our time. A community concept is needed. A focus on problem resolution rather than problem solution is more realistic and a more desirable goal.

7. *Emphasis on multiple dimensions of science.* For many students, the historical, philosophical, and sociological dimensions of science may be more valuable than a content/discipline di-

"A technologically-oriented, democratic society cannot exist with large sections of its population ignorant of science and technology."

mension. The process dimension is important, especially if it deals with practical situations such as decision making. Surely the applications of technology are more meaningful and viable for many. Political, economic, psychological, and creative dimensions are important views of science for others.

8. *Evaluation based on ability to get and to use information.* Nearly all evaluation in older models of science education focuses on definition of terms and concepts and on verification skills. Evaluation should be viewed as a part of the scientific continuum and hence basic to any study of science. Finding information and using it are two indispensable skills that must be practiced and valued in the K–12 science education.

S/T/S in Other Nations

The science/technology/society move is international. In fact, the U.S. has moved into such a focus much later than has the U.K., Israel, and many other industrialized as well as third world nations. Two national projects in the U.K. have attracted much attention. The first of these was called Science in Society. A total of 12 modules have been developed and published (Science and Society, 1981). The individual topics indicate the relevance of the materials:

Diseases and the Doctor
Medicine and Care
Population and Health
Food
Agriculture
Energy
Mineral Resources
Industry: Men, Money, and Management
Industry, Organization, and Obligation
Nature of Science
Science and Social Development
Looking to the Future

The second U.K. project is called SISCON (Science in a Social Context, 1983).

The major topics include:

Ways of Living
How Can We Be Sure?
Technology, Invention, and Industry
Evolution and the Human Population
The Atomic Bomb
Energy: The Power to Work
Health, Food, and Population
Space, Cosmology, and Fantasy

Toward S/T/S in the U.S.

The NSF recently assembled a panel of leaders to ponder the federal role in upgrading science curricula. One of their most significant recommendations was for a two-year required S/T/S sequence for grades 9 and 10 (NSF, 1983). This would all but eliminate discipline-oriented science until the last two years of high school, when it would be elective and recommended only for college-bound students aspiring for a science major. For other high school juniors and seniors, the NSF group recommended a third-year S/T/S elective.

The national panel summarized its recommendations for a K–12 curriculum for science education as follows:

> Any consideration of K–12 curriculum must be driven by an understanding of the demands put on education in a democracy that is part of a complex technological world. There is demand for scientific skills, attitudes, and knowledge. A technologically-oriented, democratic society cannot exist with large sections of its population ignorant of science and technology. Attitudes, skills, reasoning abilities and knowledge from science are prerequisite to a sense of control over human destiny on the part of the populace. Full science literacy involves the following four components: (1)Ways of knowing: What do I know? What is the evidence? (2) Actions/Applications: What do I infer? What are the options? Do I know how to take action? (3) Consequences: Do I

New Goals for School Science

Project Synthesis researchers developed goals for school science in four areas, all of which illustrate the importance of the science/technology/society perspective.

Elementary Science
1. Focuses on effective consumer behavior
2. Deals with effective personal health practices
3. Recognizes the effect of people on the environment and vice versa; develops custodianship
4. Observes variations in the interpretation of data
5. Experiences the hard work involved in resolving real problems
6. Focuses on a great variety of the dimensions of science
7. Recognizes the roles of people involved in scientific pursuits.

Biology
1. Uses knowledge to understand self
2. Uses knowledge to benefit the quality of life
3. Studies humans in natural and total environment
4. Focuses on current issues and deals with morals, values, ethics, and aesthetics.

Physical Science
1. Applies physical science ideas and information to real-world problems
2. Displays content in the context of socially relevant problems, as well as standard disciplines
3. Focuses on personal needs, societal issues, and careers related to physical science
4. Deals with real people in science where the processes they use can be observed
5. Includes real research for students as well as out-of-school experiences.

Science/Technology/Society
1. Uses knowledge to improve personal life and to cope with an increasingly technological world
2. Deals with technological/societal issues
3. Focuses on decision making
4. Provides accurate picture of opportunities and requirements needed for a wide variety of careers.

know what would happen? and (4) Values: Do I care? Do I value the outcome? Who does care? The group agrees that science literacy is essential for all students. Science manpower requirements must be built upon a foundation of science literacy. Even for students who take all available science courses, many existing K–12 science instruction programs are not adequate to produce science literacy. For the majority who take very little science, the situation is truly a national crisis.

These recommendations illustrate the nature and magnitude of the changes needed in school programs. Programs such as those found in the NSTA S/T/S exemplars are similar to action–oriented social sciences and exemplary debate programs in which students master knowledge for their own use. Science knowledge becomes powerful, valuable, relevant. Students learn for self–generated reasons—not teacher or system–demanded reasons. In exploring, explaining, and testing their own explanations, students experience the real meaning of science. The NSF studies of the late 70s reported that there were virtually no examples of science being taught in such a manner.

Some have feared that S/T/S courses will lack rigor and be inappropriate preparation for college. In the exemplary programs identified by NSTA, the opposite seems to be true. More students seek further study of science; more report high interest in science; more score better on standard measures; more show evidence of science/technology literacy.

Toward New Meaning

As our societal problems worsen, it is at once apparent that science and technology are intimately involved. Many of the decisions concerning improvement and the nature of the future for which we yearn require a basic understanding of science and technology. We must have the informed citizenry which Jefferson envisioned at the birth of our democracy. Evidence suggests that we have failed to produce such a citizenry—at a time when we are all being called upon to help make life and death decisions. We cannot afford to continue. Solving daily problems, establishing new policies, passing laws, and similar actions at the practical and policy levels are insufficient. We must deal at the purpose level; we must move toward new meaning for school science. The future of our society depends on it.□

[1]Information about these 50 programs is detailed in NSTA's monograph series, *Focus on Excellence* (Penick, 1983). These programs are worlds apart from the science programs reported in the 1977–78 NSF studies (Helgeson and others, 1977; Stake and Easley, 1978; Weiss, 1978)—in terms of goals, curriculum, instruction, evaluation, and teachers (Bonnstetter, 1983; Bonnstetter and others, 1983).

Exemplary Science/Technology/Society Programs

The following exemplary S/T/S programs were identified by the Search for Excellence in Science Education program of the National Science Teachers Association.

Earthscope
Monte Sano Elementary
1107 Monte Sano Blvd., S.E.
Huntsville, AL 35801

Solar Projects Class
Toledo High School
Olalla Road
Toledo, OR 97391

Contemporary Issues in Science
Susan E. Wagner High School
1200 Manor Road
Staten Island, NY 10314

Environmental Science
Scott High School
404 Riverside Drive
Madison, WV 25130

Unified Science Curriculum for High School
Wausau West High School
1200 West Wausau Avenue
Wausau, WI 54401

Energy and Us
Kelley Walsh High School
3500 East 12th Street
Casper, WY 82609

Mankind: A Biological/Social View
Clarkstown South High School
Demarest Mill Road
West Nyack, NY 10994

Marine Environmental Program
Quilcene Junior/Senior High School
P.O. Box 40
Quilcene, WA 98376

Wallingford Auditing Technical Team (WATT) (Energy Waste)
Dr. Mark T. Sheehan High School
Hope Hill Road
Wallingford, CT 07492

Science/Mathematics/Computer Technology
Gompers Secondary Center for Math/Science/Computers
1005 47th Street
San Diego, CA 92102

Energy, Land Use, Technology, and Natural Resources
Jefferson County R-1 School District
1209 Quail Street
Lakewood, CO 80215

Human Ecology
Brandywine High School
1400 Foulk Road
Wilmington, DE 19803

Project Life Lab
GreenAcres School
Live Oak School District
966 Bostwick Lane
Santa Cruz, CA 95062

References

Bonnstetter, R.J. "Characteristics of Teachers Associated with an Exemplary Program Compared with Science Teachers in General." Doctoral thesis, University of Iowa, 1983.

Bonnstetter, R.J.; J.E. Penick; and R.E. Yager. *Teachers in Exemplary Programs: How Do They Compare?* National Science Teachers Association, Washington, D.C., 1983.

Brandwein, P.F. *Memorandum: On Reviewing Schooling and Education.* New York: Harcourt Brace Jovanovich, 1981.

Gallup, G.H. 14th Annual Gallup Poll of the public's attitudes toward public schools. *Phi Delta Kappan* 64, 1 (1982): 37.

Goodlad, J. "A Study of Schooling: Some Findings and Hypotheses." *Phi Delta Kappan* 64, 7 (1983): 465–470.

Harms, N.C. "Project Synthesis: An Interpretive Consolidation of Research Identifying Needs in Natural Science Education." A proposal to the National Science Foundation, University of Colorado, Boulder, 1977.

Harms, N.C., and R.E. Yager. *What Research Says to the Science Teacher*, Vol. 3. Washington, D.C.: National Science Teachers Association, #471–14776, 1981.

Helgeson, S.L.; P.E. Blosser; and R.W. Howe. *The Status of Pre–College Science, Mathematics, and Social Science Education: 1955–75.* Washington, D.C.: U.S. Government Printing Office, 1977.

Hofstein, A., and R.E. Yager. "Societal Issues as Organizers for Science Education in the 80s." *School Science and Mathematics* 82, 7 (1982): 539–547.

Howe, T.G., and J.A. Gerlovich. National Study of the Estimated Supply and Demand of Secondary Science and Mathematics Teachers, 1980–82.

Hueftle, S.J.; S.J. Rakow; and W.W. Welch. "Images of Science: A Summary of Results from the 1981–82 National Assess-

ment of Science." University of Minnesota: Minnesota Research and Evaluation Center, 1983.

Hurd, P. DeH; J.T. Robinson; M.C. McConnell; and N.M. Ross, Jr. *The Status of Middle and Junior High School Science, Vol. 2, Technical Report*. Louisville, Colorado: Center for Educational Research and Evaluation, 1981.

Miller, J.; R. Suchner; and A. Voelker. *Citizenship in an Age of Science*. Elmsford, New York: Pergamon Press, 1980.

National Assessment of Educational Progress. *Three National Assessments of Science: Changes in Achievement, 1969–1977*. Denver: Education Commission of the States, 1978.

National Commission on Excellence in Education. *A Nation at Risk: The Imperative for Educational Reform*. Washington, D.C.: U.S. Government Printing Office, 1983.

National Science Foundation. *What are the Needs in Pre–College Science, Mathematics, and Social Science Education?* Washington, D.C.: NSF, 1979.

National Science Foundation. "A Revised and Intensified Science and Technology Curriculum Grades K–12 Urgently Needed for Our Future." Report to NSB Commission on Pre–College Education in Mathematics, Science, and Technology, Washington, D.C., March 11–13, 1983.

National Science Teachers Association Working Paper. *Science Education: Accomplishments and Needs*. Columbus, Ohio: ERIC/SMEAC, 1978.

Osborne, Alan, director. "A Study of Priorities in School Mathematics (PRISM)." Columbus, Ohio: Ohio State University, 1977.

Penick, J.E., ed. *Focus on Excellence: Science as Inquiry* (1); *Elementary Science* (2); *Biology* (3); *Physical Science*1(4); *Science/Technology/Society* (5). Washington, D.C.: National Science Teachers Association, 1983.

Penick, J.E., and R.E. Yager. "The Search for Excellence in Science Education." *Phi Delta Kappan* 64, 9 (1983a): 621–623.

Penick, J.E., and R.E. Yager. "Learning from Excellence." *Learning*, submitted for publication, 1983b.

Rakow, S.J. "The Results of the 1981–82 National Assessment of Educational Progress in Science." Proceedings of Iowa Curriculum Update Conference, Science Education Center, University of Iowa, July 1983.

Shymansky, J.A., and B.G. Aldridge. "The Teacher Crisis in Secondary School Science and Mathematics." *Educational Leadership* 40,2 (1982): 61–62.

Social Studies Priorities, Practices, and Needs (SPAN). NSF Contract #SED 78–17104. Boulder: Social Studies Education Consortium, Inc., 1980.

Stake, R.E., and J. Easley. *Case Studies in Science Education 1 and 2*. Washington, D.C.: U.S. Government Printing Office, 1978.

A Recommended K-12 Sequence in Science

In March 1983, 40 national leaders were assembled by the National Science Foundation to consider goals for science and technology education. Their recommendations (approved unanimously) include the following:

K–6. An integrated, hands-on approach is needed to focus on the relationships between humans and the total environment. Problem solving must be emphasized, including acquisition and analysis of data.

Grades 7–8. There should be two primary emphases: (1) on human science, including human biology and personal health; and (2) on development of quantitative skills in science. Computer-based experiences should be used appropriately to assist in developing quantitative skills that will be needed for more complex, applied problem solving in grades 9–10. Skill in quantitative analysis of data, application of probability, and estimating skills are examples.

Grades 9–10. A two-year sequence, required for *all* students to address science, technology, and society. Emphasis should be on problem solving and scientific reasoning, applied to real-world problems. It should integrate knowledge and methods from physics, biology, earth science, and chemistry, as well as applied mathematics. The rationale for this sequence is that students need to have certain development, math, and problem-solving skills that are prerequisite to the complex problem-solving tasks required in this course. It is a much higher-level course than is generally recognized as "general science" for nonscience students.

Grades 11–12. One- and two-semester courses in physics, biology, chemistry, and earth sciences should be available for students who wish to go on to further academic study in science-related courses. These are not advanced placement courses and should not replicate college-level courses. They build on and assume as prerequisites the skills and knowledge in the various science disciplines that students acquire in the science, technology, society course in grades 9–10.

Voelker, A.M. "The Development of an Attentive Public for Science: Implications for Science Teaching." *What Research Says to the Science Teacher 4*. Washington, D.C.: National Science Teachers Association, 1982.

Walsh, J. "French Reforming Higher Education—Again." *Science* 216 (1982): 834–835.

Weiss, I.R. *Report of the 1977 National Survey of Science, Mathematics, and Social Studies Education*. Washington, D.C.: U.S. Government Printing Office, 1978.

Wirszup, I. "The Soviet Challenge." *Educational Leadership* 38, 5 (1981): 358–360.

Yager, R.E. *Analysis of Current Accomplishments and Needs in Science Education*. Columbus, Ohio: ERIC/SMEAC Clearinghouse for Science, Mathematics, and Environmental Education, 1980.

Yager, R.E. *What Research Says to the Science Teacher 4*. Washington, D.C.: National Science Teachers Association, 1982.

Yager, R.E., and R.J. Bonnstetter. "Student Perceptions of Science Teachers, Classes, and Course Content." *School Science and Mathematics*, in press, 1983.

Yager, R.E., and J.E. Penick. "What Students Say About Science Teaching and Science Teachers." *Science Education*, submitted for publication, Sept. 1983.

Yager, R.E., and S.O. Yager. "Comparison of Concept Development in Science Among Nine, Thirteen, and Seventeen Year Old Students," *Journal of Research in Science Teaching*, submitted for publication, Sept. 1983.

Yager, R.E.; A. Hofstein; and V.N. Lunetta. "Science Education Attuned to Social Issues: Challenges for the 80s." *The Science Teacher* 48,9 (1981): 12–14.

Yager, R.E., and R. Stodghill. "School Science in an Age of Science." *Educational Leadership* 35,6 (1979): 439–445.