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ABSTRACT

This conference was convened to identify the most important problems and opportunities facing science teaching in secondary schools and to suggest the most practical means of addressing them. The report highlights issues involving science and technology education which were addressed at the conference. Information is presented in three major sections which are entitled: (1) perspectives (providing an overview of the conference's objectives, participant composition, and conclusions); (2) topics of discussion (synthesizing ideas on classroom reform, science education's goals, science curriculum, instructional strategies, evaluation, role of science supervisors, preparation of science teachers, and priorities for action); and (3) new directions (reflecting on the conference's mission and accomplishments). Also included are listings of the conference's steering committee, consultants, and participants and a bibliographic listing of references associated with the theme of science and technology education. (ML)

# Exeter II Conference

# Exeter II Conference

## Science and Technology Education for Tomorrow's World

*A Report of the Exeter II Conference on Secondary School Science Education*

**Phillips Exeter Academy**
Exeter, New Hampshire
June 16–22, 1985

*Edited by*
*Richard F. Brinckerhoff and Robert E. Yager*

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# Table of Contents



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# FOREWORD

This conference on secondary school science education was a joint effort of the Phillips Exeter Academy and the Science Education Center of the University of Iowa, with major support from the Esther A. and Joseph Klingenstein Fund and the Dreyfus Foundation. Its goal was similar to that of a conference at Exeter five years earlier — to identify the most important problems and opportunities facing science teaching in the nation's secondary schools and to suggest the most practical means of addressing them. As at the first Exeter conference in 1980, 40 teacher participants and a dozen special consultants of recognized stature were in residence for a week, concentrating continuously on a single common task. Twenty-five of the teachers were Presidential Award recipients, contributors to exemplary science programs, or leaders in professional societies. While some of the participants and special consultants are now associated with colleges and universities, most of them have also spent 10 years or more as teachers in schools.

This was not an effort to enrich or enlighten the participants; on the contrary, in the face of this task the teachers were the experts and the special consultants acted as stimulants and resource people for them. The conference was a think tank for contemplating science education from their point of view, a perspective from which it is rarely examined.

# Part I

## Perspectives

### Introduction

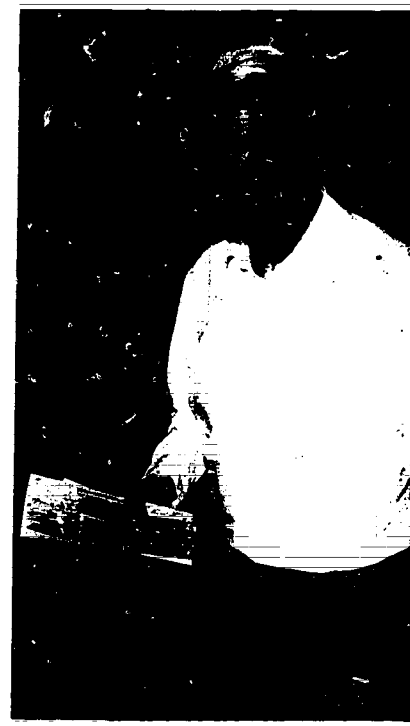
Continuing revision of school science courses has been motivated by a steadily growing public concern ever since the National Science Foundation (NSF)/curriculum studies of the 1960s documented the fact that our schools were no longer stimulating places in which to teach and to learn: and pointed to science — never considered equal in importance to the three R's — as one of the subjects most in need of reform. Six years ago, on June 15–22, 1980, at a conference known as Exeter I, advice was sought on the matter of science education reform from 38 carefully selected science teachers from public, parochial, and independent schools across the nation and 10 consultants of high professional standing, all of whom recognized that the state of science education in our schools was a matter of serious national concern.

The Exeter I conference reported two major conclusions: Science is the only high school discipline appropriate for addressing the societal and ethical consequences of modern science and technology, and there should be an infusion of material of a societal and ethical character into present science courses to comprise approximately 10 percent of the course material. The conferees also agreed that the most appropriate institutional response would be the formation of a national network of permanent science resource centers, with each center responsible for developing and distributing teaching materials addressed to societal issues at either the local or national level and providing continuous support services for teachers, including renewal of curriculum programs and revision of instruction strategies. Subsequent to Exeter I, the Directorate for Science and Technology Education of the National Science Foundation included the development of regional networks in its guidelines for grant proposals. The Exeter I report no doubt contributed to the formulation of this policy.

These conclusions were reached six years ago — years before the publication of reports such as *A Nation at Risk* and *Educating Americans for the 21st Century*. Much has taken place since that time. Additional reports have focused public attention on education, but with few exceptions these reports have been political or philosophical documents rather than educational analyses. Even those reports that originate in the educational community, valuable though they often are, generally do not reflect the counsel and perceptions of those experienced and practicing classroom teachers of science on whom the hopes of significant and lasting reforms must finally rest.

Exeter I was an effort to tap that neglected constituency. But because in the few years since that time the educational scene had changed dramatically, it seemed appropriate that Phillips Exeter Academy, the sponsor of Exeter I, combine forces with the University of Iowa, in which one of the most active science education centers in the country has emerged, to consider in a new conference what progress had occurred during the subsequent years and to raise once again the voice of the science teaching community in the cause of thoughtful and practical reform.

Forty science teachers from all disciplines can say a great deal in one week. Their discussions were sustained and intense. It is a tribute to their common sense of purpose that in the end they agreed on most of the group conclusions most of the time. From the beginning, conferees envisioned a report as a means of making policy recommendations to the public, to private foundations, to government, and to community leaders. This conference report is an effort to set forth simply and fairly the consensus of those complex discussions occurring at the Exeter II conference during June 1985.



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## Science Education in Transition

The U.S. public currently supports science education as strongly as it did in the 1960s. Industry, government, the military, politicians, and community leaders — almost all people — are anxious to support efforts for "improved" science education. To many, this merely means adding more science teachers, increasing formal preparation in science for teachers, increasing time devoted to science study during the K–9 years, and requiring additional years of science in high school. But these actions do not address the problems identified by National Science Foundation studies done in the late 1970s.

These status studies of science education represented the most comprehensive effort then undertaken to determine the state of school science programs and evaluate their teachers. The NSF studies were notable for their extensiveness, their elaboration of the problems, and the view of science education they provided at their conclusion. Unfortunately, the status studies are not used as much as they should be in planning improvements for science education today and programs designed for the future.

Societal pressure has caused the renewed interest in science education. Industry, the military, and colleges all want high school graduates with stronger science and mathematics backgrounds. The general public and national leaders are concerned with economic problems. National commissions, state legislatures, businesses, and private foundations offer a variety of initiatives to stimulate "improved" science education.

National commissions, study groups, and foundations have also issued reports and made recommendations for gaining such "improvement." The most important of the reports addressed to science educators was a report of the National Science Board (NSB) Commission on Precollege Education in Mathematics, Science, and Technology, entitled *Educating Americans for the 21st Century* (1983).

The NSB commission report asserted the importance of providing a K–12 science education for everyone. This commitment would require a major departure from science education as it is approached in most high schools — where science is viewed primarily as preparation for further study of science, not preparation for living in today's scientific and technological age.

The report urged that science and technology education at the precollege level be directed toward developing students' skills of observation and interpretation and the capacity for problem solving and critical thinking, as well as ensuring that all students acquire the knowledge necessary for exercising civic responsibilities and coping with life in contemporary society. In addition, talents for creative thinking should be developed, and students likely to pursue scientific careers should be provided the academic background necessary for advanced study in the sciences. The NSB commission report continued by underscoring the need for suitable materials for achieving these outcomes.

In a summary of the objectives for science and technology education, the committee states:

> Students who have progressed through the Nation's school systems should be able to use both the knowledge and products of science, mathematics, and technology in their thinking, their lives and their work. They should be able to make informed choices regarding their own health and lifestyles based on evidence and reasonable personal preferences, after taking into consideration short- and long-term risks and benefits of different decisions. They should also be prepared to make similarly informed choices in the social and political arenas.

One panel of the NSB commission considered the detailed contents of K–12 science programs and unanimously recommended specific science and mathematics programs for meeting the needs of all students. The NSB commission report, particularly the recommendation regarding curriculum structure, proved useful in setting priorities for the recommendations arising from Exeter II.

The Exeter II conference was conceived as a means of convening some of the nation's best science teachers to consider the issues described in the NSF status studies and the recommendations arising from the numerous other national commissions that had issued reports since the Exeter I conference. The recommendations of those commissions were taken most seriously and provided a background for discussion and debate at Exeter, although the makeup of the various national commissions and study groups included only token representation from the ranks of practicing science teachers.

This report, the effort of many, presents the resulting blueprint for needed school reform, created by the professionals who work most closely with students. The participants have attempted to see beyond this period of transition, to view school science as it might be and to propose actions that would achieve such a vision.

## Toward New Reforms

In the 1950s and 1960s, when this country directed its attention to the new frontier of space and President John F. Kennedy set our sights on the moon, the largest curriculum reform movement in educational history began. The time frame for achieving President Kennedy's goal — a decade — influenced the decisions about where to concentrate reform efforts. Since new scientists and engineers could most quickly be brought into the work force by directing reform efforts toward the high school, secondary school science was the reasonable place to start.

The goals were met. Thousands of scientists and engineers were brought into the work force, we landed men on the moon and returned them to earth, and we updated science and mathematics programs and expanded the backgrounds of thousands of teachers during a "Golden Age" of science education.

Now, because of major contemporary advances in science and technology and pressing social issues, we again require significant changes in curricula, as well as development of a perspective suitable for the 1990s and beyond.

In the 1960s programs for school science based on these goals were designed for students bound for colleges and universities and eventually careers in research and development. Emphasis on the personal use of science and technology or understanding of their societal aspects was minimal. But today it seems clear that a perspective compatible with present and future needs of society should provide an education that meets the needs and concerns of *all* students who will live, work, and participate in our society.

In 1983 the National Commission on Excellence in Education reported the educational situation and needs to the American people in *A Nation At Risk: The Imperative for Educational Reform*. The report pointed to economic and defense-related risks and to numerous indicators of our current educational establishment's inability to respond to such evidence of risk as statistics on functional illiteracy and declining test scores. Science educators proclaimed we were "raising a generation of Americans that is scientifically and tecnologically illiterate" (Paul DeHart Hurd, on p. 10), and that there was "a growing chasm between a small scientific and technological elite and a citizenry ill-informed, indeed uninformed, on issues with a science component" (John Slaughter, on p. 10). In response to the national risks cited in the report and as a way of directing reform, the commission made a number of policy recommendations, including one for science:

> The teaching of science in high school should provide graduates with an introduction to: (a) the concepts, laws, and processes of the physical and biological

sciences; (b) the methods of scientific inquiry and reasoning; (c) the applications of scientific knowledge to everyday life; and (d) the social and environmental implications of scientific and technological development. Science courses must be revised and updated for both the college bound and those not intending to go to college. (p. 25)

Recommendations (a) and (b) are similar to the goals that prevailed during the 1960s and 1970s. Recommendations (c) and (d) provide the balance of goals alluded to earlier.

While *A Nation at Risk* has had the most immediate and widespread impact, *High School: A Report on Secondary Education in America*, by Ernest L. Boyer (1983), of the Carnegie Foundation for the Advancement of Teaching, may have the longest lasting influence on contemporary educational reform. In *High School* Boyer recommends a two-year science program based on the biological and physical sciences:

> These courses should be taught in a way that gives students an understanding of the principles of science that transcend the disciplines. The search for general principles of science can be, if properly done, a superficial exercise. But, if carefully designed, an interdisciplinary view will give all students — both specialists and non-specialists — a greater understanding of the meaning of science and the scientific process. (p. 107)

This perspective suggests an integrated curriculum for school science. The approach has come to be addressed as a science-technology-society (STS) theme.

For Boyer, the study of technology should also be a part of contemporary reform: Indeed, he recommends an explicit one-semester course.

> We recommend that all students study technology: the history of man's use of tools, how science and technology have been joined, and the ethical and social issues technology has raised. During this proposed one semester course, a student might well look at one technological advance — the telephone, the automobile, television or the microcomputer, for example — trace its development, and examine the positive and negative impact it has had on our lives today. (p. 110)

Boyer continues by underscoring the relationship between technology and society:

> The great urgency is not "computer literacy" but "technology literacy." The need for students to see how society is being reshaped by our inventions, just as tools of earlier eras changed the course of history. The challenge is not learning *how* to use the latest piece of hardware but asking *when* and *why* it should be used. (p. 111)

The process of rethinking our school science programs should be grounded in the highest aspirations of our society, including the goals of citizenship and democratic participation. The broad purposes of these reports can be translated into concrete policies by introducing a concern for an understanding of social issues related to science and technology, including their personal applications, and by following an integrated approach to the science underlying these problems.

# Part II

## Focal Points of Reform

### The Topics for Discussion

The 40 teachers at Exeter II looked at science education in circumstances that had both limitations and strengths. The group's greatest limitation was time. One week — or for that matter a month or two — is too short a time for the desired achievement, nor was there an opportunity for follow-up debate and reconsideration aside from an opportunity to comment on the final report. One major strength of the group was the combination of accomplishment and scholarship on the one hand and day-to-day experience in the classroom on the other. The perspective that such a combination brought to the week's discussions provides a sound basis for the group's claim to authority.

It is worth noting that the participants' common ground was enlarged further by the assignment of extensive reading material distributed in the weeks before the conference. (These materials are included in the Bibliography, p. 30.) Each conferee was asked to consider various questions:

- What should a high school student know and be able to do as a result of his or her experience with science?
- How can science programs better meet the needs of *all* students?
- What is your idea of the science-technology-society theme?
- What is your concept of the ideal K–12 science program?
- What are some of the problems facing secondary school science education today?

Another strength lay in the organization of the small group discussions. Each participant joined one of six special interest groups that provided the focal points for discussion throughout the conference and around which the final recommendations were organized. Each group dealt with one of the fundamental elements of education — goals, curriculum, instruction, evaluation of programs, supervision, and teacher education — and sought to integrate it with the group members' knowledge and experience in the science classroom. In the course of discussion each group considered the situation currently prevailing in secondary school science classrooms — the "what is" — and sought to identify steps for moving from the "what is" to the "what should be" condition. This task was made more difficult by the need to keep in mind the long-standing purposes of education — citizenship and the personal development of students.

Each group reported on its work periodically to the whole group — for it was felt that all parts should be related and that there should be commonalities of approach. Interaction among groups was encouraged. At the end all participants discussed the relative importance of the problems they had identified, possible corrective actions, and priorities for action. The following chapters set forth the policies that were developed by the six discussion groups. Together they provide a view of science education today and suggestions for its improvement for tomorrow.

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### Goals for Science Education

Science education must be for *all* students. In the 1980s this should go without saying, but perhaps still needs restating. In past decades goals, and subsequently programs, have focused on the small percentage of students (perhaps 5 percent) who ultimately pursued careers in science and engineering. One of the most demanding challenges that face science educators today is to design courses directed more explicitly to the needs of the remaining 95 percent, including women, minorities, and the handicapped. Such a realignment requires a critical examination of goals.

The major goals of secondary science programs have traditionally been to enable students to acquire scientific knowledge, to understand scientific processes, and to explore scientific careers. In addition, there

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has consistently been a concern with preparing students to make personal and social decisions in their lives as individual citizens. These goals have always been part of the structural foundation for science education curricula and instruction, although over time these goals have been given differing emphases and priorities and have been modified and updated (Bybee, 1977).

The science teachers of Exeter II supported the following goals for science education.

1. *Prepare students to use science and technology in understanding and improving their daily lives.* Science programs should meet the needs of the individual and provide the knowledge and training in skills necessary to make everyday, science-related decisions. Subjects that provide such experience and information include consumer choice, health and nutrition, use of common technological devices, and training in locating, selecting, and applying information appropriate to a given situation.

2. *Prepare students to deal responsibly with science-related societal issues.* Science programs should provide the skills, attitudes, and knowledge necessary to solve problems and make decisions about important science-related local and global issues. Such programs will necessarily include topics from other disciplines, such as technology, economics, politics, history, ethics, and law. Sources of such issues include: energy and resource use and limitations, genetic engineering, nuclear arms, population growth, and environmental problems.

3. *Encourage in students an inquisitiveness about the natural world and an understanding of scientific explanations of natural phenomena.* Science programs should instill an interest in exploring and explaining the natural world through development of the inquiry skills and exploration of the basic conceptual frameworks of the physical, earth, and biological sciences.

4. *Encourage in students an awareness and understanding of the nature of science as an international human endeavor.* Science programs should provide students with an awareness of both the potential and limitations of scientific inquiry, and of the social and psychological context in which the inquiry occurs. Such study might include the history, philosophy, sociology, economics, and politics of science and technology, and an examination of how scientific knowledge is acquired, modified, and tested.

5. *Develop in students an awareness of science- and technology-related careers.* Science programs should introduce students to the potential jobs and careers in science and technology, stressing that there are opportunities available to all segments of our society and encompassing a wide range of abilities and backgrounds. Examples of such roles and jobs include: scientist, engineer, technician, computer programmer, health care assistant, support staff, and positions in the helping professions.

Achieving these five goals will require a fundamental change in the course of school science education, including alteration of the emphasis of school science education in favor of that great majority of students who are not destined for careers in the sciences.

**The Science Curriculum**

In most science classes the textbook *is* the curriculum (Weiss, 1978; Stake & Easley, 1978). Thus, if science textbooks do not reflect recent advances in science and technology, apply new developments in learning theory, and present science and technology information appropriate to the present personal and social goals of education, then one can conclude that the science programs are inadequate. Widespread calls for reform of science education (Bybee, Carlson, & McCormack, 1984) certainly support the notion that current science curricula are inadequate. Further, major national reports such as the prestigious NSB commission report *Educating Americans for the 21st Cen-*

*tury* (1983) have clearly indicated there is need for a reform of science programs — including textbooks.

Science teachers ought to be examining the curriculum, and indeed they did at Exeter II. Their conclusions follow.

*Curriculum ideally will reflect the needs of both the students and the society it serves.* The curriculum is the general framework upon which teaching plans and selection of instructional strategies are based. In their effort to identify a set of standards, the curriculum task group agreed that an ideal science curriculum at the secondary level should:

- take into account students' developmental stages as well as their psychological needs, and
- include opportunities to study natural phenomena both in and out of school.

*Curriculum must reflect the geographical and societal differences of a student's changing world.* The science curriculum in particular should:

- acquaint students with important local problems and later help them develop an understanding of fundamental concepts related to global issues,
- familiarize students with the benefits and problems resulting from technological advances,
- expand student perceptions of science and technology in the past, present, and future, and
- develop an awareness of human influences upon the natural world.

*Curriculum should include a body of science concepts integrated with the problems of a scientific and technological world.* The science curriculum in particular should:

- provide a balance among the physical, earth, and life sciences,
- incorporate a variety of curriculum materials including single units, modules, audiovisual materials, and textbooks,
- allow for informal educational experiences that make use of local and community resources, and
- introduce students in grades 7–12 to major science-related social problems such as air quality, human health and disease, energy shortages, hazardous substances, world hunger, population growth, water resources, war technology, extinction of plants and animals, and land use. Such issues should comprise a minimum of 10 percent of course time. (The National Science Teachers Association ideal is 20 percent.)

*Curriculum must develop skills unique to science and enhance basic skills introduced in other disciplines.* The science curriculum in particular should:

- develop skills related to science, including reading technical materials, manipulating lab equipment, formulating and solving scientific problems, and applying mathematics,
- present interdisciplinary skills, including information gathering, critical thinking, creative thinking, problem solving, and decision making, and
- highlight the processes of science, including questioning, searching, observing, measuring, classifying, analyzing, synthesizing, hypothesizing, predicting, and separating and controlling variables.

How does the science-technology-society (STS) theme fit into present school science curricula? This question is the one that Exeter II conferees felt needed most careful consideration. There is an urgent need for reform and an equally important need to respect the integrity of science teachers and their existing programs. Rather than recommend one program or one approach to implementing the STS theme, the participants encourage their colleagues to think of different curricular options existing along a continuum. At one end of the continuum there is the option of maintaining the present science curriculum and infusing STS topics through the use of vignettes of five minutes or less in length. Science teachers will certainly be able to find ample topics, and will have adequate opportunites to in-

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*Table 1*

**Instructional Framework**

| | Acquiring Knowledge | Developing Technical Skills | Developing Thinking Skills | Understanding Relations Among Science, Technology, and Society |
|---|---|---|---|---|
| **lucational im** | Acquire an organized body of scientific knowledge. | Know where, when, and how to collect and organize data and communicate information. | Develop patterns of reasoning and rational thought. | Develop an understanding of the interdependence of science, technology, and society. |
| **eaching rategies, ctivities, id aterials** | Lectures, audiovisual demonstrations, worksheets, text-books, drill, vocabulary lists, discussions, experiments, computers, pre-testing, tests, puzzles. | Laboratory investigations, math problems, measurements, charts and graphs, science literature, computer pro-grams, written laboratory reports, research papers, reading and writing instruction. | Coaching, exploring, explaining, evaluating, synthesizing, classi-fying, analyzing, hypothesizing, predict-ing, separating and controlling variables, decision making proj-ects, brainstorming, examining alternatives, public speaking assign-ments, "wait" time, debates, independent study, creative prob-lem solving. | Current events, role playing, exchange of personnel, field trips, guest speakers, debates, roundtable discussions, simulations, surveys, films, independent study, reading, interviews. |
| **udent earning** | An understanding of concepts and the ability to perform on informal and formal evaluations. | The ability to use laboratory equipment, read and use scientific literature, and apply math skills. | The ability to make decisions, reason, formulate questions, express ideas, carry out library research, and communicate the knowledge, skills, and values of science and technology. | The ability to relate and apply science and technology to life and to investigate and evaluate alternative values, motives, and attitudes relative to the limits and potentials of science and technology in society. |
| **valuation chniques** | Multiple choice tests, hands-on activities, written passages to read and summarize. | Hands-on activities, application of skills to a new laboratory situation. | Essay questions that require application of scientific knowledge, analysis of data, problem solving. Puzzles or problems that require using skills students have been learning. | Problem-solving activity involving a local STS issue culminating in oral reports, written reports, panel discussions, visual displays. Teach evaluation of students' choice of sources of data, differentiation between fact and opinion in sources, thoroughness of data collection, ability to graph or otherwise display data, thoroughness of ethical analysis, conclusions drawn from analysis of data. |

troduce short stories, news reports, and materials on local topics relevant to both societal issues and their science discipline.

Another option is the implementation of short lessons, units, or modules of varying length, ranging from several days to several weeks. Such an approach allows science teachers to develop the STS theme by concentrating on each topic (e.g., acid rain) for an extended period of time. Using the module option also provides the opportunity to weave STS themes through the entire science curriculum.

Some science teachers, school systems, and states want or have required implementation of an entire course built on the STS theme. Such courses are based on an integrated approach to science, for example the introduction of physical, life, and earth science concepts in a single course. Topics selected for such STS courses provide connections among the knowledge, skills, and values of the major disciplines of science. All school science curricula should somewhere include interdisciplinary STS courses in addition to modifying the context in which specific scientific concepts and processes are taught in the traditional program.

These options meet the need for reform of curriculum while implementing the STS theme. And approaching curriculum reform in this way allows the science teachers a decision-making role in the process of change.

## Instructional Strategies for Science Education

Teachers who lack time, funds, resources, and support systems while facing institutional constraints find it difficult to teach in a manner which fosters excellence. Moreover, institutional pressures force many teachers to focus on preparing students for standardized tests and for succeeding science courses. Thus, much science instruction today is simply a matter of conveying information. Here lies the origin of the need to improve instruction in science, for teaching is more than telling, and instruction is more than presenting.

One way science education can be improved is to identify an appropriate instructional model around which to organize lesson plans. To that end, Table 1 was developed by the conferees to assist teachers in devising instructional strategies to complement new curricula. It presents an organizational structure that may be adapted to suit the attitudes and abilities of each teacher who uses it and the needs of the students to whom instruction is directed. The sample lesson on DNA based on this instructional framework shown in Table 2 demonstrates how different elements of the framework can be incorporated into an instructional sequence.

There are many possible instructional frameworks, but which ones are most effective for science teaching? The most frequently used frameworks involve lecture and discussion, usually supplemented by laboratory experiences (Weiss, 1978).

Unfortunately, students' deficient reading ability and lack of interest and motivation can be significant deterrents to successful instruction by these methods. And, teachers report that they do not know how to use alternative instructional strategies such as the inquiry/discovery method or having students work in small groups (Weiss, 1978). One can only infer that new instructional strategies such as the 4 Mat system (McCarthy, 1980), "cooperative learning" (Johnson et al, 1984), and "teaching/learning cycle" (Karplus et al, 1977) have not become an integral part of most science teachers' methods. Perhaps the designing of the instructional framework in Table 1 will serve as the first step toward full implementation of new and efficient teaching strategies.

Exeter II participants examined several such models to see how they filled the instructional framework. The learning cycle of exploration-invention-discovery, the cooperative learning approach, the 4 Mat system, Madeline Hunter's model (Hunter, 1982), and Bernice McCarthy's model were all seen as excellent extensions of the basic organizational framework.

But an institutional model alone is not sufficient. Effective science instruction includes a blend of knowledge acquisition and the development of critical thinking and technical skills. Moreover, the teacher must consider the developmental levels and backgrounds of students, apply funda-

*Table 2*

**Example: DNA, The Social Dimensions of Science**

**Objectives:**

1. Learn the central concepts of the DNA model.
2. Learn about the laboratory techniques necessary to do DNA research.
3. Learn to communicate information about DNA.
4. Learn to relate DNA information to contemporary social issues.

| Teaching Strategies | Product |
|---|---|
| • Students bring into class newspaper articles that discuss DNA. | Acquiring knowledge |
| • Class discussion introducing DNA begins with the listing on the board of what the students know about DNA. | Acquiring knowledge |
| • The information base is expanded through a lecture and a film on DNA. | Acquiring knowledge |
| • DNA kits are put together in the laboratory. | Developing technical skills |
| • Bacteriophages are grown in the laboratory. | Developing technical skills |
| • Human chromosomes are observed and students do karyotypes on themselves. | Developing technical skills |
| • Students extract DNA and try to solve the X-ray diffraction model. | Developing technical skills |
| • Small groups discuss how students are affected by DNA and by changes in DNA. | Developing thinking skills<br>Understanding STS relations |
| • Students do reference work to determine current research on recombinant DNA. | Acquiring knowledge<br>Understanding STS relations |
| • Leaders of the groups report to the class on their findings. | Acquiring knowledge<br>Developing thinking skills<br>Understanding STS relations |
| • Small groups identify and discuss the consequences of continuing recombinant DNA research. | Acquiring knowledge<br>Developing thinking skills<br>Understanding STS relations |
| • Students set up a mock congressional investigation of recombinant DNA research. | Developing thinking skills<br>Understanding STS relations |
| • Students write to congressmen indicating their views based on evidence acquired in this activity. | Developing thinking skills<br>Understanding STS relations |

mental principles of individual and social psychology, and structure lessons in appropriate sequences. To do all this well, science teachers must have materials, facilities, and equipment readily available and time to gather resources and to interact with other professionals. Support from professional organizations, staff, and community is needed to humanize the institutional environment and make it more conducive to effective teaching.

## Evaluating Science Programs

An evaluation program should do more than provide information for grading students; feedback about the effectiveness of instruction and the adequacy of the curriculum also has significant implications for science teachers. As Rodney Doran (1980) has shown in *Basic Measurement and Evaluation of Science Instruction*, there are many purposes, types, foci, and methods of evaluation. Just as there is renewed interest in instructional strategies, there is also a new recognition of the place of evaluation in the continual improvement of science teaching.

Three major areas of concern requiring evaluation were considered by conferees: program quality, student progress, and effectiveness of teaching.

*Program Quality.* Standardized tests are frequently used to allow comparisons of programs with those of other school districts or regions. They are useful indicators of a program's success, but the results must be interpreted with caution, for most of the published tests are weak as measures of problem-solving ability and understanding of both the nature of science and the relations among science, technology, and society. Most standardized tests are weighted heavily on factual knowledge. Therefore, the tests currently used to evaluate many current science programs must be modified.

The evaluation of program quality requires identification of the goals that shape the curriculum. The simple questions should be asked: What is being taught in the science program? How well is it working? Who is, or is not, benefiting from the program? Ideally, each district and the faculty in each school should review the instructional program in science in all grades, K–12, define the goals, de ibe the courses and laboratory work, and xamine who takes the courses and who avoids them. The review should include an examination of the textbooks, the availability of equipment and supplies, and the adequacy of the program of staff development.

Any science program is a product of both the school and the community. A committee reviewing the school program should include teachers, administrators, and members of the board of education, and also representatives of local industry and of technical schools, colleges, and universities, since all of these groups have a vested interest in improving the quality of the science program. The results of the program review should be made public, for their evaluation of a program and subsequent recommendations will not produce the desired changes unless the policy developers and decision makers are publicly committed to the changes.

The students' evaluation of the programs should also be a part of any comprehensive program review and, in fact, should be included as a standard practice in every school science program. Students and alumni respond honestly to questions of their perception of the science program: its relevance, importance, and career interest. While some argue that students are not competent to judge the merits of a course, it must be remembered that many are already doing this by not enrolling in the course. Extensive experience nationwide shows that students' insights are often helpful in the revision of science programs.

*Student Progress.* Student evaluation has always been a means of providing feedback to the teacher and the student on how

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learning is progressing. A diagnostic test before instruction begins enables the teacher later to measure what has been learned in the course and makes it possible to modify the instructional process or the rate of instruction. Diagnostic tests can also serve as a basis for choosing alternative activities for individuals when problems arise. Evaluation at the end of a unit or course provides the teacher with a sampling of what has been learned and provides a partial basis for assigning students a grade.

Of course, the pressures of time and the demands of limited personnel put a limit on all such testing and record-keeping procedures, however ideal. Choices have to be made. For example, teachers usually have detailed records of each student's cognitive development and achievement, yet this information is lost if only the single score recorded at the end of the semester or year is retained. Moreover, if understanding the interaction of science and technology with the political and economic forces at work in our society is recognized as an important goal of the learning process, then educators ought to use every available means of evaluating their students' understanding of such interaction, since few tests are available that do so.

Although accepted techniques for evaluating STS materials — and students' use of them — have not yet been developed, it may be helpful to use the framework in Figure 1 for planning both the instructional strategies and the evaluation procedures needed to measure a student's progress. The vertical axis represents learning outcomes, including various aspects of knowledge and problem-solving skills. For example, while it may be appropriate to evaluate knowledge by having students describe the action of one magnet with another, it is also important that they understand the broader concept of interaction between them.

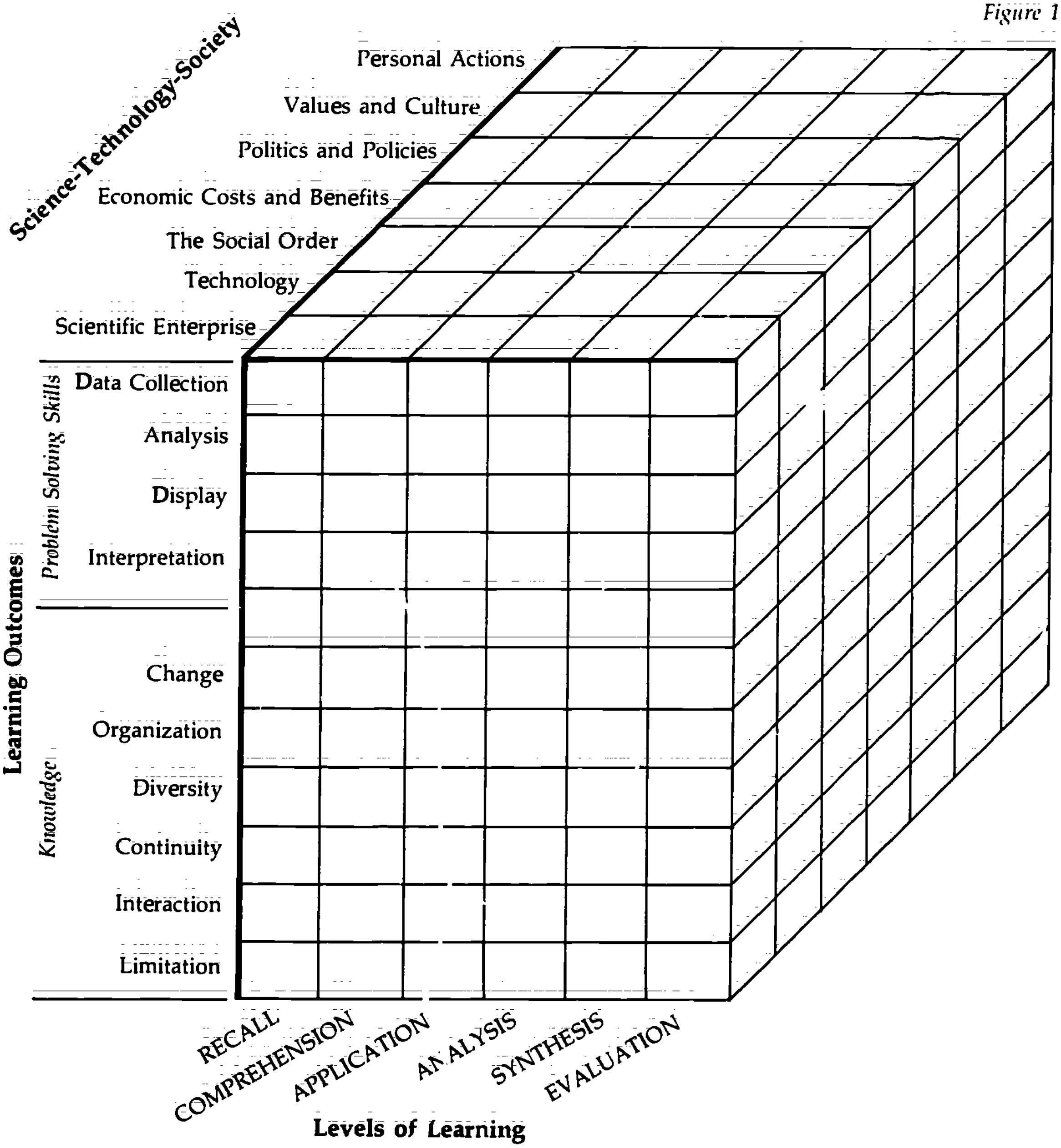
The horizontal axis displays levels of learning such as simple recall and the synthesis of information from other areas. Some topics may require testing only at the recall level, such as the correct spelling of the four components of DNA, while at other levels students should demonstrate their ability to apply scientific principles and to discuss the significance of these in terms of their own social, economic, and political order.

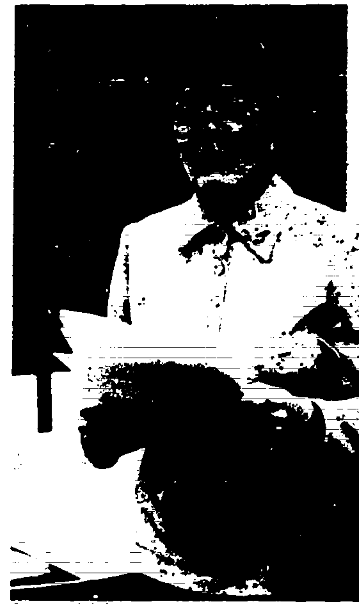
The third axis places science in a social setting with examples of STS themes, so that students and teachers see how ideas from science and technology affect the social order, the economy, and political matters, among others. An example will help to illustrate themes that are to be taught and evaluated. Nicolaus Copernicus proposed the heliocentric model of the solar system in 1543 with the publication of *De Revolutionibus Orbium Caelestium (Concerning the Revolutions of the Heavenly Spheres)*. This new model for understanding the world is, of course, of great significance, but placing the discovery in a social context allows the student to examine Copernicus' work in light of the Protestant Revolution and may led to a thoughtful analysis of the interaction between the religious teachings of the Church of Rome and the subsequent difficulties of Galileo.

As another example, in a physics or physical science class a discussion of solid state physics might be tied to the development of the transistor, which led to the integrated circuit and microchips, which finally led to the microcomputer. This opens the door to a discussion of the costs and benefits of basic science, the role of the creative inventor, and the general impact of computers on society. While this is a useful example of scientific development leading to a technological application, the microcomputer also (conversely) provides an excellent example of the effect of technology on subsequent developments in science.

The goals of science education described earlier require an expansion of the evalua-

*Figure 1*



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tion process. In contemporary science education it is probably not adequate to test a student's recall of the names of the parts of a flower, the chemical constituents of compounds, equations for heat transfer, or the different types of rocks. It is also important to document the student's ability to construct a forceful argument for or against construction of a nuclear power plant, including a scientifically correct explanation of the fission process, as well as the process and effects of radiation, and a statement of the associated risks to health, the costs, and the benefits of energy to the people in the region. Most current evaluation procedures ignore the integration of knowledge from other disciplines and the application of science in a specific social setting. A science program for tomorrow's world should require students to demonstrate competence in the use of their knowledge of science and its processes and an understanding of the interaction of science, technology, and society. Therefore, science teachers ought to develop ways of not only teaching these interactions but also documenting the effect of such knowledge on the personal values of the student.

*Effectiveness of Teaching.* Review of a teacher's effectiveness should be an integral part of any evaluation. Moreover, evaluation by students, peer review, and feedback from former students who have now gone on to college, technical school, or the work place can provide teachers with a useful assessment of the effectiveness of their teaching and suggestions for its improvement.

The results of the personnel review, coupled with program and student evaluations, should be used to establish a systematic program of staff professional development. Such a program is essential, for without it all the effort that has gone into the evaluation process will be in vain. School district administrators must realize that in a rapidly changing subject area such as science and technology all personnel need continual updating. A program of staff development based on results of a comprehensive evaluation process should be supported by school districts at a level of not less than 5 percent of the personnel budget. This should be used to cover attendance at national and regional meetings, in-service training, the development of special courses in conjunction with nearby colleges and universities, and such other features of professional development programs as are indicated by the personnel evaluation program.

## The Role of Science Supervisors

Many of the major initiatives in the current reform in science education are taking place at the state and subsequently at the local level ("Summary of Major. . .," 1985). This thrust suggests a new role for state, district, and school science supervisors. Indeed, many such individuals have been deeply involved in the reform and are experiencing a new orientation in their positions (Dowling & Yager, 1983; Gallagher & Yager, 1981). A review and revision of the supervisor's position is as much needed as are new materials and instructional strategies. The scope of this position was considered by the conferees at Exeter II.

*The science supervisor's role.* The role of science supervisor in today's schools is changing from the prevalent model of secretary-custodian-clerk to that of instructional leader. The supervisor may:

- assist in the improvement of classroom instruction through clinical supervision,
- design staff development programs,
- specialize in updating subject matter for the use of science teachers,
- advocate science education within the school district and community, and
- promote research-based, community-supported change.

To do all these things requires a unique combination of abilities and talents, for science instructional leaders should also ideally have such personal attributes as competence as a practicing science teacher, and enthusiasm, confidence, and decisiveness in working with others. An awareness of the materials and resources needed to teach school science, teaching experience in a variety of science classrooms, and involvement in science education at a leadership level are also desirable.

*Providing support and training for supervisors.* While the support of school districts must extend to all who are involved with the school science program, the Exeter II conferees strongly advocated that support for science supervisors be strengthened in every practical way by:

- assigning them authority to carry out the reform of school programs,

• providing them with sufficient time, resources, and support services, and
• supporting their professional growth through funding for professional meetings and activities.

Even with financial and moral support at the local level it would be difficult for any science supervisor to attain all the goals we have described. Hence, recognizing the central role played by supervisors and their capacity to catalyze change, the Exeter II conferees argued strongly for a national program to support leadership development among science supervisors.

The national program would train key science supervisors, such as those at the state level and in major school districts, who would in turn conduct workshops at the local level. At the local level they would, in turn, train teachers in new methods and new curriculum programs, and with their help design staff development programs for their school system, and upgrade their science programs.

In addition to providing the initial training for instructional leaders in science, the national program would establish a communication network that uses appropriate technology (e.g., electronic mail) to disseminate information and resources related to science education. The creation of informational resource centers linked to others across the country and modelled after the Pittsburgh Resource Center for Science Teachers (Carnegie Institute, 4400 Forbes Avenue, Pittsburgh, PA 15313) would go a long way toward enhancing the effectiveness of supervisors still further — and teachers, too — at relatively modest cost.

Conferees at Exeter II recognized the crucial role of science supervisors as administrators and as instructional leaders. In the past too little attention has been paid to their efforts, but now, and for the foreseeable future, with changing curricula, the supervisors are in a position to be essential agents of science education reform. In an age that recognizes the need for networks connecting individuals in many ways, the science supervisor should be seen as one who connects science teachers with school administrators, with scientists in colleges and universities, and with the public.

**Preparing Science Teachers**

The current shortage of science teachers is well documented, and there is evidence the shortage will get worse. For example, between 1971 and 1980 there was a 64 percent decline in the number of undergraduates entering science teaching (Shymansky & Aldridge, 1982). The shortage has resulted in significant numbers of teachers' being reassigned from other disciplines to science (Council for Basic Education, 1985). One estimate is that 30 percent of secondary science teachers are either unqualified or severely underqualified to teach science (Aldridge & Johnston, 1984a, 1984b).

The education of future teachers is a large and complex task, and there is a need to rethink and redesign pre-service education in order to assure that new teachers are aware of the best instructional strategies and curriculum programs. Science teachers already in classrooms need updating, too. Exeter II conferees first and foremost supported the position that the design of secondary, middle/junior high, and elementary degree programs should be consistent with criteria established by professional groups such as the National Council for Accreditation of Teacher Education (NCATE) and with program requirements from state departments of education.

Exeter II participants endorsed the NSTA position statement *Standards for the Preparation and Certification of Teachers of Science, K–12* (1983). This document provides an excellent framework for use by those reviewing and redesigning science teacher education programs.

The primary recommendation from the Exeter II conference was for a five-year program leading to certification as a science

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teacher. This recommendation includes a four-year liberal arts degree with a science major followed by a fifth year of teacher education.

Study for a liberal arts degree would be based on a foundation of courses distributed across traditional areas (such as the humanities, the social sciences, the natural sciences, and mathematics) and a major in science of one of two types. The traditional major would be in a science discipline such as physics, chemistry, biology, or geology. Prospective teachers electing a major in one of the scientific disciplines would also complete a minor in another scientific discipline or the equivalent of a minor in an interdisciplinary study such as science, technology, and society. Many colleges and universities now have science-and-society programs, and Exeter II participants recommended that a concentration in such a program be recognized as an acceptable component of a science teacher program leading to certification.

The second type of science major would be the inverse of the first type, requiring a balance of credits across the disciplines, i.e., physics, chemistry, biology, and the earth sciences. With this major also, a minor would be chosen in one of the scientific disciplines or in an interdisciplinary science-technology-society study. This broad area science major is particularly appropriate for students intending to teach at the middle school level.

The fifth year program would follow the bachelor's degree and require that a candidate meet all program requirements established by accrediting agencies and the particular institution of higher education. Any deficiencies, except in education courses, must be made up prior to entering the fifth year teacher education program. In recognition of the importance of science teaching, Exeter II participants suggested that an overall grade point average of 2.75 and a 3.0 average in science (on a 4.0 scale) should be required for entrance into the fifth year program.

A major component of the fifth year program would be an internship conducted under the guidance of a mentor teacher who has been selected through common agreement by public school and college or university personnel. Mentor teachers would be compensated for their work.

Flexibility is inherent in such a preservice program. In one approach the intern might spend one preparation period and two class periods per day in a science classroom. The rest of the day would be devoted to class attendance or study at the college or university. As a second example the intern would alternate between working in the school system full time and attending the college or university full time.

The college or university courses forming the fifth year program should include material on the following topics:

- Methods of educational research.
- Instructional models, teaching strategies, and specific responsibilities of science teaching.
- History and philosophy of education, with emphasis on science education.
- Contemporary issues in society, with emphasis on the politics, economics, sociology, and psychology of science-related social issues.
- Psychology of teaching and learning, with emphasis on theories of motivation, development, learning, and social psychology.
- Methodologies of classroom management.

After the fifth year program the intern science teacher would be granted initial certification and move to the position of resident teacher. The resident teacher would have full teaching responsibilities and a salary. This position would be, however, probationary. Resident teachers with a school district would be required to enter a district-sponsored staff development program. A mentor teacher would monitor the resident's progress and act as the resident's immediate supervisor. The school district would be responsible for compensating mentor teachers for their extra duties, much as districts now do for coaches and band directors. After the two-year residency the teacher would be eligible for permanent certification. If necessary, the probationary period could be extended for one year. Such a decision would be based on evaluation by the mentor teachers, school administrators, and other science teachers within the school where the probationary teacher had been teaching. The levels of professional development recommended at the conference are summarized in Table 3.

*Table 3*

**Levels of Professional Development**

1. **Intern Teacher (1 year)**
This person would not hold a certificate. He or she would be supervised by both college and public school personnel.

2. **Resident Teacher (2-year minimum)**
This person would hold temporary certification and would participate in a staff development program and be supervised by public school personnel.

3. **Professional Teacher**
This person would hold life-time certification or a renewable license, depending upon state policy. He or she could conduct staff development programs.

4. **Mentor Teacher**
This person would hold a joint appointment with a school district and a college or university. He or she would hold state certification and be responsible for organizing and conducting staff development programs and for supervising interns and resident teachers.

### Priorities for Action

All participants reacted to the presentations and met together as a group. Yet, the six task groups were in many respects autonomous. The individual reports were narrowly focused on their single central areas of concern. Even though much of the give-and-take occurred in the six group discussions, a broader purpose united all conferees: the quest for a "world view" of school science education within which it would be possible to reach general conclusions and frame any appropriate recommendations. One unifying view was already available and was carefully considered by all participants; this view had been put forward in the 1983 National Science Board Commission's report, *Educating Americans for the 21st Century.*

The Exeter II conferees accepted the NSB commission report unanimously. The report's recommendations provided a framework for their own discussions. Many of the conclusions in the six task group reports reinforce them, are consistent with them, or simply build upon them.

The commission report urged that every child from grades one through six spend at least one classroom hour on mathematics and half an hour on science every day and that high schools nationwide require a minimum of three years of mathematics and three years of science and technology for graduation from high school. In the course of its 17-month study, the commission prepared detailed suggestions for a K–12 science program recommended for all students, including the following:

1. *Grades K–6.* An integrated hands-on approach that focuses on the relationships between humans and their environment and emphasizes problem solving.

2. *Grades 7–8.* An emphasis on life

science, especially human biology and personal health, and on development of quantitative skills in science, including computer-based experiences, quantitative analysis of data, application of probability, and estimating.

3. *Grades 9–10.* A required two-year sequence on science, technology, and society emphasizing problem solving and scientific reasoning as applied to real-world problems.

4. *Grades 11–12.* One- and two-semester courses in physics, biology, chemistry, and earth sciences intended for students who wish to go on to further academic study in science-related careers.

A nationwide K–12 program such as the one advanced by the National Science Board will not — and probably should not — ever be completely achieved, since there will always be tension between the independent concerns of state and local school boards and any unifying national standards. But continuity of program need not mean lock-step articulation, and given the mobility of Americans and the resulting disjointed sequence of courses visited upon their school-age children, any pressures that favor continuity in the science curriculum must be counted as desirable. Thus the conferees concluded that the science curriculum of grades 7–12 in each school system should provide a connected sequence of internally consistent material patterned after the National Science Board's recommendations.

A notable feature of the NSB commission report is its insistence that science should be made a part of the experience of every child from grades K–12 — while many schools offer science somewhere in the curriculum for each of the school years, they do not by any means offer it to all the children in those grades. The Exeter II conferees agree and hold that every practical means must be found for adding science to school curricula, with the goal of involving all children with science in some way each year. Each grade level has been neglected nationwide in one way or another, but since Exeter II was primarily concerned with secondary level science education, its participants were particularly concerned with the direction of the curriculum in the upper grades.

A very large number of secondary school students diligently avoid all science courses and therefore remain ignorant of the scientific and technological forces shaping their lives and future careers. These, perhaps, are the most difficult populations of all to reach, and yet it should not need repeating that a modern democracy depends on their critical thinking, their problem-solving skills, and their decision-making abilities fully as much as those of other citizens. Not incidentally, social justice requires it as well. This is a goal that may never be reached; what we urge here is an ideal whose pursuit will require imagination and leadership and cooperation, but above all a community conviction that science literacy is for *all* students, not just a few.

At once the question arises: What are they to be taught? What should all citizens know about science and technology and be able to do?

The report of the task group on goals expands on this matter. The goals of science education for all students — including future scientists — should address personal needs, societal and global issues, inquiry skills, science as a human endeavor, and career awareness. These goals are parallel to those identified by Project Synthesis (Harms and Yager, 1981).

In 1980 Exeter I recommended an infusion (equaling 10 percent of the course) of STS material into all secondary-level science courses; a 1983 report of the NSTA argued for 20 percent. Exeter II agreed with 20 percent as an ideal for secondary-level grades and recommended 10 percent for elementary grades. Thus there was unanimous support for using STS as an accompaniment running through the entire K–12 science curriculum, sometimes infused in conventional material, sometimes dealt with explicitly and at length, particularly in grades nine through twelve.

In recent years it has become difficult to talk about the renewal of science education without including STS as part of the discussion. The relevance of its topics — problems associated with food, housing, trade, natural resources, health, energy, entertainment, fuel, defense — to everyday life is unchallenged. The subject matter is appropriate to all grade levels and serves to unite science and other subjects (such as history, social studies, and geography) and the disciplines within science as well. It appeals to students by addressing the world in which they will soon be consumers, parents, and voters. In all of these ways, STS material stands in sharp contrast to much of what is traditionally taught in chemistry, physics, and biology.

STS was central to the discussions of both Exeter I and Exeter II; indeed, Exeter I was one of the first conferences to declare the importance of STS studies to science education renewal. The endorsement of these two conferences gives weight to the argument for recognition of STS materials as essential to the meaningful reform of all courses in the science curriculum.

The attention of the conference was focused upon grades 9–12, and the teaching experience of the conferees themselves was concentrated in those grades. Much of the abundant STS teaching material becoming available is aimed at the college and senior high school levels, and most curricular development seems to be directed toward those levels, to the relative neglect of the lower grades. The conferees agreed that K–8 and K–9 curricula will need an immense amount of attention and research in the future.

The task group concerned with supervision discussed (among other things) the capacity of good science supervisors to bring about significant reform in curriculum as well as teaching practices. The task group, and indeed the full group of conferees, agreed that the supervisor's role was pivotal. Many, if not most, large school systems already have science supervisors whose responsibilities are listed earlier in this report. A good supervisor is often the catalyst who makes a poor science program into an adequate one or an adequate program into an excellent one.

But good supervisors, like good teachers, are hard to find. The Exeter II conferees agreed that supervisors were essential to the improvement of any large science program and merited particular support. Whether the programs proposed for training supervisors are national programs or state programs, it was felt that the benefits for school science programs would be greater than those obtainable from any other comparable use of funds, and that the effects would be felt by classroom teachers throughout the area.

It may be argued that efforts should be made to reach all classroom teachers directly, rather as the National Science Foundation summer institute programs did so successfully in the 1960s. But the Exeter II conferees, some of whom took part in that effort, were mindful of the greater cost effectiveness of supporting and upgrading the supervisors first, given today's financial constraints, and mindful, too, that such qualified and trained specialists will be put in a position to initiate healthy changes within the science teaching community and to pursue the cause of science education in the public arena. Accordingly, conferees agreed that school administrators and school boards should initiate funds and programs for the purposes of supporting and assisting science supervisors.

While supervisors may well be central to the cause of reform, their best efforts will be wasted without the cooperation and competence of a well-trained corps of teachers. It should be taken for granted that any program that promotes the effec-

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tiveness of supervisors will also involve teachers as the final arbiters of what is taught in the classroom — and how it is taught. Teachers' participation in designing curriculum change should be a matter of partnership with supervisors on a basis of professional equality.

The task group devoted to teacher education recognized the importance of pre-service and in-service training to the success of any program of science education reform. It also recognized the complexity of the task of creating change. While applauding the federally-supported summer institutes that helped thousands of science teachers in the 1960s keep up-to-date, the conferees recognized the improbability of such a program's being duplicated in the 1980s and the unlikelihood of any uniform standard's being adopted to guide state or local efforts. As guidelines towards that goal, however, the conferees supported the standards set by the National Council for Accreditation of Teacher Education and the National Science Teachers Association for the education and in-service training of teachers. They agreed that, as far as possible, the education of science teachers should include a four-year liberal arts degree with a science major and fifth year devoted to teacher education. The structure of the fifth year is set forth in the report of the task group on teacher education.

In the end, although science teachers need incentives and realistic opportunities for expanding their teaching abilities and upgrading their knowledge, they will take advantage of them only if they see themselves recognized as respected members of the scientific community. Fortunately, there are signs that this is beginning to happen, among them the establishment of means for the national and state recognition of outstanding performance. There is much more to be done in such matters as establishing a consensus on what constitutes reasonable in-service education and establishing hiring, assignment, and tenure standards, not to mention obtaining adequate resources for supporting in-service programs.

As the week drew to a close the conferees felt a need to set priorities as a group. There was a feeling that setting such priorities would be a means of speaking with more force than is possible when speaking individually. Also, there was a general feeling that the persons and groups to whom the final report was directed would appreciate a concise statement of the primary problems and the issues needing immediate and concerted attention.

*Priority Problems and Suggestions for Their Solution*

A total of nine problems were identified by the group as priority problems. All discussion on the final day was devoted to an analysis and ordering of these problems. Four problems were identified by vote as the most critical ones — they were deemed far more important than the other five priority issues. These four megaproblems are:

1. *An inappropriate science curriculum.* Current programs lack relevance; they depend too much upon relatively few textbooks with little difference from level to level and community to community. The science curriculum is seen as too compartmentalized, too discipline-bound, unrelated to student needs, and isolated from other parts of the school program and from life in general.

2. *Goals with a lack of vision.* It was generally agreed that current science courses typically lack clear and socially significant goals and a sense of mission. Stated goals are bound to content, out of touch with current needs and societal issues; they do not provide a blueprint for curricula, teaching strategies, or evaluation.

3. *Too little attention to the nature of instruction.* Most past concerns have focused on course content and related goals. The most common form of instruction is the lecture, which is inappropriate for most students. The strategies most teachers em-

ploy are not effective, creative, or research-based. Too much science instruction is based on explaining, reviewing, and elaborating on concepts from textbooks; too much is geared to tests and testing procedures.

4. *Teachers' lack of status and self-esteem.* Too many teachers are unmotivated, apathetic or lacking in confidence. Teachers basically feel that their profession is one with low status.

Considerable time was spent discussing the relationship of these problems to each other as well as the actions recommended for their resolution. It was noted that all four are problems teachers have the power to resolve.

The five remaining priority areas involve situations that are beyond teacher control. Since there are no quick, general, or unique solutions to these problems, much less time was spent in discussing them.

5. *Lack of leadership.* Most districts do not have a science supervisor or coordinator. As a result, there is little integration, poor coordination, and inadequate communication among teachers and school leaders. Teachers are less effective than they might be; they feel they have no power for change because of the lack of science education leadership.

6. *Inadequate programs for teacher preparation and staff development.* Many teachers lack adequate science and science education background. Few programs are available to provide continuous support and promote growth.

7. *Lack of adequate resources for teaching.* There are poor lines of communication among teachers, schools, and professional levels. Teachers often feel that class time is inadequate, necessary teaching materials are not available, equipment is out-of-date or unavailable, and facilities are in need of refurbishment.

8. *Inadequate institutional support systems.* There is too little institutional support and an inadequate budget. Political barriers are seen to discourage superior performance and hinder improvement. Scheduling often causes problems.

9. *Students' poor attitudes, which contribute to their lack of success.* Many teachers identify students as unmotivated and apathetic. Many lack basic skills, and science teachers have little time to provide extra assistance.

The task group chairs helped extract the recommended actions from their reports and deliberations. These recommendations and positions — each corresponding to one of the priority issues — include:

- *Curriculum.* A strong feeling was expressed in favor of an articulated K-12 curriculum taught with consistent goals throughout the 13 years and integrated with other subjects. Curricula should conform nationwide as nearly as local circumstances might permit. Strong emphasis on science-technology-society topics would increase the relevance of material and decrease the compartmentalization found too often in current courses, but traditional goals of science education (scientific knowledge, methods of inquiry, and career exploration) should *not* be eliminated to make way for the STS theme.
- *Goals.* Science education must be for *all* students — women, minorities, physically handicapped, and educationally disadvantaged included. Moreover, since current school science courses frequently address the needs of only the tiny minority who ultimately pursue careers in science and engineering, it is imperative that a major reordering of priorities make it possible to address the needs of students who are not planning careers in science.
- *Instruction.* Current research in new instructional strategies has identified practical ways teachers can transcend the conventional lecture and discussion models of teaching geared to textbook memorization and standardized tests. Schools and individual teachers should investigate alternatives of proven worth that are available.
- *Professional Status.* It has become a

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cliché that teachers are too often beset with a sense of low status, are ill-prepared, and lack motivation to improve themselves. With a quarter of all school teachers seriously considering leaving the profession within the next five years, low morale is demonstrably a major problem. Increased support from the community, improved communications and resources, and professional development programs would help raise morale and motivation.

• *Supervision.* The conferees agreed that the science supervisor is the key to effective reform. The leadership of a carefully chosen supervisor who has specialized training and sufficient authority can make a large and immediate improvement in a science program. A nationally supported program for supervisor training would provide a realistic opportunity for significant reform in school science education in the near future.

• *Teacher Education.* The conferees recognized the impending shortage of trained teachers and endorsed the teacher training criteria established by the National Council for Accreditation of Teacher Education and also the report *Standards for the Preparation and Certification of Teachers of Science K–12* developed by the National Science Teachers Association. They drew up a detailed outline for an ideal five-year program leading to certification as a science teacher.

• *Resources.* Teachers report a need for more time to do their job well, as well as materials, equipment, in-service support, and the kind of communication network with other teachers that is essential to the support of morale in what is often a lonely occupation. Science teacher resource centers are a step in this direction.

• *Institutional Pressures.* Increasing budgets and reducing political barriers and scheduling restraints would help overcome the problem of low morale. Increasing salaries is important, but solves only part of the problem.

• *Students.* The conferees noted the widespread lack of motivation and basic skills among current students. They discussed improvements in programs that they believed would produce some beneficial effects on students.

Setting priorities was a difficult task and one that many found uncomfortable and distasteful. The chosen priorities represent a coalescence of ideas and compromises of deeply held convictions, opinions, and interpretations. These "sense-of-the-meeting" statements lack some of the crispness and vigor with which they were expressed by individuals during the six task group deliberations. Nonetheless, they represent realistic, workable, and consistent reforms appropriate to the needs of secondary science education.

*Principal Recommendations*

Five points reported earlier in this chapter stand as the principal recommendations of the conference. They are consistent with the above list of priority problems and suggested solutions.

In summary, these positions are:

1. In each school system the science program in grades 7–12 should be articulated in such a way that there is an identifiable sequence that is designed to meet the recommended new goals for science for all students.

2. Science education must be planned for *all* students from all social groups and be included as a central component of the program for each student each year.

3. Science-technology-society materials and approaches are essential to the meaningful reform of all courses in the science curriculum.

4. School administrators and school boards should initiate funds and programs for the purpose of enhancing the effectiveness of science supervisors.

5. The education of science teachers should include a four-year liberal arts degree with a science major and a fifth year devoted to teacher education.

## Post-Conference Reflections

As co-directors, we have benefited from the feedback from those conferees who responded, often thoughtfully and extensively, to the first draft of this report, and now we would like to offer our own thoughts on what we think the participants might have recommended if Exeter II had gone on beyond its alloted time of one week. While we take the risk of seeming to speak for the conferees, we do speak for those who felt quite naturally that the conference was silent on matters they would wish to have addressed. In either case, we accept the blame for any omissions or implied commissions; the following thoughts are ours alone.

As the week went on, the several specialized task groups presented their positions to the entire body of conferees, and after extended discussion general agreement was reached on a series of position statements which are detailed in the six task group reports in Part II. To observers of the process several consistencies began to appear in the discussions, and by the end of the week they became sufficiently pronounced to permit a tentative internally consistent statement. A kind of cultural center of gravity seemed to establish itself that, though it lacked formal recognition, could be included with the five recommendations summarized in the previous section.

Then there were other matters that might have been considered but were in fact overlooked entirely. Doubtless it was lack of time that prevented a more thorough look at research in science teaching for guidance in devising curricula and instructional materials. Also, the question of how a science teacher can best introduce material that involves controversy and value judgments is a pedagogical matter on which science teachers are not informed, although their social studies colleagues deal with such material in their classes every day. What is the most appropriate material to introduce, and what cognitive skills are involved in relating science and technology topics to social issues that students cope with in their personal lives? Not only is there very little information available to curriculum planners devising the curricula we have advocated, but also there is a need for techniques for testing the effectiveness of the proposed curricula and teaching methods, especially those concerning STS issues.

Such material is beginning to become available (the NSTA series *What Research Says to the Science Teacher* is an example), but there will always be the problem of dissemination. Much valuable research is conducted locally, and much useful teaching material is created at the local level. Active teachers wish to obtain this material, and many also want to take part in its creation. A major reason they do not do so is that they do not know what meetings and research are taking place, what teaching material is available, or how to obtain the materials and information. Exeter I grappled with this problem in 1980. The problem has grown steadily more severe in the meantime and is bound to go on getting worse.

A natural response to this problem, as the Exeter I conferees recommended, is formation of teachers' resource centers. If it is true that science and technology are developing at such a rapid rate that even a trained and dedicated science teacher cannot keep abreast of new developments or reflect on all their consequences for society, and if it is true that the tools needed for the most effective teaching are often expensive or hard to find, then a science teacher needs access to a resource center. Such a center can function as a register of a community's speakers, of apparatus available for loan or giveaway, of slides, films, printed material, and local field trips, all cross-cataloged by subject and by grade level and available to any teacher via telephone call or computer link-up. Tests, jour-

nal articles, hints for making apparatus, laboratory report outlines, and research reports on science teaching are becoming ever more accessible through such linkages among computers, even distant ones. Ideally such a center should occupy a building (not merely an office) where meetings, seminars, and displays of apparatus and printed material can take place and teachers can socialize with other area science teachers. The Pittsburgh Resource Center for Science Teachers is such a place. Its creation was one of the consequences of Exeter I.

Turning to another issue discussed at the conference, we would like to comment on the pervasive topic of science-technology-society. Of course we support the goal of infusing STS material in any appropriate format ranging from a full formal course down to brief allusions within a course. However, if our goal in doing so is the nurture of responsible citizens capable of making informed and thoughtful decisions, then we must resist the idea that the education of such citizens lies exclusively within the science classroom. We cannot do it alone. Understanding science-related social issues such as acid rain or the causes of environmental bankruptcy in Africa requires a synthesis of information and concepts from the disciplines of history, economics, politics, law, and science and technology, all viewed in a global context. There are many such interdisciplinary issues that science teachers are simply not equipped to deal adequately with on their own. This admission will please many science teachers who find it easy to think of the "society" in science-technology-society as the nearly exclusive property of social studies teachers, anyway, and use this as an excuse for inaction. Furthermore, science teachers generally claim they are ill-prepared to deal with such issues and temperamentally reluctant to raise questions that require value judgments and have no right or wrong answers. These arguments undoubtedly have merit, but events have overtaken us. Daily the increasing influence of science and technology on human welfare is creating societal and ethical problems for which the traditional contents of science or social studies courses alone can offer no solutions. There is an increasing mismatch between the science we conventionally teach in our high schools and the complex, bewildering world in which we live. The people destined to be leaders and decision makers in that world are in our classrooms this very day. We cannot go on indefinitely "passing the buck" to our colleagues.

Of course, social studies teachers, in turn, argue that *they* do not consider themselves competent to deal with issues that have a large component of science and technology. Each teacher needs the particular background and specialized classroom expertise of the other; neither is any longer capable of doing the job well alone. A strong case should be made in favor of close collaboration in any of the many possible ways. Little has been written but much can be done in the direction of research into effective patterns of collaboration between science teachers and social studies teachers in dealing with the great issues surrounding STS education.

# AFTERWORD

What are our hopes for Exeter II? This report is a statement of the current thinking of practicing classroom science teachers who are alert to the teaching culture around them. They recognize that the numerous reports calling for the reform of education are addressed to the professional world that they know intimately and have thought about hard and constructively. They recognize that reforms are going to occur only with the active support of teachers and that teachers should therefore have a voice in their design. While one week may well have been too brief a time for more than a superficial examination of the issues, Exeter II, like Exeter I before it, demonstrated nonetheless that meetings of so large and so varied a group can accomplish a great deal in a short time. While one person acting alone cannot usually do very much, a few teachers and nationally recognized specialists acting in concert can make a significant statement.

Most reports, and certainly those advocating reform in education, have a limited life expectancy, and surely this one does too. What benefit may result from this conference must be recognized promptly if it is to have much effect. But it is fair to hope that, whatever the fate of their particular recommendations, Exeter I and II will be remembered as examples of a process worth repeating, perhaps on a regular basis. Carried on year after year, meetings composed in a manner similar to Exeter I and II would paint a continuously unfolding picture of science education, sensitive to its evolving needs, reflecting the experience of its practitioners and, equally, the views of specialists and thoughtful observers. It would be a seed bed of ideas and views originating closer to the scene of action than most recent reports, and because of its mix of theoreticians and practitioners, its recommendations ought to possess an uncommon force and realism.

Like a few silver iodide crystals dropped in a supersaturated cloud creating a chain reaction of condensation, multiple efforts like Exeter I and II may someday encourage a change of state in an educational system that is sensitive and ready to evolve in new directions.

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