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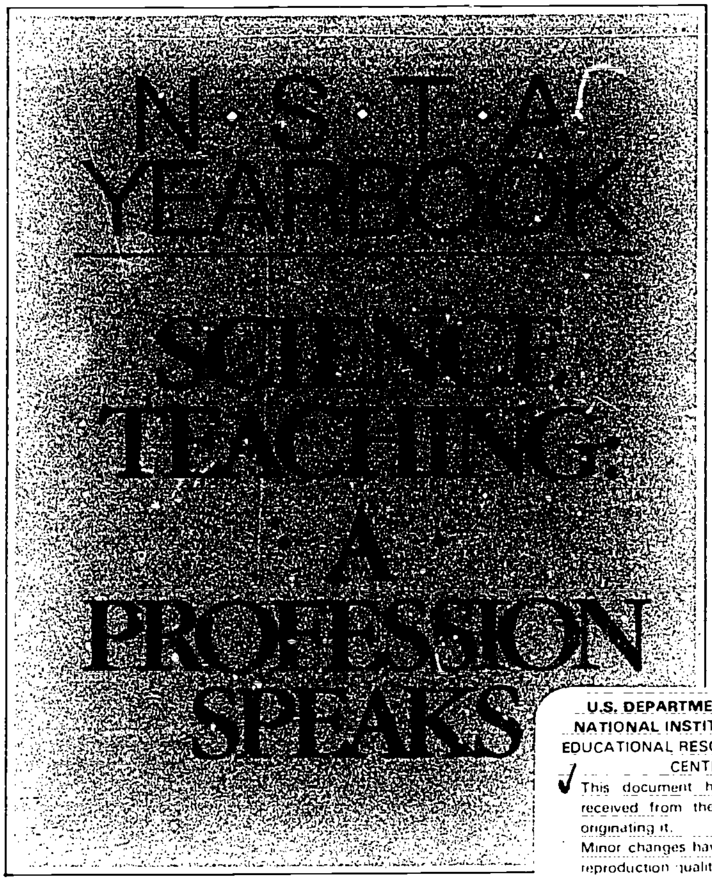
ABSTRACT

This three-part yearbook begins with a characterization of science education practices based on extensive national studies conducted during the period 1977 to 1983 and a discussion of several efforts which address the current crisis in science education. The second part consists of essays focusing on practical, program, and on political and policy concerns in science education. Among the areas examined in these essays are whether or not: scientific literacy makes a difference; basic beliefs of scientists and society are tapped in schools; science is made available for all students and for women; science is linked with industrial and local community resources; the individual uniqueness of students is tapped in school science; school science nurtures creativity; science teacher preparation nurtures effective science teaching; teacher's knowledge improves his/her instruction; school science taps the key resource of the elementary principal; school science fits the needs of each learner; school science enhances writing and language literacy; and whether or not science teachers influence political or policy decision-making. The final part, addressing the need for a national identity for science education, discusses a national laboratory for science education and the contributions of such a laboratory. (JN)



N·S·T·A YEARBOOK

SCIENCE TEACHING: A PROFESSION SPEAKS

NATIONAL SCIENCE TEACHERS ASSOCIATION
1742 Connecticut Avenue N.W.
Washington D.C. 20009
202 328-5800

Dear Life and Comprehensive Members:

Here is your complimentary copy of the 1983 NSTA yearbook, Science Teaching: A Profession Speaks. This publication has been selected for you in fulfillment of one of your membership benefits because it is a timely reference. We believe that it will stand as an important document on the status of science education in our time.

Although this edition will be the first of many yearbooks to come, we cannot guarantee that they will be selected from among our NSTA Special Publications for free distribution to our Life and Comprehensive members.

Additional copies of this 1983 yearbook can be obtained by sending $6.50, plus $2 for mailing, to NSTA Publication Sales. You might consider reserving a copy of the 1984 edition now as well. We will be happy to bill you next year.

Sincerely,

Bill G. Aldridge
Executive Director

Science Teaching:
A Profession Speaks

1983 YEARBOOK
OF
THE NATIONAL SCIENCE TEACHERS ASSOCIATION

Edited by
Faith K. Brown and David P. Butts

1983 Yearbook Advisory Board

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by Robert E. Yager, Bill G. Aldridge, and John Penick

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Foreword

This is an exciting time for the National Science Teachers Association to embark on a new publishing venture—a series of NSTA yearbooks. The *NSTA Yearbook* is envisioned as a review of the issues that have predominated in the field of science education during the preceding year. Each installment in the series will assess problems, record current thinking pertinent to science education, and outline efforts by members of the profession who are working to improve it.

Each year, the *NSTA Yearbook* will be released to coincide with our annual meeting, at which a special *Yearbook* symposium will involve the *Yearbook*'s editors (one affiliated with a university and one a classroom teacher at precollege level); the authors; and selected readers who wish to respond. Such a symposium will provide an opportunity to learn about the *Yearbook* and about reasons for the selection of *Yearbook* topics. The *Yearbook* and the symposium, then, will enable Association members to consider and discuss the status of their profession.

As the first edition in our series makes clear, 1982-1983 has highlighted for Americans—leaders in government and industry, as well as private citizens—the troubling condition of science education in our country. State governors have established commissions and task forces to study the crisis; state lawmakers are working, through their legislatures, to resolve the problems; among many initiatives in the U.S. Congress for fiscal 1984, H.R. 1310 included $425 million for science mathematics education. A total of $15 million has been made available at the National Science Foundation (NSF), for fiscal 1983, to begin a national effort to restore school science to the position it merits.

The 1983 *NSTA Yearbook* begins with a characterization of science education practices based on extensive national studies, which were conducted during the past five years. (It has been estimated that $5 million [mostly NSF funds] has been spent in assessing precollege science education during the period 1977-1983.) It is probably correct to assert that thanks to this accumulation of research, we now know more about current practices in science education than we ever have in the past. Part I of the *Yearbook* summarizes these studies and presents a brief exposition of some current efforts which address the crisis.

Part II comprises essays by NSTA members in which they offer their views on where science education today *should* be. These authors take on practical considerations: the problems inherent in the school setting, curriculum problems, and societal concerns.

The *Yearbook* ends with a delineation of a needed national identity for science education.

NSTA's officers expect that science educators will continue to make their voices heard and that as a new volume is added each year, the series will evolve into a contemporary profile of our discipline.

Perhaps the most important function of any publication is the stimulation it provides its readers. The success of this first *NSTA Yearbook* will be measured by the dialogue that it occasions; and, presumably, some issues that it evokes will be considered in future yearbooks of this series.

I would like to congratulate the editors of this first volume, Faith K. Brown and David P. Butts, for their accomplishment. Of course, the Yearbook Advisory Board assumed a huge task in establishing the book's plan, arranging for authors, and preparing the book for publication. The first is always the most difficult—with no models to follow, the task of securing funds, and adjustments of all sorts in order to meet deadlines. I would also like to acknowledge the contributions of Bill G. Aldridge, NSTA executive director. I am sure the entire membership as well as the larger science education community join me in saying, to all who contributed, "Well done!" Preparation for the second installment in the series is already underway; the *Yearbook* symposium will be an important feature at NSTA's 1984 National Convention in Boston. We can anticipate provocative new ideas and issues, and grist for future yearbooks.

Robert E. Yager
NSTA President, 1982-1983

Preface

In 1983, schooling is in trouble. In a recent study of more than 1,000 classrooms, Goodlad found them characterized by one quality: monotony. The sources of the monotony lie not in what schooling *has* but in what it does *not* have. It lacks

- effort to help pupils achieve
- teacher interest and cooperation
- expectation for virtually any cognitive demand
- pupils' active participation and involvement in the learning process (that is, they sit, listen, and receive while the teacher talks)
- exploration or interaction or the excitement of discovery

The rule for teachers seems to be: Know whom you are to stuff with facts; stuff them; and then see if they were stuffed. Goodlad concluded that schooling is essentially paced according to the lowest common denominators, with competency exit exams designed to measure only these lowest denominators.

As reflected in science and mathematics opportunities in schools, his conclusions find wide support. Student performance in science and mathematics continues to slide downward. Qualified teachers are disappearing rapidly. And for those teachers who do work to involve students in the joy, excitement, and intellectual power of science and mathematics, the curricular options are carefully controlled by a textbook industry which delivers only those products that guarantee a high profit. Although half of all the world's scientific knowledge has been produced since 1965, the textbooks that sell are those that reflect pre-1965 scientific knowledge.

Can or should we listen to our critics? As one critic has facetiously noted:

> There is something positive to be gained by acknowledging one's critics. Like all God's creatures, critics have a purpose in this world. They offer criticisms of one's conduct (albeit insights) that are not always provided by friends. They also encourage self-esteem. How would we know the magnitude of our own worth without someone so worthless attacking it?

We can ignore critics while continuing to do what we have been doing. (It has been said that if the authorities in charge of certain schools had been in charge of our space program, today we would have the world's largest sling shot.) Or we can act with dispatch.

PREFACE

In any troubled situation, two questions are always helpful: What are the problems? What should be done about them? School science is in trouble. Searching for the problems behind this trouble and the most desirable solutions must begin with professional science educators' actively defining these problems. The essence of any problem's solution resides in the very process of carefully defining that problem.

Note our frequent use of the plural "problems." As long as the scientific community assumed that cancer was a single disease, researchers sought a single cure. With fresh evidence that cancer is at least 100 identifiable diseases; cures specific to each disease are now being found.

We science educators believe that every child should have science instruction every day. To what extent is this true now? What can or should be done to make it true? How can we marshal our resources to reach that goal?

In this *Yearbook*, science teachers are speaking out as a profession. In Part I, science teachers describe the current school crisis and some ways in which it is being addressed. The thoughts of these authors mirror both positive and negative aspects of our profession's public image today. In Part II, 25 leaders of the National Science Teachers Association outline what they think school science can or should be. In Part III, NSTA's president Robert E. Yager (1982–1983), and executive director Bill G. Aldridge jointly describe a vehicle for clustering resources to make school science what it should be.

Together, and in cooperation, we as a profession are speaking out about the teaching of science.

Faith K. Brown
David P. Butts

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Silver Burdett Company
An anonymous donor whose gift started the fund

Part I

Science Education In the United States

Part I
Science Education In the United States

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Science education in the United States received unprecedented national attention after the launching of the Soviet Sputnik in 1957, but school science has lost its favored position. Federal support has eroded. The role of technology in Vietnam gave a bad image to science. Despite declining school enrollments, Americans became uninterested in public education. By 1976, the National Science Foundation (NSF) suspended all education programs designed to improve science teaching, and severely curtailed further development of active curriculum projects concerned with producing materials for school science.

The crisis in science education at the precollege level has received widespread publicity in 1982 and 1983. The National Science Teachers Association has been deluged with requests for detailed information, as well as suggestions for solutions. NSTA data, collected through several different surveys conducted over the past three years, have been summarized to characterize the current status of school science; and NSTA has been involved, on a variety of fronts, in addressing the crisis.

A. CURRENT PRACTICE: SCHOOL SCIENCE TODAY

In 1977 and 1978, three important research efforts attempted to document the status of science in the U.S. educational system. The first study [3] summarized the literature from 1957–1975, surveying information on school practices, instructional materials, teacher education; administrative-financial control, and needs in K–12 science. The second study [10] surveyed teachers, administrators, supervisors, and other school personnel nationwide concerning curricula; course offerings, teaching methods, enrollments, individualized materials; teaching assignments, support services, and demographic information. The third study [8] consisted of 11 case studies of schools representing different types of communities; and it included extended on-site visits and in-depth analyses of the case study reports.

Also in 1978, the National Assessment of Educational Progress (NAEP), in its third *Assessment of Science* [5], revealed that student interest in science decreased between the third and seventh grades, and declined further between the seventh and eleventh grades. A number of research reports revealed that student interest in a given science course was *lower* at the end of the course than at the beginning.

In 1978, the National Science Foundation (NSF) awarded a major research contract for the purpose of synthesizing and interpreting the more than 2,000 pages of information from the three NSF status studies and the NAEP reports. This research effort, Project Synthesis, involved a team of 23 science educators from throughout the U.S. [1] The research teams were divided into five focus groups charged with examining components of K–12 science education in, respectively: biology, physical science, inquiry, elementary school science, and science/technology/society. Each group worked independently with the same framework of goal clusters and critical elements for teaching.

The general research procedure characterizing Project Synthesis was the discrepancy model frequently used for qualitative research. Basic to this design is the development of ideal state conditions, followed by descriptions of the actual state. Discrepancies between the two conditions are identified, making possible recommendations for future actions.

Still another response to the challenge of the mid-1970s was a greatly expanded effort by NSF in science education research. Reports of these studies continue to appear, and NSTA has focused its monograph series, *What Research Says to the Science Teacher*, on results of such efforts. [14] Such analyses are rich sources of information concerning successes and failures of science teaching in the U.S.

Information from a wide variety of writings and reports, current projects, and research converges in a characterization of current science as plagued by ten common, recurring problems.

1. *The Textbook Is the Curriculum.* Recent NSF Status Studies reveal that 90 percent of all science teachers in the U.S. use a textbook most of the time. The textbook determines the course content, mode of instruction, and evaluation. The most significant curriculum decision that U.S. teachers make is the choice of their textbook. Once this has been determined, teachers attempt to cover all content in the book, usually in the prescribed order and with the instructional aids provided or suggested.

2. *Goals Are Narrowly Defined.* A principal justification for school science at every level is the preparation it provides for the next academic level. Teachers frequently defend their course; the content covered; and instructional strategies because "these are expected by the teachers students will have next year." Surely, this is worse when secondary school teachers insist that college teachers expect certain material to have been covered. The evidence suggests that, in science, teachers at the next level rarely expect much more of students than the ability to read.

The goals of science instruction are also commonly limited to specific knowledge and specific processes. Such an orientation is limiting and inaccurate, for like most complex human enterprises, science is multidimensional. Some of these dimensions are as appropriate in the classroom as the process and content dimensions.

Failing to define science content other than through a discipline orientation quickly reduces most discussions of science teaching to a consideration of the relative emphasis and sequencing of given science topics—almost always those traditionally packed into discipline-bound courses. This view of science also explains our inability to consider other dimensions of science.

3. *The Lecture Is the Major Form of Instruction, with Laboratories for Verification.* Other serious problems are rooted in our inability to move beyond the lecture as a form of instruction, followed by student recitation. We have emphasized the presentation of content for student mastery. Recitation becomes useful as a form of motivation only for students who want to succeed in traditional ways.

Most science courses fail to include even one experiment that allows students to identify and define a problem, propose procedures, collect and interpret results, or make decisions. Students rarely engage in activities for which the answers are not provided by the textbook authors, by the teacher, or by other students. Many activities in science classrooms are mere exercises in following directions and verifying information given by the text or teacher.

4. *Success Is Evaluated in Traditional Ways.* Evaluation of success in school science mirrors our emphasis upon content for its own sake, teacher lectures, and textbook presentations. By emphasizing definitions and the knowledge dimension, we tend to circumscribe science, to make puppets out of students, and to reduce science teaching to a concern for definitions, vocabulary, and laws.

5. *Science Appears Removed from the World Outside the Classroom.* It has become common in the U.S. to omit the human dimension from science courses. This first occurred during the 1960s, when "pure" science was stressed. All sensitive or controversial areas were removed or de-emphasized. Science seems to have been separated from the society of which it has always been, and must be, a part.

The science classroom and laboratory have come to be seen as exclusive settings where science is done. We have packaged courses, including laboratory activities, to fit neatly into class periods, the school day, and the school year. We have been slow to use the vast resources that the personal experiences of every student could add to the science class. We have failed to acknowledge that the world itself is the real laboratory for science studies. Some now feel that most of what a student knows, feels, and does relating to science comes from nonschool experiences. Instead of affecting student behavior in out-of-school settings, school science seems to have little relevance to the rest of life.

6. *A Shortage of Science and Mathematics Teachers Has Led to the Widespread Use of Unqualified and Underqualified Teachers.* NSTA's fall 1981 survey of 600 colleges and universities which prepare science and mathematics teachers showed a shocking, ten-year drop in these areas of enrollment: a 79 percent decline for mathematics, and a 64 percent decline for science. Data from another survey, which NSTA conducted in fall 1982, show a further decline. According to data from the National Center for Education Statistics (NCES), the decline over this same period for teachers in other fields was only about 25 percent, and the decline in enrolled students was smaller yet, about 20 percent.

The demand for science and math teachers is even greater, however. According to NSTA's fall 1982 survey, 52,000 classes in science and mathematics could not be scheduled in 1982–1983 for lack of teachers and/or resources. Instead, some 640,000 youngsters who wanted to take science or mathematics were required to take courses in other subjects for which no teacher shortage existed. Of the 17 million children in grades 8–12 this school year (1982–1983), 6.3

million are not taking science, and 6.1 million are not taking math.

Given that the supply of science and math teachers has dropped so drastically, how can the schools be finding teachers to fill classes? They have been employing *unqualified* and *underqualified* teachers. In 1981–1982, half of the newly employed science and mathematics teachers in the U.S. were unqualified (see Figure 1, pp. 8 and 9). Such teachers were hired with provisional or emergency certification, or when extremely low certification standards were in effect. Emergency measures have made possible the reassignment of teachers from physical education, home economics, social science, elementary education, and other fields where surpluses exist.

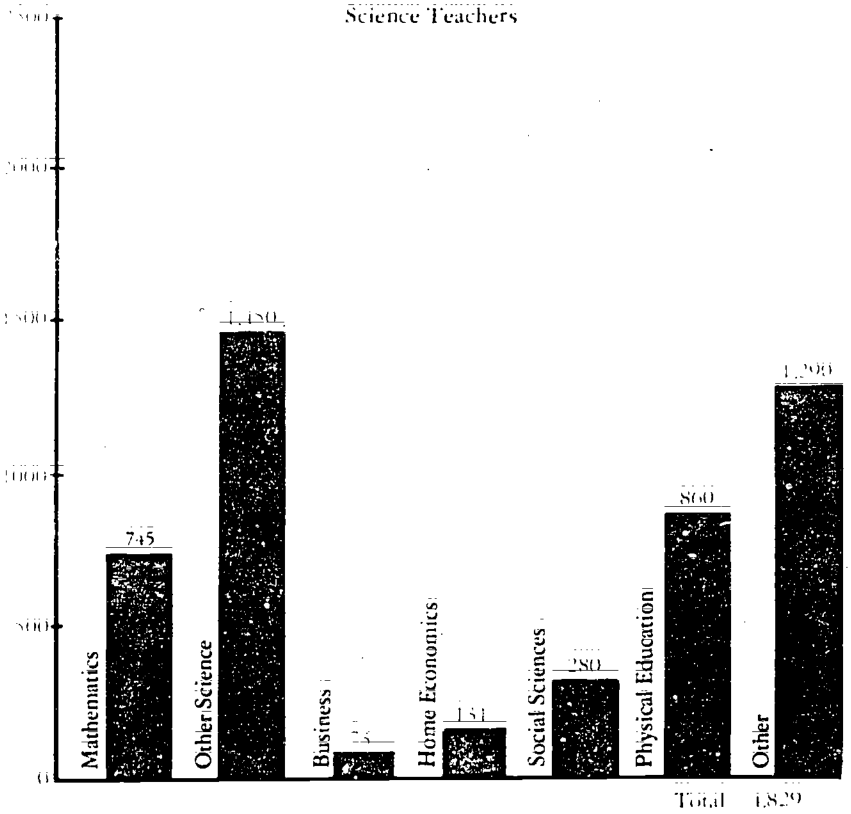
Teachers are also commonly transferred within science, for example from biology to chemistry and physics, without sufficient qualifications to teach the subjects they have been assigned (see Figure 2, p. 10). Currently, over 30 percent of all science and mathematics teachers teaching in grades 7 to 12 are unqualified or severely underqualified.

Principals are faced with an overall decline in secondary school enrollment, a surplus of teachers in some areas, and a shortage of science and mathematics teachers. Who can blame a principal who reassigns a long-time faculty member from a nonscience field into a science or math slot when no qualified teacher can be found? Moreover, even if a qualified person is available, tight budgets and teachers' contracts can preclude a principal's hiring a new staff member; thus the principal is forced to meet the need through staff reassignment.

7. *The Outdated Curriculum Neglects the Needs and Interests of Most Students.* The problems caused by a lack of sufficient numbers of trained teachers are compounded by the mismatch between science and mathematics courses and the needs and interests of students. The science and mathematics courses in U.S. schools today are, for the most part, only slightly modified versions of those developed by teams of scientists and teachers after Sputnik. Yet, as Jerrold Zacharias, MIT physicist and originator and developer of the Physical Science Study Committee (PSSC) Physics, reported in testimony on February 19, 1980, before the Subcommittee on Science, Research and Technology of the Committee on Science and Technology, U.S. House of Representatives, "We had aimed only at the college-bound and college students because we could not do everything at once."

Our present science and math courses focus on pure science and usually omit practical applications, technology, and the relevancy of science to society's problems. They do not prepare people to enter the myriad nonscience occupations that require general technological

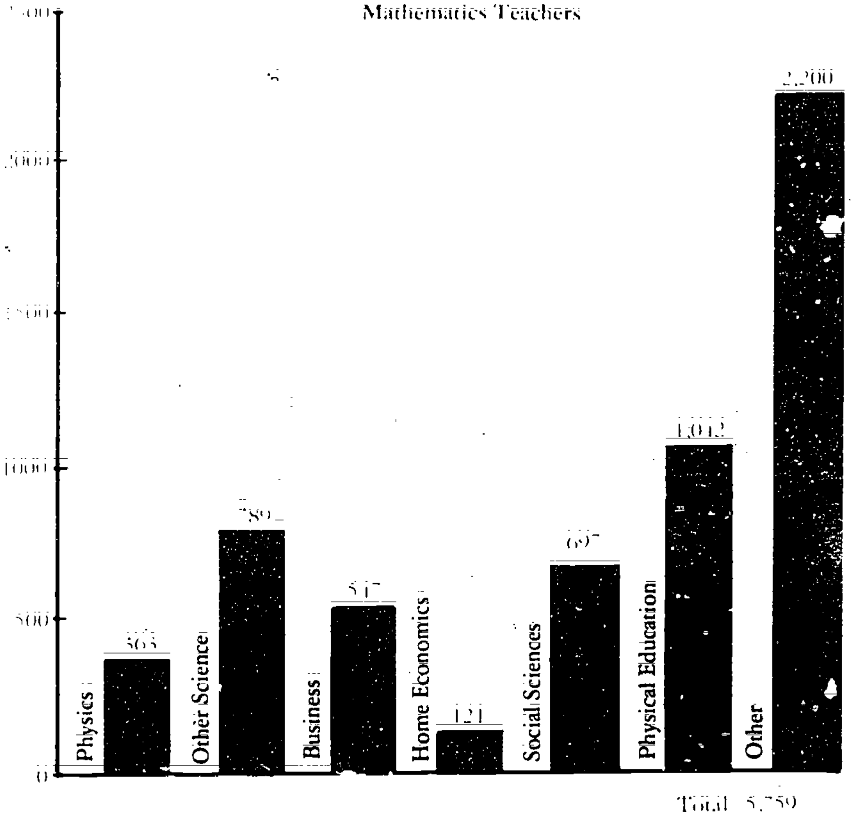
Figure 1. Teaching Fields of Newly Employed, Unqualified Science and Mathematics Teachers, 1982–1983, by Field of Preparation and Number



knowledge for which science is the base. Nor do these courses properly take into account the use of computers and modern electronics.

Critics have suggested that the future job market will be most favorable for unskilled persons who will work as janitors, nurse's aides, sales clerks, cashiers, and waiters/waitresses. The assumption is that these jobs will remain the same and will be unaffected by automation. Ten years ago, such critics would have predicted high employment for service station attendants. But now, with automated self-service gasoline pumps, the need is for high-tech design, sales, repair, and maintenance personnel—and few attendants. We have increased productivity in marketing gasoline.

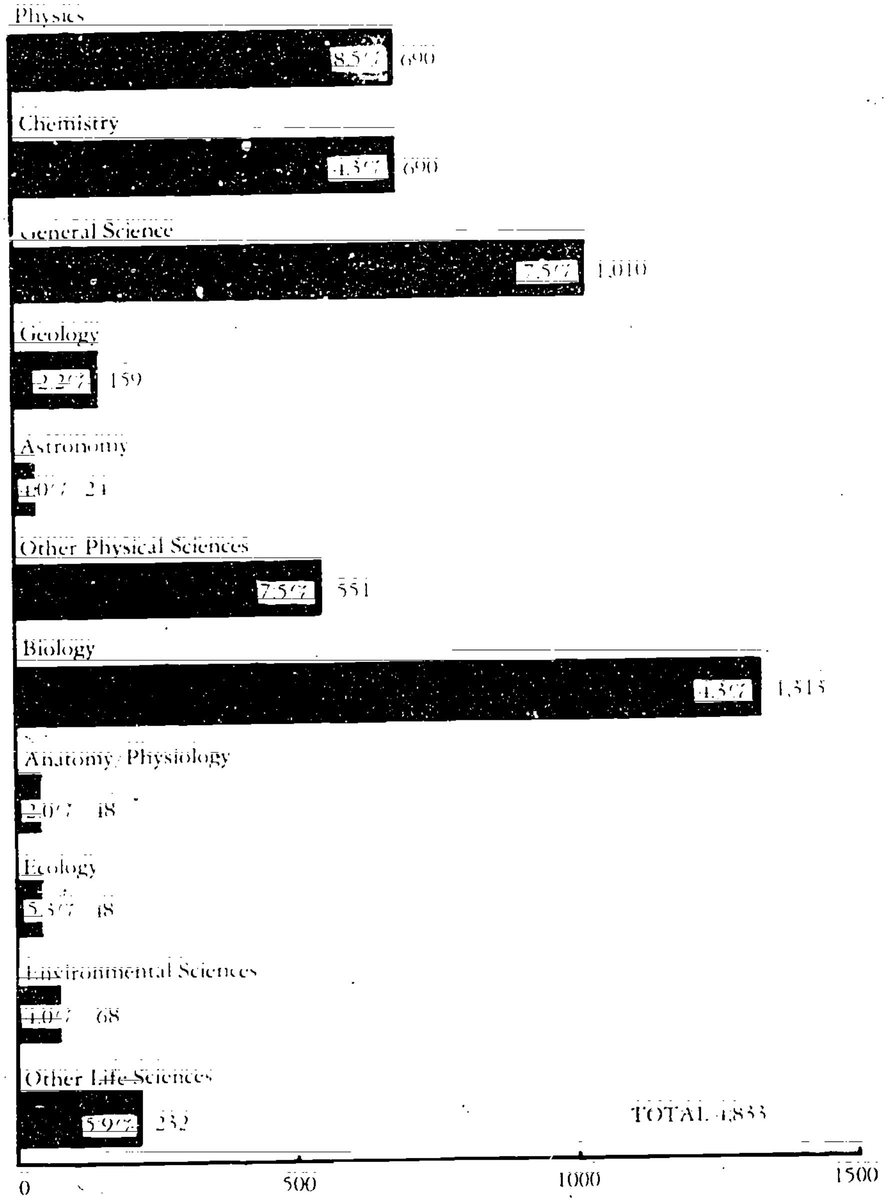
Similarly, the trend toward automation cuts across virtually every



area, reducing the number of unskilled jobs while increasing opportunities for the more technical jobs. The processes of inventing, designing, engineering, producing, selling, installing, and maintaining automatic equipment require considerably greater skills than any needed by people who operated equipment manually once upon a time. The same number of people, or somewhat larger numbers, are needed for the new chain of functions; but the output per worker is increased by an order of magnitude, thereby increasing productivity.

Technically trained personnel are essential for the creative activity of inventing the new devices that would automate jobs for janitors, sales clerks, nurse's aides, and others. Productivity in these fields, as well as in manufacturing, can be increased only when our work

Figure 2. Subjects Taught by Newly Employed, Unqualified Science Teachers, 1982-1983.



force—like Japan's—has the scientific and technical knowledge to see *on the job* what must be done to improve.

8. *Current Science Instruction Ignores New Information about How People Learn Science.* The last ten years have provided much new information concerning the way human beings learn. The current literature presents exciting new data about the adolescent mind and how it develops. Information from studies in cognitive psychology has application to school science classrooms. Various new studies on the structure of the sciences themselves suggest new ways for science teachers to approach instruction.

9. *Supplies, Equipment, and Other Resource Materials are Severely Limited or Obsolete in Most Science Classrooms and Laboratories.* Those that exist are inappropriate for the science course content and teaching methods needed to update precollege science education.

10. *Science Content in the Elementary Schools is Nearly Nonexistent.* Teachers are ill-prepared, resources are lacking, and the focus on the so-called basics has tended to ignore science.

B. ADDRESSING THE CRISIS

1. *The Search for Excellence.* Descriptions of current practice make interesting reading in any profession; but they are of limited use in bringing about change and innovation with more surety than afforded by the usual trial-and-error process. There is some merit, as Thomas Edison said, in knowing a lot of things that won't work. However, knowing what does work is a considerably more direct route to success.

The Search for Excellence in Science Education was a logical and rapid outgrowth of this idea. Sponsorship by the National Science Teachers Association and the Council of State Science Supervisors (CSSS) was equally logical. NSTA, with a membership of 40,000 science teachers, and CSSS, whose members are state science coordinators from each state's department of instruction, are national and active organizations. Another important sponsor, the National Science Supervisors Association (NSSA), helped immensely with publicizing the search for exemplary science programs. Partial funding was provided by the National Science Board (NSB) through its Commission on Precollege Education in Mathematics, Science and Technology.

For 1982, this new and continuing effort identified 54 examples of excellent programs throughout the U.S.—50 through NSTA's annual effort, and one each selected by the Education Division of the American Chemical Society (ACS), the National Association of Geology Teachers (NAGT); the American Association of Physics Teachers (AAPT), and the National Association of Biology Teachers (NABT). Complete descriptions of these programs are being published as a series of monographs available from NSTA beginning in 1983.

The criteria for this search came about through results of Project Synthesis. During the 1982 NSTA Search for Excellence, goals and the general descriptions of the desired state for each of the five focus areas were used to define excellence in school science programs (see Table 1, pp. 14 and 15).

In the spring of 1982, state science consultants in each state nominated outstanding science programs in their respective states. Often, site visits were made to verify program conditions. A statewide committee read the nomination papers in each case. In all situations, the same stated criteria and the same search process were applied.

By mid-1982, nearly 165 state nominations were submitted to the project director for consideration at the national level. These state exemplars were examined by committees comprised of some members of the original Project Synthesis researchers. The 50 programs most closely fitting the desired state criteria were named National Exemplars: 12 in Elementary Science, 10 in Biology, 8 in Physical Science, 10 in Inquiry, and 10 in Science/Technology/Society. The review committees also selected 6 programs as portrayal sites to be known as Centers for Excellence. Three-person teams (including appropriate state chairpersons) spent approximately two weeks at each site during spring 1983. These Centers for Excellence represent a broad range of subject matter and geographical distribution; most were selected as exemplary in more than one focus area.

Each of the 50 exemplary programs has provided extensive data about teachers in the program as well as information on the program itself. Coordinators or contact persons within each exemplary program distributed questionnaires to teachers within their program who they felt clearly reflected the rationale of the exemplary program itself. These questionnaires combined the questionnaires developed by Weiss [10] and the Science Attitude Inventory [4], supplemented by additional demographic questions. Almost 300 questionnaires were completed.

Each exemplar contact person also completed a 100-item narrative questionnaire which provided detailed information about the nature of the program and learning activities; evaluation criteria; and the past, present, and future of the program. Appropriate data from the teacher questionnaires have been compared with results from the same questionnaire administered by Weiss to a random sample of all science teachers in the U.S. in 1977. The narrative questionnaires provide descriptive information as well as examples of practice within the exemplar programs.

Visits to the Centers for Excellence are providing even more detailed information about the history and day-to-day operation of six exemplars, which will be portrayed in a monograph available from NSTA in late 1983. Portrayal visits involved at least one member of the original Project Synthesis team, the state chairperson, and the Search for Excellence project director. Other team members included special consultants to the particular program and a member of the NSTA Search Committee. The portrayal team collected information and perceptions from teachers, students, administrators, community leaders, graduates, and school board members regarding science program goals; successes; and impact. Each team member identified and rated factors associated with this form of excellence.

2. *Federal, State, and Local Responsibilities.* In the U.S. the *delivery* of precollege education is clearly a state and local responsibility. Thus, teacher salaries, normal supplies, materials, and preservice and inservice education programs must remain a local and state responsibility.

Research—both basic research on learning and the use of various technologies to facilitate it; and research on curriculum content and sequence—is an appropriate sphere of activity for federal agencies. The federal responsibility for precollege science and math education should be executed mainly through two agencies: the U.S. Department of Education and the National Science Foundation.

The U.S. Department of Education, through grants to state and local education agencies and through programs at the Department's National Institute of Education (NIE), is able to play an important role in addressing the science education crisis. State and local funds for preservice and inservice training should be augmented by federal support through the Department of Education. Private sector support could be stimulated by such means as tax credits, but should focus mainly on local community assistance in the form of matching funds, resources, and personnel.

In educational research, NIE should be principally responsible for basic research on learning; NSF should be responsible for research on course content; structure; and applications resulting from NIE-supported basic research.

Table 1. Abbreviated Criteria for NSTA's Search for Excellence in Science Education.*

Elementary School Science

1. Focus on effective consumer behavior
2. Deal with effective personal health practices
3. Recognize people's effect on environment and vice versa; develop custodianship
4. Observe variation in interpretation of some data
5. Experience the hard work involved with resolving problems
6. Focus on great variety of basic sciences
7. Recognize the people involved with scientific pursuits

Biology

1. Use knowledge to understand self
2. Use knowledge to benefit quality of life and living for human beings
3. Study human beings in natural and total environment
4. Focus on current issues and deal with morals, values, ethics, and aesthetics

Physical Science

1. Apply physical science ideas and information to real-world problems
2. Display content in context of socially relevant problems; also as science "disciplines"
3. Focus on personal needs, societal issues, careers related to physical science

3. *Federal Initiatives*. In the 97th Congress, 17 bills were introduced to address the crisis in science education. By March 11, 1983, in the 98th Congress, several of these had been reintroduced and new ones introduced as well. The U.S. House of Representatives has already passed H.R. 1310 for $425 million, of which $130 million is for NSF; at least six bills relating to science education have been introduced in the U.S. Senate.

It is the National Science Foundation, however, that has the authorization to maintain the health of science and the science education which supplies scientists. As described in Public Law 507, 81st Congress (64 Rev. Stat. 149, S. 147), Section 3(2): "The Foundation is authorized and directed—to initiate and support . . . science education programs at all levels . . . ." The existence of the present crisis and the variety of Congressional initiatives are clear evidence that NSF's policymaking body, the National Science Board, has been negligent over a long period of time.

4. Deal with real people in science where processes they use can be observed
5. Include real research and out of school experiences in instruction, as well as standard laboratories

Inquiry

1. Teachers value inquiry, encourage such an orientation, and possess such personal skills
2. Classrooms use science objects and events where students focus on investigation
3. Curricula and units of instruction give attention to science processes
4. Teachers act as role models in debating issues, admitting error, examining values, and confronting their own ignorance
5. Instruction focuses on exploration rather than "coverage"

Science/Technology/Society

1. Use knowledge to improve personal life and to cope with increasingly technological world
2. Deal with technological-societal issues
3. Focus on decision making
4. Provide accurate picture of opportunities and requirements needed for a wide variety of careers

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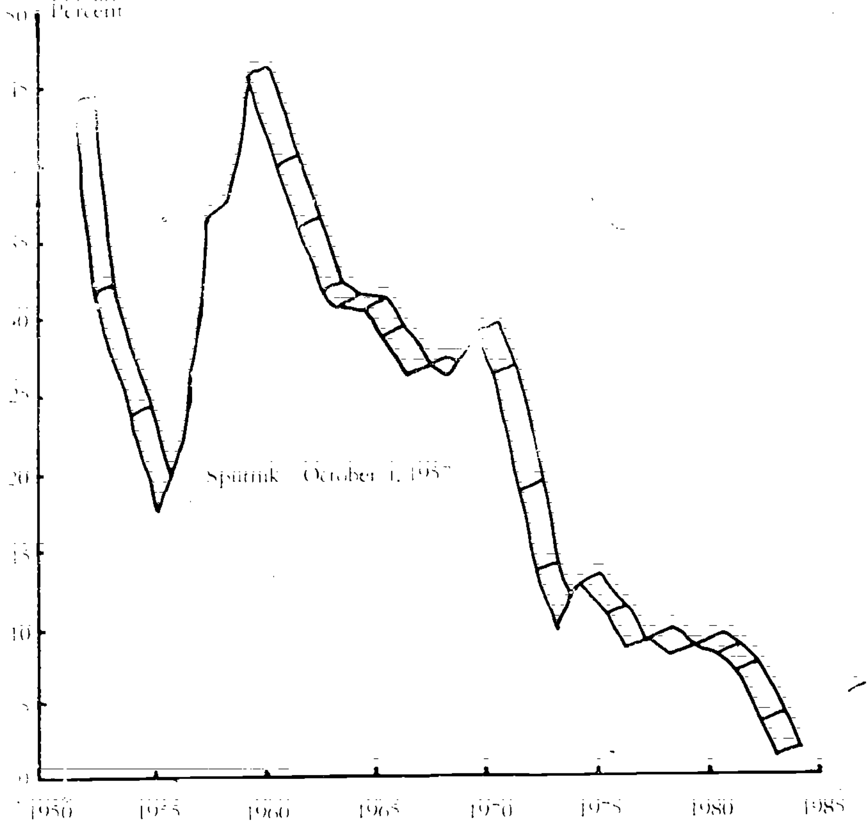
*The goals are described more fully in NSTA's monograph, *What Research Says to the Science Teacher*, Vol. 5.

The NSB is supposed to set policy and to recommend programs and budgets to support those programs. In an effort to protect and promote support for scientific research, the NSB has systematically reduced support for science education for more than 20 years (see Figure 5, p. 16). We now face the consequences of that long-term neglect.

In his testimony before Congress in February 1980, Jerrold Zacharias stated the NSB problem well:

> . . . [T]he Education Directorate (at NSF) is struggling against an almost impossible enemy—an enemy from within. From its inception the Science Board (NSB) that supervises the NSF has treated the Education Directorate as a trivial country cousin. They have said that the government should give the NSF money for scientific research and never mind what happens to the two hundred million people who don't do research. It is those very people whose lives, jobs, leisure, entertainment, food, security, and everything else depend on a sound economy in a democratic society. The federal government can no

Figure 3. Science Education Funding (as percent of total National Science Foundation budget)



longer allow itself to neglect the schools, and the NSF has in its charter the responsibility and authority to do something about them.

In spite of the NSB's lack of action in carrying out its statutory obligation, science educators continue to believe firmly that the original reasons for lodging science education programs at NSF are still valid and important. We must develop science and mathematics education materials and train our teachers in a partnership with those scientists who discover new knowledge. That knowledge, and the methods used by scientists to acquire new knowledge, are constantly changing. Science and mathematics teachers need direct, cooperative relationships with scientists and mathematicians. Involvement of research scientists in science education is essential. NSF is a small, independent agency with a reputation for administering programs of very high quality selected *on merit*.

Even though the NSB has been slow to respond to the present crisis, as indicated by the lack of NSF initiatives, scientists at universities and in the private sector, as well as those at the American Association for the Advancement of Science (AAAS) and the National Academy of Sciences (NAS), have shown great interest and concern.

4. *NSTA Initiatives.* NSTA has been involved, in a variety of ways, in addressing the crisis in science education. The NSTA position statement "Science-Technology-Society: Science Education for the 1980s" (Appendix, pp. 109–112), has received widespread acceptance. The officers and staff of NSTA are working with the media to inform the public. For example, in 1983 the Association's executive director has been interviewed on all three major television networks. Articles referring to NSTA have appeared in *Newsweek*, *Time*, *The Wall Street Journal*, and hundreds of newspapers across the country. The efforts of NSTA members, as well as our affiliates, are having a profoundly positive effect. *We*, not others, are setting the agenda for science education in the 1980s and beyond.

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Part II

The Science Teaching Profession Speaks: Where School Science Should Be

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The Science Teaching Profession Speaks: Where School Science Should Be

Under the guidance of the Yearbook Advisory Board, the members of NSTA's leadership team (board members and major committee chairmen) were invited to consider the following: .

> There is a general agreement that the level of scientific and technological literacy of Americans is below that required by the demands of our society. This problem is a matter of national debate. Commissions have been formed to study the problem and to make recommendations for its solution.
>
> Here is where we as science educators must make substantive contributions to the national debate. We need your analyses—and your recommendations for action. To be more specific, of all that you believe can or should be done, suppose that you had to make a recommendation for the *single most* important action to be taken.

Their responses fit into three categories: *practical* concerns, *program* concerns, and *policy* concerns.

In the first group of papers, the practical concerns—about resources such as students, staff, and money—are highlighted. These questions are explored.

- Does scientific literacy make a difference?
- Do we tap the basic beliefs of scientists and society in school science?
- Do we make school science available for all students?
- Do we make school science available for women?
- Do we link school science with industrial resources?
- Do we link school science with local community resources?
- Do we link school science with nonschool constituents?

In summary, a profession speaks regarding practical concerns of science teaching, the relevance of school science to human concerns, the availability of school science, and the linkage of school science to nonschool resources. Should we be addressing these concerns?

In the second group of papers, program concerns about curriculum, instruction, and teacher skills are emphasized.

- Do we include the essential aspects of science in our definition of school science?
- Do we expect school science to nurture creativity?
- Do we tap the individual uniqueness of students in school science?
- Does science teacher preparation nurture effective science teaching?
- Does a teacher's knowledge improve his or her science teaching?
- Do we tap the potential of continuing education to strengthen teaching?
- Do we have resources to develop the new teachers needed for school science?
- Does school science tap the key resources of the elementary school preparation?
- Do we link school science to the science supervisor as a resource?

As professionals, are we aware of needs for curriculum tailored to individual student differences, and to the needs and interests of teachers? Can we attend to these program needs?

The third group of papers focuses on policy or political concerns related to perceived needs in school science.

- Do we make school science fit the needs of each learner?
- Does school science in the elementary school facilitate the goals of schooling?
- Does school science enhance writing literacy?
- Does school science enhance language literacy?
- Do we as science teachers influence political or policy decision making?

When questions of policy and politics are examined, the kinds of larger questions about what we *actually* do are inevitably linked to further questions that require value judgments. These ask what we *should* do, in light of what we *can* do.

A. PRACTICAL CONCERNS

Does Scientific Literacy Make a Difference?

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James B. Conant described science as ". . . a speculative enterprise . . . science is not only a quest for certainty; it is rather a quest which is successful only to the degree that it is continuous."[1] We have demonstrated our inability to develop in the majority of our young people personal motivation to pursue science, or at least to pursue an understanding of science. A closely related concern is our inability to develop in most students a satisfaction, if not excitement, from exploring the mysteries which school science provides.

If the reason for our lack of scientifically oriented people, including teachers, is that not enough people really enjoy the study of science, then what can be done?

Few people would challenge the perception that school science has never been favored with full acceptance as a vital part of the elementary and middle school curriculum. Even during the curricular revolution in the wake of Sputnik, only about one fourth of America's schools directly benefited from fundamental change. Additionally, there is reasonable belief and some evidence that even schools that adopted the new curricula of the 1960s did not fully adjust to the theoretical base upon which these new ideas were founded.

There have been and are exemplary schools and teachers who excite America's young people about science, but their number is miniscule. The bright, shining stars of preservice programs are too often lost in a Milky Way of school systems that neglect science education.

Neophyte and experienced teachers alike soon lose their enthusiasm for teaching science in an environment of basic skills achieve-

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[1] James B. Conant, *Science and Common Sense* (New Haven, Conn.: Yale University Press, 1951).

ment and the collection of milk money. Teachers are no different from anyone else in their response to the existing reward system. If the principal, superintendent, board, and public demand success in basic skills, school science is reduced to secondary importance. When this condition is coupled with an ignorance of the positive relationship between learning science and developing language facility (a relationship which research findings imply), then school science may be either neglected or eliminated entirely.

Shulman and Tamir [13] suggested that politicians have as much to say about molecular biology as does the National Science Teachers Association. Although this is regrettable, it also tells us something about politicians. They have power, the same power that launched NSF curricular efforts in the 1960s and that passed and funded Public Law 94-142. The use of this power is viewed here as our only realistic chance to attack the "cause" of our science problems rather than continuing to treat symptoms.

We must radically and vigorously mount a massive national commitment to establish science as one of the necessary components of a school's curriculum. Weinberger stated it this way:

> Our youngsters need to be exposed as early as possible to science, math, and technology. Unless we begin now to motivate and equip them to pursue scientific and technological careers, the shortages will persist. [14]

Such an effort would not only involve a national financial commitment much greater than that which occurred in the 1960s, but would also require considerable incentives to states so that good science programs in all schools would be assured. This effort would have to guarantee that school science be presented as having at least the same importance as mathematics and reading.

There are at least three strong areas of support for this recommended revolution in science education:

1. *Attitudes are often formed very early in life*. Lack of exposure to science instruction removes an option for children. They cannot develop positive attitudes about something they have neither known nor experienced. Choosing a career is a process which takes place over a long period of time [2], and the middle school years are especially significant for science. [3] Fennema concluded that girls have positive attitudes about math until about sixth grade [4]; then cultural factors begin to interfere, and more stereotyped attitudes begin to form. Fear and anxiety related to the study of science have become so pronounced that a Science Anxiety Clinic has been founded by Loyola University of

Chicago. [6] A similar institute in Washington, D.C. has focused on mathematics anxiety and avoidance. Worthy stated [15] that among Japanese children, especially girls, there seems to be none of the fear of science and mathematics that is found in the U.S.

2. *Skills, content, and methods differ for each academic level.* In order to develop a positive attitude toward science from an early age and to capitalize on innate curiosity and interests, enthusiastic teachers properly trained in *science* education should teach at *each* grade level.

Our modern world is a highly technical one, and technology is the outgrowth and by-product of science. Therefore, every person in society needs to learn the biology of the human body and the broad concepts of environment in which he lives. Citizens should know about many kinds of living things and how they relate to one another. Citizens should learn about the nature of matter, its composition, and how its forms are related to organisms on Earth and in the cosmos. Only with a basic understanding of science can students begin to cope intelligently with problems presented by society and technology.

Scientific content that relates to society and technology should be taught in a manner appropriate to the level of student interest. Problems in society that have been generated by technology should be addressed when they are pertinent to the curriculum and when the student has some basis for relatively unbiased, logical decision making. At this point, the student should also be led to realize that problem solving is never permanent; solutions today may need to be revised tomorrow. Greater scientific literacy, provided through such an approach in our public schools, should enable our future citizens to make many more intelligent choices and even devise better, or alternative, solutions.

3. *Research is needed.* Current evidence supports the idea that active science instruction improves learning in other areas, such as logical thinking and basic skills. Positive gains in language development, word comprehension, vocabulary use, listening skill, sentence construction, and paragraph interpretation are just some of the benefits associated with activity-oriented science instruction. [1;7;9;10;11; 12] Science instruction can and does contribute to the development of basic skills beyond the learning of science content and processes.

Daniel Greenberg [5] has warned that we are producing successive generations of scientific illiterates, to the detriment of industry, defense, and culture. Grants, loans, summer jobs, higher salaries, and similar inducements for teachers may reduce symptoms temporarily, but anything short of a massive, national commitment to providing quality science instruction for all U.S. elementary and middle school children is not likely to treat the cause.

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Do We Tap the Basic Beliefs Of Scientists and Society in School Science?

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Public Attitudes and Education

Margaret Mead's classic study on high school students' image of scientists demonstrated the persistence of many myths in our society. One might assume that the negative image of science that existed 25 years ago is gone, but this is not necessarily true. Saturday morning cartoons on television and many popular movies today still portray scientists as secretive, aloof members of their own mysterious fraternity who are out to tamper with nature and gain control over others. Opinion polls suggest that the general public still views science with awe, suspicion, and mistrust.

It is clear that science no longer possesses the importance that it did from the late 1950s to the early 1970s. Why is this so? One basic reason is that the majority of citizens in this country do not understand the nature of science. They do not appreciate the fact that investments today might take a decade or more to materialize as some technological product or improvement in the human condition. Throwing money at science today will not result, as some believe, in solving world problems by tomorrow.

Public schools also occupy a social position different from that of a decade or two ago. While many think we have "bottomed out," there is still grave concern over the level of state and federal support for education. Teacher morale is at its lowest since the Great Depression. Particularly in science and mathematics, the teaching profession is simply not attracting and retaining its fair share of talent.

Like science, education is a long-term investment. Politicians running for office get elected by making short-term promises. Thoughtful, thorough, long-range educational planning is not an issue on which a politician in our country can get elected. The general public and our government leaders do not value education as much as they value certain other things. Teachers are not treated with the respect they deserve and, like scientists, are often misunderstood. Public attitudes and values toward education, much like those toward science, are not as positive as they should be.

Attitudes of Scientists and Professional Educators Toward Science Education

It is perhaps possible to "explain away" part of the general public's lack of support for science and for education. After all, these are hard times economically, and neither science nor education is appealing to an unemployed worker or a hungry student in school. More difficult to understand, however, is the attitude present in the scientific community toward science education. On most large university campuses, scientists and professional educators do not work together to prepare high-quality science teachers. Professional educators are often viewed as members of a bureaucratic establishment that perpetuates itself by prescribing an excess of required courses in education. Academicians in science, on the other hand, are often seen as crass promoters of their own discipline, uncaring about students majoring in other areas. Scientists are often criticized as elitist, insensitive, and intimidating to those who might be planning to become teachers at the precollege level. Science education as a profession will never attain the heights it deserves until university-based scientists and academicians support it.

Following the exciting days of the early and mid-1960s, science education programs in colleges of education have received less and less support. Supervisors of science in large school systems have been replaced by other kinds of specialists. Departments of science education at major universities have been placed within departments of curriculum and instruction, or have been reorganized into broad divisions of secondary education. While we hear about concern that our nation is falling behind in science, it is extremely rare to hear a dean of education or a superintendent of schools stand up and say that we must insure that science education be one of our strongest curricular programs. Instead, we see universities growing in areas where federal funding is greatest and where current fads are the most sensational. Emphasis on the subjects of English, foreign languages, social studies, mathematics, and science has given way to programs controlled by educational generalists.

For many decades professional science educators have advocated scientific literacy for all students. Yet this concept has never won wide acceptance. It has been supported neither by scientists nor by school leaders nor by classroom teachers. Science, unfortunately, is still viewed by most people as a difficult course of study that should be reserved for the special few who will go on to college to major in science, engineering, or medicine. Therefore, it is not viewed as a "basic" in the elementary school curriculum or as a general course suitable for all secondary school students.

Recommendations for Changing Attitudes toward Science

Before confidence in science education can be restored to a healthy level in this country, citizens, parents, students, scientists, and educators must become committed to the fact that science is an important subject in the school curriculum and that it should be taught in a manner that encourages *all* members of our society to become intelligent consumers. To reach this goal requires the following:

1. Science must become a basic subject in the elementary school curriculum. Every child at every level should receive some instruction in science every day.

2. Science in the middle and upper grades should be designed for students of all interests and abilities. Our most talented students need to be challenged; our less mature and less motivated students should receive instruction in science that is meaningful to their lives.

3. Federal and state governments should provide active leadership in science education by encouraging levels of excellence commensurate with the national goals of this country.

4. Scientists should become concerned about communicating science to the masses. University and college academicians should insist that students in introductory courses receive excellent instruction. Producing students with positive attitudes toward science should be a goal of all introductory courses in science.

5. Professional educators should take a stand on science, and colleges of education should support teacher-training programs designed to produce top-flight science educators. Science and mathematics education programs should be given visibility within teacher-training programs; and standards of excellence should be applied in recruitment and selection of future teachers.

6. Finally, the scientific community, educational leaders, and society in general should do everything possible to improve the stature of teaching as a career. Not until science teaching becomes attractive enough to engage and retain its fair share of bright young professionals will we be able to cure the major ailments of science education in this country. Not until scientists and school administrators alike begin looking up to teachers as the most important ingredient in our educational system will the full potential of science education as a distinct enterprise be realized.

In summary, it is evident that science is not as highly valued in our society as it once was, nor as it is in some other progressive countries. Unless this trend is changed, the United States is destined to lose its worldwide superiority in science and technology. If this happens, our strength as a nation and our influence as a world leader will be diminished.

Do We Make School Science Available For All Students?

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The subset of science teachers who need assistance in making science accessible to handicapped students does not have a fixed membership. A biology teacher with 15 years of teaching experience can suddenly be faced with having a quadriplegic student in class. This same teacher might never be confronted with a similar situation, but several years later could have a student who is blind. Of course, some science teachers in the classroom for 20 years never face the challenge of making their science courses accessible to a handicapped student.

It is difficult to provide either preservice or inservice programs for science teachers that go much beyond making teachers sensitive to the needs of handicapped people. Science teachers can become familiar with general information about the conditions of a variety of handicaps and the general implications for the science classroom. However, it is not possible to predict in specific detail all conditions or solutions likely to occur with handicapped youngsters. A teacher's strategies in the classroom cannot be determined until the teacher is faced with a student who functions in a certain way. Even if it were now possible to project specific solutions to problems, there is no guarantee that these solutions will be viable in two years. The rapid advancement in technology can easily outdistance the solutions we propose today.

How can science teachers receive timely assistance in making their classes accessible to a specific student who functions in a certain way? How can the profession adequately respond to the plea of individual teachers: "Help! What should I do?"

Our solution might reside with a technique familiar in many communities throughout the country: crisis centers, established as a means of assisting people when they need it. Each September, many science teachers throughout the nation face a crisis when suddenly confronted with the task of teaching science to a handicapped student. There should be a place to which these teachers can turn for help. These science-teaching crisis centers could be located throughout the country.

The crisis center would function in two basic ways: as a locator of information and resources, and as a lender of materials. When a teacher requested help for a specific situation, the center would respond with current information and, in some cases, with actual materials.

Suppose a science teacher were to call the crisis center and say, "I have a visually impaired student in my physics course. Can you help me?" First, the center would ascertain how the student functions in a learning situation. Does the student read braille? To what extent does the student possess psychomotor skills? Does the student possess any visual memory? Next the center would ascertain the characteristics of the science course. Do the students use microcomputers? Do they have weekly lab activities? To what extent are visual media used in class?

Once the center had evaluated a particular situation, it would give the teacher specific suggestions for coping. The response might indicate where the text and related literature could be obtained in an appropriate form such as in braille, on tape, or in large print. Curricula and instructional guides with information on modifying regular instructional strategies or on alternative strategies could be identified and perhaps lent to the teacher. The center might also identify a visually impaired person who had already taken physics and would be willing to provide ideas to the teacher and student. If the use of a light sensor or other special device were deemed appropriate for conducting lab activities, the center would loan the device to the school for the student to use during the course.

By serving as a lending agency, a center could save schools from having to invest money in resources that receive limited use. For example, a school might enroll only one blind student in the physics course in a ten-year period. Thus, it would not be economically feasible for the school to purchase specialized items. It should be noted that this lending aspect would not duplicate services already available through other agencies such as state libraries for the physically handicapped.

Centers would be staffed by persons with expertise in science education and in the teaching of students with handicaps. The staff would continually seek pertinent information and compile it in a usable form for science teachers. The centers would maintain a current inventory of resources unique to teaching science to handicapped students.

A national effort must be made to develop a system to assist every science teacher. The ultimate solution to the problem of providing quality science education to handicapped students lies within the confines of the classroom. Science-teaching crisis centers could serve as a source of immediate help to teachers and would make science classes fully accessible to students with handicaps. Since most science teachers do not regularly have handicapped students in their classes, we must have information and resource centers that can respond effectively to the needs of individual teachers, students, and schools.

Do We Make Science Available for Women?

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Today women comprise approximately 50 percent of the work force; yet only 6 percent are employed as scientists and engineers. Explanations for the dearth of women in science have ranged from differences in spatial abilities due to a sex-linked gene [4] to differences in early childhood toys and games. [3] However, analyses of the recent National Assessment of Educational Progress (NAEP) survey of science reveal startling inequities in the classroom science experiences of boys and girls. This extensive survey of 9-, 13-, and 17-year olds shows both negative attitudes and lower achievement levels for girls. For example, on the average, females score between 1.6 and 2.5 percentage points below the national mean at each age level. [7] Their responses to items concerning opinions about science classes and feelings toward science as a career are consistently negative. [8] Thirteen-year-old and, especially, 17-year-old girls respond that the content of science is "facts to memorize" and describe science classes as being not "fun" but "boring." Although 9-year-old girls respond that science does not make them feel "successful," most of their feelings are positive and comparable to those of 9-year-old boys. However, by ages 13 and 17, they state that not only does science fail to instill feelings of "confidence," "success," or "curiosity," but it also makes them feel "stupid."

Lower achievement levels and poor attitudes are explained when one probes the NAEP data more deeply, for this national survey indicates inequities within the science classroom. Although differences between boys and girls in science achievement are not apparent until age 13, differences in science experiences are documented as early as age 9. Briefly, by age 9, girls record significantly fewer opportunities to work with science materials and instruments, to observe natural phenomena, and to participate in extracurricular science activities in spite of their desire to do so.

Although their reported opportunities increase between elementary and middle school, at age 17, or when they graduate from secondary school; girls have had significantly fewer opportunities to experiment with magnets, electricity, heat, solar energy, and erosion. Furthermore, there is a clear difference in girls' participation in traditionally feminine tasks as compared to their participation in traditionally masculine tasks. Although secondary school girls report far fewer experiences with electrical or mechanical tasks than the national average, the numbers of times they report having cared for an unhealthy plant or animal exceed the national average. Furthermore, females range from 1 percent to 7.6 percent below the national mean on activities such as watching science shows on television; reading books, magazines, and newspaper articles about science; and working on science projects or hobbies. In addition, although girls indicate an interest in taking a variety of science-related field trips, fewer girls than boys do so in reality.

Strategies

Studies by gender have not found significant differences in aptitude or ability between preadolescent and adolescent boys and girls. [5] However, according to Maccoby and Jacklin's analyses [6], the average score of a group of males is slightly higher than that of a group of females on tests measuring spatial visualization. Within science classes, laboratory and demonstration activities that provide spatial experiences might enhance the spatial abilities of adolescent females. As Treagust points out [11], "A student with poorly developed spatial abilities should not be taught primarily by verbal means." In addition, laboratory groups must be carefully structured so that girls actually work with science apparatus. Teachers can pair boys with boys, and girls with girls, during science experiments and recruit females to do science demonstrations. Girls must be actively encouraged to do science projects, join science clubs, and take science field trips. In addition, girls must be urged to enroll in mechanical drawing, industrial education, and other courses that have activities designed to develop spatial abilities. Finally, science teachers as well as counselors must insist that girls enroll in mathematics and physical science courses.

Science experiences for girls can be supplemented by increasing the number of experiences available in general. On the average, only 17 minutes per day is spent on science in the lower elementary school, while in upper elementary school, that time increases to only 28 minutes per day. [13] Lack of sufficient opportunity for science is a widespread problem. In the United States, only one sixth of all school districts require more than one year of science for graduation. [9] To insure adequate science education for all, schools must increase the time allotted to science, states must increase the graduation requirements in science, and colleges and universities must raise the entrance requirements in science.

Science teachers, as well as school counselors and administrators, must guard against unconscious bias in their presentation of science courses and careers and in their scheduling of science classes. For example, physics courses should not be scheduled in conflict with honors English or advanced French. The written and verbal use of nonsexist language in the classroom as well as in the text and other instructional materials is critical. Furthermore, the contributions of women must be portrayed seriously in narrative as well as illustrative material. The token inclusion of women photographed in lab coats is inadequate; their real contributions must be discussed. Research indicates that the sex-role stereotyping of science as a masculine endeavor is one of the most powerful deterrents to adolescent girls' enrolling and excelling in science courses. [12,2] If the repeated message from teacher and text is that scientists are males, then adolescent girls, unsure of their femininity, will shy away from science or, if enrolled, may perform poorly.

Since only 24 percent of secondary science teachers are women, girls have few role models in science. Both the National Science Foundation [10] and the American Association of Physics Teachers [1] have developed films and slide/tape presentations on women in science. These should be included in the science curriculum. In addition, universities such as Stanford University and Massachusetts Institute of Technology have successfully used undergraduate women in science and engineering to recruit high school girls into these fields.

Perhaps the most effective role models for girls are women or girls just a few stages ahead of those in a certain group. Girls might form science clubs at both the elementary and junior high levels to encourage those in the lower grades. Social perceptions of acceptance and "belonging" could be fostered, and the negative attitudes developed between ages 9 and 1[illegible] might be ameliorated. During the early high school years, girls should have the opportunity to speak with both collegiate undergraduate and graduate women in science as well as professional female scientists and engineers.

We can ill afford to allow girls to receive second-rate education in science. The majority of our students enroll in fewer science courses, perform fewer science activities, achieve at lower levels in science classes, understand science less well, and have negative attitudes about the role of science in their lives and in society. We Americans cannot develop a large pool of skilled technicians, scientists, and engineers unless we overcome the discrepancies in science education for girls.

The strategies suggested to meet the recommended action can occur in every science classroom. Perhaps conscious efforts will be needed in the beginning, but as students, teachers, counselors, and administrators practice them, these strategies will become routine. The public's recognition of inequities in science classrooms and the implementation of remedial instructional and curricular strategies are critical first steps in developing an adequate pool of scientists and technicians.

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Do We Link School Science With Industrial Resources?

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Businesses and industries are the primary beneficiaries of the skills and abilities of our science graduates, while the population at large is the primary beneficiary of the goods and services from businesses and industries. This close interrelationship strongly suggests that the science curriculum should meet the needs of persons who daily must confront issues and problems in a highly scientific and technological society. Now is the time for us science educators to begin a dialogue with persons in businesses and industries.

An examination of the literature quickly makes it apparent that businesses and industries want to be partners with education—and without strings attached. Weaver, a manager with General Motors Corporation, stated: ". . . [E]ducation can legitimately expect industry to help insure the high quality of its mission with financial aid where it is available, with professional expertise where it is helpful, with cooperative job opportunities, internships, and other work experience . . . ." [5] Dayton [2], chairman of the Dayton-Hudson Corporation, Honicky [4], a director at American Telephone and Telegraph, and Cooke [1], vice-chairman of the Economic Development Council have echoed Weaver's statement in their calls for business-industry-education cooperation.

The types of business-industrial-high school science education cooperation can be grouped into five broad categories: personnel; equipment and materials; facilities; employment; and finances. [3] This discussion will focus on one area that can make the most immediate impact on the science curriculum: employment of teachers by businesses and industries.

Employment of teachers in business or industry can be beneficial to both employee and employer. [6] The employed teacher learns about an industrial process and the nature of an industrial or business career. Laboratory and classroom lessons are given a dimension that cannot be obtained from a textbook or college preparation. Learning becomes meaningful when abstract concepts are applied to real processes.

Moreover, the career dimension becomes much more meaningful and realistic when one walks in the shoes of a person who has chosen the selected field as a career. Employers also benefit. Carefully selected and appropriately placed teachers can make a contribution to a profit-making organization.

Would this be a step toward the solution of our crisis in science education? The answer is yes. At present there is very little communication or cooperation between persons in business and industry and those in science education. Neither group knows the nature or requirements of the other group. Yet each group is highly dependent upon the other's product. For years, successful vocational education programs have used advisory committees partially composed of members from business and industry to determine goals and objectives and the means to obtain them. Cooperative planning between vocational educators and persons from business and industry has been profitable for both groups. Vocational educators have been able to design programs that focus on the development of contemporary work skills and habits. They also have enjoyed the support of the business and industrial community as well as the community at large. On the other hand, business and industry have benefited greatly by preparing a pool of graduates to enter the work force. We in science education, however, have not fared so well; our graduates are unable to apply concepts and skills learned in the science classroom to their daily lives.

In Britain, several well-thought-out chemistry programs, developed around a business-industry-education linkage, allow chemistry teachers to work part-time in the chemical industry. The teachers then incorporate into their chemistry curriculum examples reflecting the industrial uses of chemical processes. A large-scale effort to combine the best features of the vocational education advisory board model and the British model would be a significant step toward solving the U.S. crisis in science education.

Selecting a few outstanding science teachers in every community to work in a local business or industry could accomplish some auspicious results:

- the work experience would provide the basis to modify the content and activities in the science curriculum
- the revised curriculum would reflect identifiable applications of science in local businesses and industries
- graduates of such a revised curriculum would be in a position to relate science to the philosophy that says "through science to better living"

- students would better understand how science is used in their world

Similarly, persons in businesses and industries would learn first-hand of the problems facing science education. Most representatives of businesses and industries are willing to cooperate with educators in seeking solutions to problems faced in education. As has been demonstrated in vocational education cooperative planning of goals and the means to reach those goals results in a broad base of community support for the program. Science education has not enjoyed this type of support, since most members of the community, many of whom are our graduates, do not know what we are attempting to accomplish.

The projected cost of this kind of solution to our crisis in science education is another attractive feature of the proposed program in these times of declining financial resources because there would be no cost to taxpayers. The teachers selected to participate in this program would be paid by the participating businesses and industries. With additional employment, the gross yearly income of participating teachers would rise. The increased income, coupled with the responsibility and recognition associated with curriculum development, should help school districts attract and retain outstanding teachers of science.

With curricula attuned to the uses of science, a broad base of community understanding and support, and science teachers' receiving recognition and salaries commensurate with their training, we can anticipate some real solutions to many of the problems that have led to our present crisis in science education. Ultimately, our purpose in such an approach to teaching science is to have students experience science as a viable human endeavor. They will see science as a means to understand the world about them and a means to enhance the quality of life for everyone.

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Do We Link School Science With Local Community Resources?

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As federal resources have been sharply curtailed in recent years, the responsibility for developing initiatives in science education has been left to state and local governments. Many are calling for renewed support from the federal government and for immediate responses from the states, both of which may be necessary. But care must be taken to avoid a short-lived, crisis response. There is a growing perception that solutions to many of the problems in science and mathematics education and the resources for implementing these solutions can best be found at the *local* level. What is needed is an approach which will involve a broad spectrum of community leadership to mobilize local concern, develop significant understanding of the issues, and identify local solutions and resources to address the particular needs of science education programs.

Based on some initial experiments in North Carolina, our proposal for development of locally based science education improvement projects involves the cooperative efforts of local schools, area colleges and universities, local government, businesses and industry, and other community groups.

The objectives of locally based programs for improvement would be

a. to work with existing community resources, including political, business, scientific, and civic organizations, in the continued assessment and improvement of science and mathematics education programs in local schools

b. to implement specific programs to improve teaching in these subjects, increase student enrollment and performance, link the curriculum and learning experiences to local resources and needs, and provide adequate instructional and laboratory resources for excellent science and mathematics education

c. to maintain interaction between scientists, physicians, and engineers on the one hand and teachers and students on the other

d. to stimulate teachers, principals, superintendents, school boards, and parents to support an expanded role for science and mathematics learning experiences for students in grades K–12

A locally based improvement project would involve both public and private sector efforts to improve the quality of science and mathematics education. For each school system, a local resource team would be assembled, consisting of school administrators, local business executives, teachers, scientists and engineers, physicians, parents, and college or university personnel. These teams would

1. assess the quality of the science and mathematics education programs
2. define specific problems that could be addressed
3. develop strategies to solve these problems
4. identify the human and material resources that they could mobilize to solve these problems

These resource teams should function on an ongoing basis.

Local improvement projects in science in no way foreclose the involvement of state and federal government in curriculum development and program improvement. In fact, an essential by-product of the local efforts is the kind of broad-based consensus and political support necessary to sustain the states' and federal agencies' legitimate efforts. Through the National Institute of Education, the U.S. Department of Education, or the National Science Foundation, for example, the federal government might resume competitive funding of local initiatives in science education. It could establish procedures similar to the National Diffusion Network for certifying their effectiveness, and disseminate information about effective programs by sponsoring on-site visitations and institutes. States might contribute by networking the local programs and using them to provide information for state policymaking in science and mathematics education.

There is evidence that local business and community leaders are ready to form the partnerships necessary to take on some of the problems associated with improving science and mathematics education. They recognize the need for employees who not only have better technical skills in science and mathematics, but who also have the ability to adapt and learn on the job. They are also reawakening to the fact that investment in human potential, in the form of support for public education, is ultimately in their own best interest. There is a growing awareness that the quality of science and mathematics instruction at all levels of education is linked to the benefits of economic and technological growth. [3]

The issues associated with the need to improve science and mathematics education are becoming well defined. [1] Initial responses to these issues are already underway. [2] What is needed now is a mechanism to channel this interest into specific, productive improvement programs *and* a long-term, sustained commitment, rather than a short-lived crisis response. We propose the development of locally based improvement projects as a means for developing both immediate strategies for improvement and the broad community consensus required for a sustained commitment to excellence in science education.

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Do We Link School Science With Nonschool Constituents?

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There is an advertising message on television almost daily that urges people to "reach out." Science educators need to take that message to heart. In recent years, we seem to have failed to do so. We haven't reached out to parents and other members of the community, and they seem not to realize how serious the current problems of science education are. We haven't reached out sufficiently to the nonscience student, and an important result of that failure is that too little science is understood by people who will need it later in their lives. And we haven't succeeded in reaching out to legislators at local, state, and national levels to inform them about the importance of basic science education. Inadequate support for science education can often be traced to this lack of communication.

Reaching out to our various constituencies could be the most important thing science educators need to do if things are ever going to get better. For without a strong base of support, school science programs at all levels could continue to erode in the years ahead. Each of us can, however, make a difference if we act now.

The process involves working with people—people of all types and ages. It begins with the recognition that most people really *do* like science. They might not like what some science courses have become, or they might not like some of the "products" of science, but they really do like science! The evidence is there, right in front of us, if we will only recognize it.

Item: Sales of "popular" science magazines are at an all-time high, as is the number of such journals now available. In two years, for example, the circulation of *Discover* magazine has grown to 835,000; its publishers claim that it is "still growing rapidly."

Item: Attendance at science-oriented museums, exhibitions, and centers has never been higher.

Item: Television programs such as *NOVA*, *Cosmos*, the National Geographic Specials, and *The Undersea World of Jacques Cousteau* all continue to receive high viewer ratings.

Certainly, the evidence from these informal sources of learning is clear: Americans are interested in science. We must capitalize on that interest, because it can help us to get school-based science moving again.

Where do we begin? One starting point might be to take a close look at what makes science special to those who read science magazines, attend science museums, and watch scientific television programs. When we do, elements such as the following stand out:

- The topics dealt with are ones to which people can easily relate; even if some of the topics seem esoteric at first, they ultimately have meaning for the individual.
- Science, technology, and other areas of knowledge are shown to be interrelated; in popularized science few, if any, artificial boundaries exist.
- Content is handled in interesting, fun-oriented ways; even seemingly difficult content is made understandable.
- Strong emphasis is placed on communicating effectively with the viewer/reader/learner; concepts are explained through clear illustrations or engaging experiences.
- Controversial issues are not avoided, perhaps because they seem inherently interesting to people.
- The unanswered questions of science serve as central points of inquiry; science is not presented as a set of conclusions but as a continuing process of discovery.
- The human aspects of science and scientific research are highlighted honestly; the trend is away from Hollywood's stereotypical scientist (a white-coated, pipe-smoking male who always thinks rationally) and toward a realistic representation. Scientists come from all groups in society.
- A person doesn't have to be a "genius" in order to enjoy, appreciate, and learn about science. The Exploratorium science center in San Francisco, for example, seems to have something for just about everybody. This does not mean that the content is watered down—typically, the content stretches the capabilities of the learner.

What can science educators learn from all this? How can we build a wider and stronger constituency for science? The answers can be summed up in the phrase which the telephone people have so successfully employed: "Reach out, and touch someone!" Each of us must take that phrase to heart by actively reaching out; a strong base of community support for science will not simply build itself.

This base is composed of several, equally important constituencies:

Parents and the Community, including boards of education, business and industry, and the media. Think about the power that parents can wield! What if a large number of parents in a community began to press for more and better science? What if key business/industry groups in an area began to lobby intensively on behalf of science? What could their support mean to the science program?

Students. After all, they are our clients. However, beyond required courses, they will enroll in science only if teachers work to attract them. The quality of school science determines in large part how strongly students will support it. Remember, too, that today's students are tomorrow's parents, business leaders, and legislators.

Legislators. Legislation strongly supportive of science education does not occur of its own accord. Certainly, we all know that we need the support of legislators at all levels of government. But we can only gain it—and their confidence—by making a commitment to work for it.

Nonscience Colleagues, both teachers and administrators. They are a constituency much larger then we are—and their strong support for science would help enormously. To gain it, we will need to show them how science contributes to each area of the curriculum and how it enhances the total education of students.

Other Science Teachers. There can be no doubt that we need one another's full support during these challenging times. That support can take many different forms.

Clearly, science needs the support of each of these groups. Here are some ideas that can help us to earn the backing of each of these constituencies:

Working with Parents and Community Groups

A good deal of our responsibility here lies in providing helpful and reliable information. Parents and others need to know how important science is and will be for their children. They should be reminded of the urgent need in science courses for lab activity and field trips. Interestingly, when adults are asked what they remember best from their school science, their most frequent recollections are of lab activities and field trips.

Parents also need to hear about the good things that happen in science classrooms. While some of this information sharing can be accomplished through traditional "Parents' Night" programs, other mechanisms also need to be explored. One school invited fathers to spend a half day in school with their son or daughter. This approach permitted fathers to participate in science and other activities alongside their children. The results of this program were very positive, for both the school and the parents.

As we move increasingly into a new type of technological age, business and industry are becoming more and more aware of the need for strong school science programs. We need to reach out to these groups by providing information, and making our needs known. They can help by lobbying on behalf of more and better science, by providing financial or material support, by making human resources available, and by supplying information about careers.

Reaching Out to Students

We need to assess very carefully what we do in the name of science in our classrooms. We need to popularize science without diluting it. Good science is anything but boring. It's an exciting and entertaining enterprise to which millions of scientists and science teachers devote their professional careers. Our classrooms have to recapture that joy and enthusiasm.

This is certainly not the place to try to list all the things that could be better in science classrooms. However, those popular science magazines, television shows, and museums do suggest several avenues worth pursuing.

We need to relate science more closely to the things important to students. Should not biology courses focus more on human beings and bioscience concerns and issues? Issues such as genetic engineering, the inheritance of human genetic defects, and human medical experimentation are inherently interesting to young people; they should not be ignored in the classroom. Would not the study of forces and vectors be more interesting if it were dealt with in the context of a real human problem such as the use nonuse of automobile seat belts? In chemistry, why not place more emphasis on topics relating to basic environmental concerns?

We need to treat science as a series of as-yet-unanswered questions about the universe. Too often, present curricula seem to suggest that everything is already known, and that all students need to do is memorize a body of facts. Students must be led to realize that what they learn is helpful in organizing information, but that all knowledge is tentative—being continually subjected to testing and revision. When scientists memorize information, they do so in order to test other, still-unanswered questions. Memorization is a vehicle, rather than an end in itself. Classroom teachers need to make that distinction clear.

We need to emphasize science process and manipulative skills which can help students after they leave school. Better observers make better citizens, better physicians, better automobile mechanics, and better parents. Science skills also help students to become better decision makers, and society never exhausts its need for people skilled in making decisions.

We need to touch our students at the human level. The research literature leaves little doubt that this is vital. Students do better when they know that you care. Which teachers do you remember best, and how did they influence you with regard to their subjects?

Reaching Out to Legislators

Legislators must write and vote on a variety of legislative issues. Sometimes their understanding of the concerns of science and science education can be incomplete. The story, probably apocryphal, that one state legislature passed a bill to change the value of pi to 3.00 in order to simplify computations illustrates the point: Legislators need a better understanding of the problems and issues of science and science education. The efforts of science educators to inform those in public office about science—through correspondence or telephone contact—are important. In some cases, these efforts to inform can be crucial.

Reaching Out to Our Nonscience Colleagues

It is essential that science teachers gain the support of school administrators at all levels, as well as that of other school personnel not directly involved with science. "Reaching out" to administrators primarily means keeping them informed—informed about the role of science in the total curriculum, about the needs of a good science program, and about what science courses can and cannot accomplish. Administrators to whom we demonstrate the value of new teaching/learning materials, texts, or equipment are more likely to be supportive. The research is very clear: Effective principals help teachers and programs improve. We can help principals to become more effective by keeping them informed about the things that are important in science education.

Among the other school personnel not directly involved with science, perhaps none is more important than the guidance counselor. By virtue of their unique position, counselors strongly influence students. We need to work with guidance personnel to keep them better informed about science, science instruction, and science career opportunities. This is a potent constituency which we have to enlist on our side.

Cooperation with teachers of other subjects is also essential. They need to understand what science courses are about, and we need to develop ways of collaborating with them to make the total education of students more efficient and effective. Some teachers seem to believe that their subject is the most important, and science teachers can be as guilty as any of this misconception. Reaching out to other teachers involves communicating with them about a variety of issues, including ways to coordinate curricular goals. There is a great need to make studies in one subject produce positive impacts in other subject areas as well. All this is in the best interest of our students.

Reaching Out to Other Science Teachers

It always has been important for science teachers to reach out to one another, and organizations such as NSTA play a pivotal role in making that possible. But in times such as these, it is even more important for us to maintain strong ties. Each of us has worthwhile ideas for making what we teach more meaningful, but far too many of those ideas are lost because we fail to share them with colleagues.

Moreover, in these challenging times, none of us is immune to the malady called "teacher burnout." One condition fostering that malady is the isolation that each of us senses at times. We have too few opportunities to engage in conversation with colleagues who share our dreams, our concerns, and our anxieties. One way to head off a severe case of science teacher burnout is to remain in active contact with other science teachers—from other districts and schools as well as within our own school. Reach out and establish those contacts!

* * *

The suggestions offered here are quite simple. However, what seems so simple to do is often perceived as not worth doing—"How can something as mundane as that help?" However, these very small things, when taken together, can make a big difference. We cannot change all of education by ourselves, but can cope with the things within our reach. By influencing some little piece of the world, we can indeed make some worthwhile things happen. The problems of the 1980s are complex ones for which no simple solutions exist. Our task—yours and mine—is to do those things within our reach that can help. So let's not wait. Let's accept one or more of these challenges, and help get science on the move once again!

B. PROGRAM CONCERNS

Do We Include the Essential Aspects of Science In Our Definition of School Science?

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The teacher in the classroom is the image of science before the pupils. Science teachers are emissaries who carry the message. Those who write curricula, textbooks, and the other materials of instruction are remote and can at best rely upon a limited personal experience with certain schools and certain groups of students. They attempt to visualize pupils and places; but they have limitations to their perspectives.

Therefore, it is of utmost importance to consider the teacher's image of science. Does the teacher see science as an unending search to create stability in our images of the world; of relations among the myriad, apparently discrete things and happenings in the world of experience; of a search for the "hidden likenesses" couched in novel and abstract terms? Or does the teacher view science as a body of knowledge, essentially complete, which is her or his responsibility to pass along to pupils as part of their cultural heritage? This will govern the teacher's approach in the classroom as "convergent," a closed book filled with "right answers"; or "divergent," a way of asking and answering questions for the time being.

As Munby and Russell have recently asked, will the teacher encourage a view of science that is "rational, moral, and authentic"?[1] Specifically, will the teacher emphasize that science has its limitations, not only of observations and abstract imagery but also of domain, and that science is only one way of reaching rational views, such as those in

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H. Munby and T. Russell, "A Common Curriculum for the Natural Sciences," in *National Society for the Study of Education Yearbook* (Chicago: The University of Chicago Press, 1983), p.147.

history? Also, some of us might believe that the domain of science does not include many important aspects of life such as beauty, hope, and love. The criteria we use for evaluating our perceptions have different rationales, depending upon the context. Science is only one of several rationalities and is applicable only in certain contexts.

Similarly, Munby and Russell consider the role of moral judgments in school science. While many argue that teaching the interrelationship between science and society through technology is an essential obligation of the science teacher, perhaps shared with the social studies teacher, we must ask whether the teacher is willing and able to consider topics that have strong moral overtones. In the development of the teacher, have there been opportunities for personal involvement in discussions that have no clear answers of "right" and "wrong"?

Munby and Russell make a third point, on the authenticity of much that passes as science in the classroom. When it appears occasionally, the history of science is presented briefly as a success story with little consideration of alternative conceptualizations or false leads. Usually these are unknown to the teacher.

The view of science in the classroom is created by the teacher and mirrors the views of that teacher. In general, college courses emphasize a narrow view for future scientists. Later, one develops a broader view of science as a way of knowing and an understanding of the relations between science and society. Those who observe such a gradual development have a responsibility to provide opportunities for consideration of the larger role of science in the education of all people (most of whom will not become scientists).

Do We Expect School Science to Nurture Creativity?

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Stent, writing in *Scientific American*, finds a commonality in the traits of artists and scientists. [9] He emphasizes that scientific statements "pertain mainly to relations between . . . public events," whereas artists' statements "pertain mainly to relations between private events of affective significance." He posits that the transmission of information and the perception of meaning in that information constitute the central content of both the arts and the sciences. A creative act on the part of either an artist or a scientist would mean his or her formulation of a new meaningful statement about the world, an addition to the accumulated capital of what is sometimes called our cultural heritage.

In seeking hidden likenesses in the work of scientist and artist, Stent defines creativity in a way that requires emphasis: The creative act adds *new and meaningful* works to the culture. For the practices of schooling, the term "creativity" is ambiguous and is used variously to describe (a) behaviors that are beyond the norm for a particular grade, (b) acts of inquiry that are "new" to the activity expected of the young, or (c) acts of discovery (the results of different acts of inquiry) which delight and surprise teachers and parents. In this discussion, the *creative act* will refer to works that add new and meaningful statements to the culture, or works directed at securing new judgments or new presentations of generalizable knowledge. Indeed, Bell defines knowledge as consisting of "new judgments (scholarship and research) or new presentations of older judgments (teaching and textbooks)." [1] Giftedness as an attribute will refer to those judged to be capable of such creative acts.

Early in my work, I became interested in particular traits of scientists which seemed to characterize the scientific mode and manner as distinguished from that of other workers, say artists, businessmen, and others. Shortly after high school graduation, I secured employment in the Littauer Pneumonia Research Laboratory. Through the kindness of the directors of this and, later, other laboratories, I was able to pursue my undergraduate and graduate work in the sciences while I did research in these laboratories. Having had early experience with artists, I was impressed with what then seemed to me, as an adolescent, to be specific differences in the personality traits of scientists and artists and their approaches to their work. When I began teaching, I continued my studies, focusing on the traits of junior and senior high school students who selected science as a career. I also directed attention to the kinds of programs (that is, environments) that might effect and influence such career choices. I wondered: *Were there any traits, that could be detected early, which were necessary and sufficient to the development of youngsters especially skilled in inquiry and thus those who might become scientists?*

A bibliography of early papers relating to this question is found in a collection of papers by Brandwein, Metzner, Morholt, Roe, and Rosen. [4] Metzner reports [4] that Cooley [5], using my data, "concluded that there is no simple entity that may be called *science ability.*" However, Cooley [5] indicated (as Metzner substantiates) that the most reasonable approach appears to be *"self-identification with free flow in or out of any given program for the talented; individual guidance then plays an important role whenever reliable information becomes available"* (italics mine). This substantiates Brandwein's earlier hypothesis [2], reaffirmed in a continuing study [3], that *"self-identification* catalyzed by a demanding instructional program permitting original experimental work in *the school laboratory*" might play a role in the development of young scientists-to-be. Metzner, however, is clear in his conclusions that *"no single technique has been devised that will identify students who are gifted in biology, or other sciences, with complete accuracy or reliability"* [4] (author's italics). Perhaps the discussion to follow amends this conclusion somewhat.

The works of Getzells and Jackson [6] and of Torrance [10] indicate that a high level of general intelligence (as measured in the I.Q.) does not, as Roe [8] also concludes, ensure *creative behavior*, which seems to involve factors other than those studied through tests of general intelligence. In fact, for purposes of identifying scientists-to-be the term *creative behavior* can be replaced by "ability in effective inquiry." (On this, see also Roe. [8]) The observations of Brandwein [2,3] confirm many findings that three personality factors need to be considered in assessing the schooling and education that nurtures scientists-to-be. These three factors are described as "questing" (or a skeptical view of accepted positions which also embodies what is generally called curiosity); "persistence" (or a degree of independence which sustains effort); as well as a "key factor" (or the environment of psychological safety and freedom necessary for experience in *experimental work* in science provided by a teacher). True experimental work, which calls forth "questing" and "persistence" within an environment of "psychological safety and freedom" can indeed be useful in probing the kind of knowledge "one is not supposed to know." [7]

A spectrum of traits characteristic of "developing scientists" is described by Brandwein, Metzner, and Roe. [2,4,8] Based on observations of 104 schools with programs for the gifted, four assumptions were made in the 1962 study by Brandwein *et al.* [4]:

1. We may assume that in those schools where the freedom to investigate is highly characteristic of the curriculum and teaching there exists a greater opportunity for students to learn the methods and advantages of the investigator's life. (For "investigate," read "inquiry.")

2. We may assume that opportunities for early identification of potential investigators will occur in those communities where the schools make opportunities for investigation early in the school career; that is, in the elementary schools.

3. We may assume that where there is a broad approach to the curriculum, the more favorable will be the environment for investigation.

4. We may assume that when the "pattern" of the school encourages and rewards individual responsibility for personal behavior and stimulates development of independent scholarship, the stimulation of individual investigation will be greater.

In our continuing effort to secure a tenable hypothesis that might shed light on the self-selection of scientists-to-be, we note this point: Of a group of 624 students who participated in the science program at Forest Hills, New York [2], 62 were selected for further observation as the experimental group (rating above 4 on an inventory of traits comparing them to working scientists); and 62 served as controls, rating below 3 on the inventory. The 62 experimentals and the 62 controls were matched in I.Q. and general scholastic average.

At this point, some 30 years after the initial study, from still-preliminary study of those who have been followed, it appears that 22 of the experimental group of 62 have committed themselves to scientific research; and 13 have committed to technological fields in the area of science. Twelve committed themselves to teaching science in the high schools. Among the 62 "controls" (tentatively selected as probably intending careers other than science or technology), 6 are in scientific research, 8 are in technological fields, 6 are in teaching science in the high schools. An unsurprising but useful finding is: Out of 67, I have been able to observe at work and to interview at this period in the continuing study the 28 working scientists; and 11 out of the 19 engineers are people who in their schooling were persistent and almost indefatigable *in pursuing experimental work probing unsolved problems*. They used an inquiry approach on the highest levels.

The operation called "doing an experiment" involved work in solving a problem for which a solution was *not* in the literature. This was so attested by working scientists. Further, in interviews, the 28 working scientists were still able to recall their early pleasure in pursuing experimental work. (This, of course, calls upon abilities and traits of personality different from those required by the usual laboratory exercise.) They also recalled the effect this had on their decision to pursue a scientific career.

For instance, an experiment (as compared and contrasted with a laboratory exercise) takes much more time, often a year or more. It calls on a constant interplay of intelligence and imagination, as well as on personal abilities to plan, quest, persist, and endure conflict, not to say failure and discouragement. It is, thus, an operation in which the young experimenter is tested not only for scientific abilities, but also for complementing personality traits. In addition, conducting an experiment calls upon additional facilities in the school or home environment as well as on particular traits of the teacher.

Summary

An environment conducive to the conduct and completion of at least one experiment as compared and contrasted with the usual laboratory exercises might well be included in curricular strategies and instructional tactics.

The literature is sparse on what seems to be a special ability, a high level of skill in scientific inquiry. A sufficient number of the papers tend to support the postulates recounted here, and none oppose these ideas. Clearly, we are obliged to consider the nature of the critical impact of science and technology in the decades to come. It is an obligation of the schools to develop an environment that gives scope to the young who would become scientists.

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Do We Tap the Individual Uniqueness of Students in School Science?

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"But, actually, I did not teach freshmen. I taught attorneys, bankers, big businessmen, physicians, surgeons, judges, congressmen, governors, writers, editors, poets, inventors, great engineers, corporation presidents, railroad presidents, scientists, professors, deans, regents, and university presidents. For that is what those freshmen are now, and of course they were the same . . . then." [5]

That there are varieties of children, with great varieties of interests and ever greater varieties of yet-to-be-defined career opportunities, is well-established. And times have changed! Jobs that were once easy to find and appropriate for students who had dropped out of school, without math, science, or computer science skills, are now performed by machines. The choice has become an either-or choice: Either provide people with math, science, and computer science skills, *or* support people because they will be unemployed and, due to basic skill deficiencies, unemployable.

Literature supporting the claims that learners vary widely and that instruction generally has a differential effect can be found in almost every issue of all our professional journals. There are the left-brained, right-brained, factual, conceptual, intuitive, persistent, reflective, and impulsive learners. The many varieties of learners are, largely, taught by identical instructional methods. As has often been predicted, this results in high correlations (typically about +.70) between pre-instruction aptitude scores and postinstruction achievement scores. When the kind, quality, and quantity of instruction are varied according to learner needs, however, almost all learners achieve mastery of the subject. [2]

Financial constraints might prohibit us at the moment from individually tailoring instruction for each learner. However, the practicality, feasibility, necessity, and real value of doing so should be made known. Individual achievement must become our primary objective.

The thought of providing an individual instructional prescription for each child is daunting when the school budget barely provides enough money for the science textbook; when 35 students are placed in a 24-student laboratory, when the subject the teacher is teaching is not his or her area of concentration, and when the only software for the classroom's sole computer is of dubious value. But we cannot hide behind excuses when we know that much has already been accomplished that would allow us to provide for some, if not all, individual differences in most classrooms. For example, consider the curriculum materials designed after Sputnik, when we assumed that really "good science"—that is, science as it is practiced in the laboratory—would be inherently interesting to all students. Today, many claim the post-Sputnik curriculum reforms have failed. We have discovered that some teachers couldn't or didn't teach science in a manner consistent with the curriculum philosophy. [4] Further, some parents preferred the rhetoric of conclusion to which *they* were subjected as youngsters and which *they* forgot. We found that some students prefer memorizing to thinking, probably because students are not provided ample opportunity to practice thinking. In fact, the post-Sputnik curriculum efforts may actually have had considerable success. Recent studies report that "students who plan scientific and engineering careers are receiving an adequate educational foundation" in spite of the declining emphasis on science and mathematics. [5] This finding supports the claim that the alphabet curricula probably are excellent for students planning science careers. Hence, the alphabet science curricula should *not* be discarded, although they clearly need to be modified. We should ask: Have certain curricula and instructional approaches facilitated significant science achievement? Can we identify learners who have—and learners who have not—been helped by the curricula? Will other variables facilitate learning among other kinds of learners? Are there defined problems that learners will face in life that a knowledge of science will help them solve? Can we *prepare* problem solvers?

The answer to each of these questions is Yes! What remains is the task of assembling the puzzle pieces and matching the student to the appropriate variety of instruction—the variety that begins the student along a path of purpose and success leading to science achievement.

Like others [6], I have assumed that the science-related problems that people will face in life are known. I have assumed that schooling (and education) should prepare learners who have the desire and ability to come to grips with these problems. Furthermore, I believe that schooling organized around student interests and the solution of science-related, real-life problems will facilitate learning among all varieties of learners. That is why I argue for curricular variety.

Some will learn science best if they study science as history—a history of ideas; of people and their inquiries; and of success through persistence. Others will learn science best by studying the inventions made by technologists using science. Others will find futuristic science appealing. Some will be attracted to the beauty of the natural world and wish to explore science from an aesthetic viewpoint. Others will need a philosophical approach. And some will gain science appreciation by relating science and mathematics. [1]

There are varieties of learners as well as varieties of science curricula. Ideally, learners could be matched to curricula by interest. As Tyler indicated [7], interest is the point for departure. Get learners interested, keep them interested, and nothing will stop them from learning the significant science they need for successful life in a democratic and technological society.

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Does Science Teacher Preparation Nurture Effective Science Teaching?

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Does the training of science teachers nurture effective science teaching? This question refers not only to the training of the subject matter specialists we find in most secondary schools, but also that of the elementary generalist. This training includes the curriculum taken by preservice, and to some extent inservice, teachers as well as the curriculum they will be expected to teach.

Science ought to be a favorite subject because it includes a naturally motivating element; namely, tangible materials. Young children possess natural curiosity which attracts them to tangible things, but as they get older they become less motivated by curiosity. So what happens to this motivation? Carl Sagan [3] commented, "People have been taught that they are too dumb to understand science." Two important variables the young child encounters in school are the teacher and the curriculum. These two variables need to be examined.

Prospective teachers take college science courses, and these courses vary considerably. According to a recent survey, [illegible] teachers became turned off to science because the format of science courses kills curiosity. College isn't the first place where such disappointing courses are encountered; they are present in many pre-college schools. If teachers teach the way they were taught, then the way these college courses are taught becomes increasingly significant.

A lecture-lab format characterizes nearly all college science courses. The lecture precedes laboratory exercises that develop from it and verify it. What is generally considered important in these courses is memorizing facts, plugging numbers into formulas, and writing up little-understood laboratory reports. Seldom are students taught by any method resembling an inquiry-based approach, which would require original thinking. The preservice teacher majoring in science usually sees the inquiry method for the first time in a science teaching methods course—and by that time, it is too late! College students taught this way then proceed to teach their secondary school students just as their professors taught them! The spirit of inquiry is missing because it was never really discovered. The same can be said for preservice elementary teachers, except that they have the additional problem of knowing even less content.

"Memorize this, compute that" is the message passed on down to precollege students. It is no wonder that students are not motivated to learn science and do not pursue it. These circumstances have persisted for a long time.

The curriculum projects of the 1960s and 1970s made excellent attempts to change this. How successful were they? Shymansky, Kyle, and Alport [illegible] looked at research studies reporting on the effects of the activity-oriented, inquiry-based elementary programs of Elementary School Science (ESS), Science Curriculum Improvement Study (SCIS), and Science—A Process Approach (SAPA) in the performance areas of student achievement, attitude, process skills, related skills, creativity, and Piagetian tasks. They state, "Our quantitative synthesis of the research clearly shows that students in these programs achieved more, liked science more and improved their skills more than did students in traditional, textbook-based classrooms." This is truly an impressive result. But many teachers never used these projects even in their heyday, and even fewer are using them now. [1]

Another study comparing inquiry-oriented teaching and expository teaching, with the procedures spelled out in detail, found that ninth graders taught by the inquiry method did better than the expository group in areas of I.Q. gains, intellectual development gains, and achievement. [4]

This is where we need to start. If we can keep the natural curiosity of our students alive by going back to these curricula and using them in the way they were intended to be used, we will be on our way to improving scientific literacy. Some science educators and other concerned people think that we can solve the problem of unprepared teachers simply by increasing the number of required science courses. Instead, we should look at how these courses are taught. More is not necessarily better; in fact, increases in the number of required courses might aggravate the problem.

One study, developed on the learning cycle model of SCIS in physical science for preservice teachers, showed that all students increased their intellectual development, but results varied on attitudes toward science and science teaching. [6] This attitude variation might have occurred because this was the first course of its kind that many of these students had had.

Teachers already in the classroom present yet another problem:

Realistically, their motivation to go back to college is at least somewhat tied to the potential for increased salary that accompanies additional credits and degrees. Usually it means they must take coursework at the graduate level. However, if teachers' academic preparation has been inadequate, the rigors of advanced courses are beyond them and probably wouldn't be very helpful. This is especially true for the nonscience majors now teaching science. What may be needed are beginning level courses taught in an inquiry format for graduate credit, but getting such courses [illegible]ed by college science departments and university curric[illegible]ittees is nearly impossible. Thus, by cloaking themselves [illegible]ual elitism, our colleges and universities are adding to the pro[illegible] of the inadequately prepared inservice teacher. This problem is especially acute for elementary teachers.

How can we change the notions of our subject matter-oriented colleagues? Academic scientists aren't going to change their minds easily. After all, they say, science includes rigorous subject matter and should be treated with rigor. If this is the established attitude, then all the funding we can secure for science education isn't going to help much. The road to success isn't an easy one. Those of us in colleges and universities have our work cut out for us.

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Does a Teacher's Knowledge Improve His or Her Science Teaching?

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Several researchers have already contributed to the determination of the kinds of laboratory teaching competencies science teachers need to teach a modern science course. In the most complete investigation of biology laboratory teaching competencies [2], Kreuzer examined the five most extensively used biology textbooks and developed a preliminary list of 75 lab teaching skills essential to teaching a first course in high school biology. The list of competencies was then sent to 189 biology teachers who had received the National Association of Biology Teachers' Outstanding Biology Teacher Award (OBTA). The teachers were asked to rate each technique as to its importance for biology teaching, on a scale: highly essential, 5; essential, 4; of average value, 3; of little value, 2; and of no value, 1. They were also asked to add techniques that did not appear on the list. A final list of 60 techniques was synthesized from responses of 125 of the OBTA winners.

Samples of biology competencies from the Kreuzer study include the following.

Prepare an infusion such as a hay or peppercorn infusion.

Make use of the technique of paper chromatography.

Perform an activity that demonstrates osmosis.

Make use of a technique for extracting chlorophyll, and other pigments, from leaves.

Prepare solutions of various molar concentrations; for example, a 0.1M sodium hydroxide solution.

Dissect a frog in order to study its internal structure, organs, and systems.

Collect and analyze samples of fresh water.

Experiment to study phototropism in plants.

Observe the heartbeat of daphnia (or another small organism) under a microscope, and investigate the effects of various temperatures, stimulants, or depressants on the heartbeat rate.

Perform a bacteriological analysis of water or milk products or other food products.

In addition to the biology competencies, chemistry, physics, and Earth science competencies were developed and validated by teachers in those subjects who supervised student teachers in science. Samples from each group follow:

Sample Earth Science Competencies

Determine the density of different objects.

Make a demonstration fog bottle.

Identify rocks and minerals by physical and/or chemical tests.

Demonstrate rotation and revolution of each planet (example: show day, night, seasons, and planetary motion).

Demonstrate the relative humidity.

Set up a model to investigate movement of water through particles of different sizes; measure rate at which water rises through coarse and fine sand, and graph data.

Sample Chemistry Competencies

Calculate a molecular weight from laboratory measurements.

Construct different kinds of molecular models.

Demonstrate electrical conductivity.

Determine vapor pressure, boiling point, and freezing points of pure liquids.

Study factors affecting rates of reaction.

Determine an equilibrium constant experimentally.

Sample Physics Competencies

Use linear air track to illustrate and make measurements of:

- unaccelerated and accelerated motion
- conservation of momentum
- inelastic and elastic collisons
- conservation of energy
- simple harmonic motion

With Polaroid camera, photograph various motion phenomena using stroboscopic techniques.

Using classical experiments, measure: the quantization of electric charge (Millikan's experiment) the ratio of charge to mass of the electron.

* * *

Two recent studies further describe needed laboratory teaching competencies. Voltmer and James [3] list 60 laboratory teaching competencies viewed as essential by science educators. The following safety and operational competencies were ones for which students received *low* rating.

Safety Competencies

Handling, storage, disposal of laboratory substances and chemicals
Knowledge of correct and incorrect procedures to handle student injuries

Operational Competencies

Microcomputer use
Recording; mercurial aneroid barometer use
Telescope use
Adjustment of the pH of a solution to a new level
Serial dilution techniques
Aquatic collection techniques, including plankton, bottom fauna, large organisms
Culturing and maintaining daphnia, planaria and drosophila in the classroom
Use of single-lens reflex camera
Preservation of plants and animals for display and use in the laboratory
Chemical analysis of water to determine the presence of phosphates, nitrates, acids, gases, and minerals
Field equipment use
Construction, procurement, and improvement of low-budget and homemade equipment
Use of teaching aides and student assistants in the laboratory
Location and use of resource people; materials in the community
Evaluation of student progress in the laboratory using attitude measures and cognitive tests

Regional Science Education Centers

Cobbins [1] developed a list of 68 laboratory and field skills essential for secondary school biology teachers. This list was sent to 238 secondary school and college biology instructors for validation, and as a result 58 skills were identified as essential.

Knowledge about what skills are necessary for science learning does not mean, however, that these skills are available or put to use. The concern for the improvement of laboratory science teaching points to the necessity of establishing regional science education centers. These centers should be staffed by scientists, science educators, and science teaching counselors. Support for the centers would be on a three-year basis, with most funding through the National Science Foundation (NSF). Centers would be approved by means of competitive bids to NSF. Industry, local school districts, and science equipment suppliers might support the centers as well.

Ideally, such centers would be attached to a university. The primary focus of each center would be to update the teaching skills of teachers who had not been properly prepared or who were no longer professionally current. Some teachers would be enrolled for an academic year, while others could be enrolled for a summer institute only. The teachers would receive new science content instruction and, in particular, laboratory competency instruction. After their science and science skill preparation, follow-up assistance in the local school could then be given by each center through a science teacher counselor program. Such an ongoing program could have immediate and long-term results in improving secondary school teaching.

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Do We Tap the Potential of Continuing Education As a Source to Strengthen Teachers?

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Over the past 25 years, millions of dollars and much effort have been invested in the development of science curricula. We have learned from that experience, learned that we cannot build "teacher-proof" curricula and that good teachers are central in motivating students and in promoting science learning. We also have confirmed that there is more to good teaching than being an expert in a science discipline and that poorly qualified teachers provide less-than-optimal learning experiences for students. Unfortunately for us today, even fewer teachers are properly qualified for science teaching than was the case 25 years ago.

A number of factors contribute to being well qualified and promote professional growth and renewal among science teachers. We shall highlight only the central role of continuing education in encouraging vitality, professional renewal, and competence in science education.

We believe a competent and professional teacher is more than a trained technician. A professional is aware of problems, rationally assesses those problems, digests available information, envisions solutions, makes decisions, and takes appropriate action in the classroom. This teacher-initiated action leads to the resolution of problems and promotes learning appropriate for individual students. Such professional analysis, sensitivity, and resolution is not automatic, nor is it present in the majority of beginning teachers, even those from good preprofessional programs.

The level of professionalism, competence, and expertise that we expect probably is best developed through appropriate continuing education experiences. A very visible example emerges from preliminary analyses of the NSTA Search for Excellence in Science Education

(SESE) study. (The NSTA *Focus On Excellence* monograph series provides details on 50 exemplary programs in science education, nationwide.) Teachers in SESE exemplary science education programs generally have been active participants in long-term continuing education and have taken personal action in developing their own curricula and creating an environment conducive to professional growth.

Continuing Educational Alternatives

Good professional experiences in continuing education depend on time for reflection and synthesizing experiences and ideas. A sensitive system of mentors can greatly increase the power of a teacher's experience as well. Appropriate continuing education alternatives can include:

1. working in areas relevant to the science discipline taught; for example, in industrial, medical, or research laboratories
2. participating in discipline-relevant programs in higher education, such as science education, science, or computer applications
3. conducting or participating in research on the teaching-learning process as it relates to science or science teaching
4. being involved in extended curriculum development or adaptation and evaluation
5. being a coordinator or principal support person for a major curriculum implementation effort
6. developing appropriate curriculum enrichment materials, such as computer-assisted instructional activities and simulations, laboratory investigations, personalized experiences, and concept applications
7. exchanging positions for one semester with a teacher in another region or country
8. serving as a supervisor or instructor in a preservice teacher education program
9. teaching courses for inservice teacher education
10. taking major responsibility in a regional or national professional science or education association
11. being a major contributor to a book or other resource published by an established publisher

Many other continuing education alternatives are available locally. We should point out that while we anticipate some variation in the quality and intensity of various alternatives, they are intended to be more than just high-quality, relevant, alternative experiences. Promoting professional renewal, development, and maturity is our main goal. To increase the probability of such development, we must include opportunities to process new information and to synthesize and apply new information and world views to the local school setting and curriculum.

Professional associations like NSTA should act assertively in joining government agencies and other professional associations to set up continuing education alternatives of the highest quality. In addition, an organization like NSTA can function as a source of information about such alternatives, about creative model programs, and about what is happening in various locations. Communities and organizations with valuable information about alternatives are more likely to envision additional relevant activities and projects that can be undertaken locally. They might then begin participating in this important national movement which is in the best interests of local education and of community growth and development.

NSTA and other organizations must act to promote an environment in which teachers are considered mature professionals. Preservice teacher education and licensing are only rudimentary in this cycle of professional growth, maturation, and continuing education. In a complex technological age, it is naive to believe that mature professional competency can be acquired in one short burst of preservice instruction. It is equally naive to believe competency can be maintained for a lifetime without carefully developed continuing education.

As a nation, we have a right to expect professionalism from science teachers. As professional teachers, we must help other teachers to achieve their own potential. We must set up systems that not only will demand but will foster the knowledge, skills, and attitudes of professional science teachers.

Do We Have the Resources to Develop [illegible] New Teachers Needed for School Science?

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The capacity of America's colleges and universities to prepare enough qualified science teachers to serve the country's schools in the future is in doubt. Currently, however, little information is available for determining whether they can increase this capacity.

At present, there is a severe shortage of physical science teachers, and in some locations there is an equally serious shortage of teachers in other science areas. The school-aged population is about to start a sustained, steady increase in numbers. During the next ten years, a large number of professors of science education will probably retire. This will greatly reduce the capacity of teacher education institutions to train new science teachers.

Recommendations

To assess the current status of the population of science education professors in the U.S., a survey should be conducted to determine

1. the average age of professors of science education currently teaching in teacher education institutions
2. the average number of years until their planned retirement
3. the percentage of those who plan to change professions, by becoming college or public school administrators, for example
4. the availability of time and resources to add to their work load in training new science teachers
5. the current numbers of science education doctorates being produced, and the availability of time and resources to add to professors' work load in advising new doctoral candidates in science education
6. the percentage of time spent in teaching, research, and inservice activities
7. the percentage of time spent in teaching courses other than those in science education

If the data from such a survey indicate that the population of science education professors is aging and that production of new doctorates is insufficient to replace potential losses, then a stimulation of the production of new doctoral candidates would be helpful. This could take the form of fellowship programs, similar to the National Defense Education Act (NDEA) fellowships sponsored by the federal government during the 1960s. Even if such programs were not possible, science education departments of major universities could use the data from the study to encourage more local support for new doctorates in science education.

A second study should be conducted to determine the capacity of teacher education institutions to increase their recruitment of students, and thus their production of science teachers. The heads of science education departments at colleges and universities should be surveyed to determine

1. the average size of science methods classes
2. the average number of sections of science methods classes
3. the ability of the institutions to increase the size and number of sections of science methods classes
4. the ability of the institutions to increase the numbers of student teachers in science that they accommodate

If the study shows that teacher education institutions lack the capacity to expand the production of new science teachers, then a program should be established to help these institutions to do so. Grant programs could be established, for example. If the problem were deemed serious enough, federal grant programs might even help pay salaries, on a temporary basis, for new positions for science educators.

Most likely, if the data show a coming shortage of science education professors and a lack of capacity to produce new science teachers, and if these data are widely publicized in the educational community, the problem will correct itself. Knowledge that jobs are available usually inspires people to seek the education necessary to fill those jobs.

Although the problems cited here are only potential ones, any delay in finding out just how serious they might become could add to the scientific illiteracy of future generations.

Does School Science Tap the Key Resource Of the Elementary Principal?

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After several decades of national effort and the expenditure of millions of dollars to improve science education, one might legitimately ask, "Where did we go wrong?" Nobody seems to be blaming elementary principals for the sorry state of elementary school science. And rightly so, for the surge of support for science education in the 1960s and 1970s virtually ignored principals. While a few participated in the National Science Foundation (NSF) sponsored curriculum development projects and inservice programs for supervisory personnel, the number was only a tiny fraction of the critical mass required to launch a successful national effort to improve science education. Instead, the bets were placed on the development of alphabet-soup curricula with acronyms like SAPA, SCIS, and ESS*, and on the retraining of a relatively small percentage of the nation's elementary teachers. Principals were not even in the race.

No one doubts the importance of teachers or good science curricula; science learning simply cannot occur without them. But since curriculum improvement has long been a responsibility of elementary school principals, it is ironic that so little attention has been paid to the key role they could play in the improvement of science instruction. If principals had been in on the action from the beginning, maybe we wouldn't be in the predicament we are in now.

The Principal Is the Key

In studies in schools around the United States, NSF researchers have described the role of a typical elementary school principal: "The principal serves a unique role of boss, shepherd, counselor, and manager all rolled into one. He or she is usually the major factor in the school's operation . . . ." [5]

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*Science—A Process Approach; Science Curriculum Improvement Study; Elementary School Science.

The National Congress of Parents and Teachers says that the principal is the "key factor" in the success or failure of a school. [5] The Congress tells us that teachers need someone they can turn to when they need help. They need someone to assist with selection of textbooks and other resources, to design inservice programs that sharpen teaching skills, and to provide time for curriculum planning. That someone is the principal.

Moreover, principals are in a position to initiate or limit curriculum change. As Brickell said:

> The administrator may promote—or prevent—innovation. He cannot stand aside or be ignored. He is powerful, not because he has the monopoly on imagination, creativity, or interest in change—the opposite is common—but simply because he has the authority to precipitate a decision. [1]

The National Academy of Sciences concurs: "Principals . . . are the key agents for educational change or for maintaining the status quo." [5]

The importance of the principal's role seems also to be borne out by research. A recent article in *Phi Delta Kappan* [4] reviewed ten studies of effective schooling. All ten demonstrated that principals were clearly important in determining the effectiveness of schools. Principals in the schools where achievement was higher were stronger instructional leaders. They were assertive. They led. They made the difference.

The principal's important overall role in school operations has been cited repeatedly. What specific effect has it had on the way science is taught and learned in schools? Many would say, "Not much." Unfortunately, many principals feel uncomfortable, even inadequate, with science. About one out of four principals recently surveyed felt "not well qualified" to supervise science instruction. [9] A mere 11 percent had majored in science; most had concentrated in reading, language arts, English, or social studies—those areas which seem to account for a bigger portion of the elementary school curriculum. [6] With too many principals, science receives low priority when compared to other school subjects. What can be done to strengthen their science leadership skills?

Plan for Action

Clearly, if one single action is to be taken to improve science education at the elementary school level, it should be to aim our efforts directly at principals, training them for science curriculum improvement while taking advantage of their natural leadership role. Just reaching a significant number of the 60,000 K–8 principals in the U.S. represents a real challenge, however.

One modest effort is underway. Funded by a small grant from NSF's now-defunct program, Information Dissemination in Science Education, NSTA has initiated a project entitled "Promoting Science Among Elementary School Principals." The project is designed to assist principals in taking a leadership role in science curriculum and instruction, to help them assess their own science programs and implement action plans for improvement, and to help them recognize the potential of science instruction for helping children develop lifelong learning skills.

Warren T. Greenleaf, editor of *The Principal* magazine—the journal of the National Association of Elementary School Principals—describes the NSTA project as "one pinprick of light" in the gathering gloom. According to Greenleaf,

> The project represents one of the few current attempts to arrest the continuing decline of science education in the schools; and to halt the growth of "America's fastest growing minority . . . the scientifically and technologically illiterate."[2]

Although the NSTA project provides a valuable [illegible] more comprehensive effort is now required. Here are several [illegible]s:

1. Either NSF (in its renewal of support for prec[illegible]ence education) or the U.S. Department of Education should initiate a program aimed specifically at improving science leadership skills among elementary school principals. A substantial sum, perhaps $5 million to $5 million, should be allocated for these purposes exclusively. Programs could be patterned after Chautauqua meetings; academic-year conferences; or summer training programs lasting one or two weeks.

2. Professional science education associations should encourage their leaders and members to carry the message of science education to the principals on their home turf, with conferences in their schools; programs at their regional, state, and national conventions; and articles in their professional journals. A concerted effort should also be launched to invite and encourage principals to participate at science conventions, specifically in workshops and other programs designed to increase their science leadership skills while providing practical, easily implemented ideas for use in their schools.

3. Many businesses and industries have experience and expertise in providing management training programs for their own employees.

They should be invited to join with the science education community in developing and implementing methods of leadership training. Such training should be specifically designed to increase the science leadership and management skills of elementary school principals.

Summary

Science education at the elementary school level is floundering. While considerable attention has been devoted to improvement through both curriculum development and inservice programs for teachers, principals have largely been ignored. Though they are the recognized school leaders, little money or time has been devoted to strengthening their science leadership skills—and principals are the key to good science programs. It is unlikely that many changes will occur without their support and assistance. In fact, elementary science education in the U.S. might never be improved unless principals are involved in a concerted effort to improve it. We need programs to help elementary school principals develop their leadership skills in science. These should be programs developed and implemented by the federal government, professional associations, and businesses and industries. Action is needed, and needed now.

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Do We Link School Science to Science Supervisors as a Resource?

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Like many other areas of science education, science supervision evolved as an American response to the shock of the Soviet Union's Sputnik 25 [illegible] ago. Supervisors in science, mathematics, and foreign languages were given the function [illegible] these areas of the curriculum. [7] What has happened [illegible]

Ritz and Felsen [6] found that [illegible] were most likely to occur during a typical work week of a science supervisor in New York: (1) consulting with teachers, (2) teaching pupils; (3) curriculum activities, (4) activities related to supplies and equipment; and (5) evaluating teachers. Conducting a survey in Florida to determine the status of science supervision, Ellis found that people's perceptions about supervisors differed from current research recommendations for professional preparation programs. [1] In Puerto Rico, Ortiz [illegible] [illegible] asked four groups of district superintendents, teachers, and science coordinators about their role expectations for science coordinators. She found some agreement among groups, but the amount and degree of consensus varied.

One of the most recent studies of science supervisor role perception was directed through NSTA's Division of Supervision. [4] In a national survey, teachers, administrators, and other professionals were asked to rank the roles of the science supervisor in the order that would most closely fit their needs. In order of preference, these roles were:

1. *Instruction*: assistance in the development of instructional materials; implementation of curriculum changes; encouragement of student involvement in extracurricular programs; review and refinement of methods of instruction

2. *Curriculum*: facilitation of teacher involvement in curriculum

development [illegible] evaluation of new methods and materials; communication of significant new developments and of the status, accomplishments, and needs of the science program.

3. *Staff development:* initiation of inservice programs; coordination with other school personnel; communication of opportunities for staff development; research in curriculum and instruction; development of long-range program objectives.

[illegible]*:* initiation of opportunities for teacher exchange, class visitations, cooperative teaching, and demonstration [illegible] dissemination of information about funding sources; involvement of teachers in the design and remodeling of facilities; development of proposals for instructional projects.

5. *Management:* organization of materials for efficient use in daily preparations; coordination of supply allocations; dissemination of information about laws pertaining to safety and liabilities and about district policies; dissemination of information concerning current financial developments and budgets.

6. [illegible] analysis of system-wide test results; maintenance of data on student achievement; examination of teaching objectives based on test results; assistance in individual teachers' professional growth and performance; assistance in developing, administering, and interpreting an assessment program.

7. [illegible] assistance in teacher assignment; equalization of teaching load; resolution of conflict; selection of staff.

The results of these and other studies [8,4] should interest not only science supervisors but all those involved in the educational enterprise. Such studies demonstrate that people are raising more questions about science supervisors than are being answered.

In summary, the crisis in science supervision should be viewed [illegible]. Many studies indicate a need for supervisory science personnel. The work of the science su[illegible] implementing the science program, K–12 could and sh[illegible] significant contribution to scientific literacy. Study of t[illegible]'s role should help school districts that currently empl[illegible] supervisors as well as those that are planning to have them. [illegible], it should benefit colleges and universities in preservice science education. A clear definition of the requirements and role description for the position should serve as a basis for the education and training of science supervisors. Moreover, understanding expectations held for the role of the science supervisor is vital for an understanding of his or her performance. [2] Further research toward this end is desirable.

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C. POLITICAL AND POLICY CONCERNS

Do We Make School Science Fit the Needs Of Each Learner?

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America is not the same as it was as little as ten years ago, and the changes are accelerating. As pointed out by John Naisbitt [2], the predominant U.S. occupation, until the very early twentieth century, was farmer. Then the industrial laborer eclipsed the farmer, and while the cities of America's Northeast and Midwest became industrialized, the farm became mechanized. Laborers, much like the machinery they operated, were nearly interchangeable; and their training needs, as far as science was concerned, were minimal. The engineers who designed and managed the factories needed first-rate training, and they received it. The same is true of other science professionals today. [1]

However, in the last two decades the accelerating growth of information technology, coupled with a decline in manufacturing has propelled clerical workers ahead of laborers as America's largest group of workers. Just as industrialization changed farming, now high technology and information processing are changing industry. (Robots are here.) The second largest occupational category today is professional—teacher, engineer, lawyer, nurse, librarian, accountant, social worker, dentist, newspaper reporter, clergyman, scientist. The people in these two job categories, clerical and professional, have some characteristics in common: First, they do not make anything (that is, they do not turn natural resources into products); and second, their raw material is knowledge, a renewable resource.

People whose work is based on knowledge manipulation clearly require a more complete education, including the sciences, than their forebears received. In addition, people build, operate, and repair information processors and robots; so increasingly more technically trained personnel are needed; soon technician may eclipse clerk as our number one job.

Changes in the American scene will not stop here, however. Consider our growing control over fundamental options in our lives: We can receive genetic counseling and [illegible] information on which to base [illegible] decision whether a [illegible] born. We learn more about the effects on our health [illegible] and personal habits; and instead of relying on the [illegible] us, we are able to take more responsibility for our own well-being. Increasingly, we face decisions about death; families decide whether it is appropriate to prolong the life of a gravely ill relative who is dependent upon medical technology that sustains life. Knowledge, usually what we call scientific knowledge, and the need to process that knowledge pervade our lives from birth to death.

In all spheres of activity, scientific knowledge undergirds the life of every American. But too many children and adults demonstrate, through their actions and words, that they have not grasped the importance of science in their lives. With the realization that no single action will solve a complex problem, I recommend that our number one priority ought to be to *convince students of the personal utility of continued science study*, so that nearly all students will choose to complete four years of science and mathematics, prior to high school graduation. This indispensable science and mathematics study could be accomplished by an appropriate governmental directive, but fundamentally, students and decision makers must themselves perceive that study to be useful in the lives of all people.

Science study beyond biology has been considered necessary only for students preparing for careers in medicine, science, or engineering. Although the situation is changing, large numbers of women, minorities, and handicapped persons still view science as "not for me." And when so few from these groups have been depicted among the scientifically literate, why should they think otherwise? Lacking any conviction of personal utility from science study, many students, from a variety of backgrounds, opt out of science (and to a lesser degree, mathematics) when confronted with elective high school science courses, usually chemistry and physics.

To reverse this mind set, we must especially work to reach youngsters in grades five to nine, the time when students can begin to make some decisions about science study. We must show these students that science knowledge is needed in order to pursue most occupations and to deal with human problems that confront everyone. "Science is [illegible] or me" is an idea that must be brought home to all students.

To demonstrate the utility of science study, students should be interacted with people from the community who use science in their jobs—not just the engineer, doctor, and research scientist, but also the pharmacist, athletic coach, industrial technician, business manager, and home economics extension agent. These professionals should visit the science classroom in the middle school/junior high when the students are studying science concepts that the community resource people can discuss. For example, when students are studying chemistry, a medical technologist might have students test vinegar and household ammonia with an acid-base indicator, the decanted liquid from red cabbage boiled in water. Having captured their interest, the medical technologist could explain how pH is used on the job in chemical analysis of blood and urine. The same activity could be presented by a toxicologist, dairy chemist, or a variety of others. Students would then receive a practical answer to their question: "Why should we study that?" Implicitly and explicitly, they will find science study leads to a career payoff.

Similarly, during a study of health, the athletic coach could lead students in simple stretching exercises while explaining the purpose of each and then relate how kinesiology and physiology are useful to coaches. These live role models could be supplemented with short or extended visits to workplaces and with posters [1], movies [3], filmstrips [7], and stories [5] that show the broad usefulness of science study. In career exploration activities teachers should emphasize the importance of continued mathematics and science study by making sure that the use of mathematics and science appears in the descriptions provided for each occupation.

The selection of live and media role models is crucial to dispel the narrow notion, common among students, that science study equals scientist. Role models from many occupations must be shown. The American occupational mix is changing so rapidly that many students will end up in jobs for which no contemporary role models exist. Even so, if we can keep them in the science-mathematics preparation pipeline now, then they will have the requisite knowledge to open job options. Moreover, "nontraditional" role models must be liberally included to show nearly all students the importance of science for people like themselves—whether men, women, minorities, or handicapped persons.

In addition, a change in science curricular emphasis is needed in grades [illegible] to [illegible]. The move should be away from developing fundamental science concepts (as exemplified by Intermediate Science Curriculum Study [ISSC]) toward applications of science in everyone's life (as in the Health Activities Program [HAP] developed at the University of California's Lawrence Hall of Science and BSCS's *Human Sciences*). Fundamental concepts will still be mastered; however, the concepts should be taught with reference to their applications. For example, energy concepts could be taught in relation to the operation of an automobile, then broadened to other modes of transportation. Ideas about soil could be taught in relation to the community where the students live, and they could apply these ideas to a pending or ongoing construction project. As is done by HAP, students can be taught about human anatomy and physiology by measuring themselves first and then developing the concepts. Along this line, one entire school organized itself around a physical fitness theme. Students, teachers, other school personnel, and even parents undertook a program of cardiovascular fitness, including proper exercise, diet, and rest. They not only achieved the practical outcome of improved health, but they also learned how formerly abstract anatomy and physiology concepts had real personal meaning and usefulness. [6]

During the 1980s, to a degree greater than ever attempted before, science educators and people in the community who rely on science—and that is virtually all of us—must join hands to make certain that the vast majority of students receive a complete science education that emphasizes the usefulness of science for everyone. To do less would shortchange both students and the society which requires knowledgeable graduates as employees and citizens. And we might even learn that schooling is only one aspect of education; the entire community, not just the schools, may resume its rightful responsibility for helping young people grow up.

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Does Science in the Elementary School Facilitate the Goals of Schooling?

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Suppose primary teachers, parents, and school administrators were led to recognize that science activities contribute to the development of reading and mathematics skills. Maybe then some time could be found for science activities in the classroom. Suppose the same groups of people were to be convinced that children could develop reasoning and thinking skills through science activities. Adding science activities to the curriculum might then be even easier and more appealing. Suppose teachers, school administrators, and parents were made aware that students showed more interest in school because of success in science experiences. It might then be difficult to keep science activities out of the classroom if we tried!

The aforementioned proposals can all be substantiated. Reading readiness and reading skills do improve with the use of science activities. [1] Developmental levels of thinking do progress when science activities are provided for young students. [3] Science activities can provide the meaningful context for the development of computational and thinking skills in mathematics. [2] Students do increase their interest in science and in other areas of the curriculum through the use of science activities. [1] These results have been realized incidentally, without directing use of the science activities toward these outcomes. The potential for even greater success exists, if only efforts were made to use science activities specifically for the realization of these outcomes.

Past opportunities to promote science activities for the development of the general goals of education have been overlooked in favor of goals related to science content and science processes. Doing science for the purposes of understanding science, of becoming a scientist, and of understanding what a scientist does has been emphasized. *It now seems appropriate to recommend that action be taken to promote the use of science activities for the primary purpose of furthering the general goals of education at the elementary school level.* A first step is to convince teachers, parents, and school administrators of the potential that science activities have for attaining these general goals of education. In[illegible] support is needed for developing curriculum materials [illegible] use science activities as vehicles for teaching the "basics," [illegible] scientific thinking, for developing social skills, and for [illegible] student's self-image. A third recommendation for action: the provision for both encouraging and training inservice and preservice teachers to direct science activities toward accomplishing the general goals of education.

Should this last recommendation be implemented, some additional outcomes might result. Teachers using science activities to teach reading, for example, might find their fear of science disappearing or at least reduced. These same teachers could end by actively pursuing scientific knowledge for its own sake. The creative teacher might take advantage of opportunities to integrate the learning of other subjects through science activities. Students, in any event, will have the chance to do science. They may acquire the same science skills and information expected from a science program directed specifically toward science outcomes. At the very least, students' background of science experiences will enable them better to appreciate the science concepts they learn in later years. Science itself is more likely to be perceived as an integral part of the elementary school curriculum rather than as a separate subject.

Teachers may find it nonthreatening to use science activities to accomplish other curricular goals. As a result, they might be more likely to demonstrate that they are not afraid of science. Students, too, will begin to view science more favorably. More positive attitudes toward science on the part of students and teachers can be expected. It is hoped that the practices of using science activities to accomplish other goals of instruction and to integrate the total curriculum [illegible] spread to the upper elementary and secondary school curricula. Science may even become a part of the daily experience of every student in every classroom in every school in this country. This is quite possibly a dream, but it is a dream worth dreaming; and work to make the dream a reality certainly deserves our best efforts.

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Does School Science Enhance Writing Literacy?

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The lack of scientific literacy in our society is cause for alarm. [2] The goals of science education are being rewritten to place more emphasis on the problem of attaining scientific literacy. [1] How might these new goals be put into practice at the local level? One very successful example developed in the North Olmsted, Ohio, public and

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Table 2: Science-Related Activities in Project Write

In writing, the science student will be able to:

1. define science vocabulary terms
2. explain why something happened
3. write formal reports on experiments (The report should include purpose, procedure, observations, and conclusions.)
4. state hypotheses and conclusions to experiments in complete sentences
5. [illegible] lab reports
6. list safety rules
7. list steps in problem solving
8. [illegible] materials
9. [illegible] on modern scientists, discoveries, or research items. (This could include reports on Nobel Prize winners.)
10. summarize news magazine articles; write an abstract
11. write a science fiction story
12. write a science article for a class encyclopedia
13. participate in writing a theme book (Have each student write an article on an animal and then put all articles together in book form.)
14. list materials needed for an experiment
15. interpret a diagram or graph
16. [illegible] a project or an experiment
17. keep a journal of classroom experiences
18. monitor an animal or a plant for a period of time and note any changes
19. summarize a lecture, TV program, book, or article
20. write a research project
21. locate, collect, and analyze data from a reference source

parochial schools; has had an impact upon the scientific literacy of an entire school population. Termed Project Write, it is a program that could be undertaken in any school system or classroom.

Project Write is a system-wide program in which students at all levels of instruction engage in a wide variety of writing experiences. Its long-range goal is to have students demonstrate a mastery of writing skills and be able to expand those skills to acceptable performance levels in career-related fields. Its basic premise is that if students are going to write well, they must have opportunities to write often for various audiences in a variety of academic subjects. Writing is taught in each grade and in each subject, in relationship to potential life experiences and career opportunities. Short written pieces for

22 take class notes

23 list facts about an event or object

24 respond to test questions in essay form

25 classify by characteristics

26 review a science-related book

27 outline the steps of the scientific method

28 write a biographical review of a scientist

29 criticize a science news article

30 prepare an annotated bibliography on a topic

31 outline a chapter in the textbook

32 write instructions for a class activity

33 react to a media presentation

34 investigate and report on a theory, a career in science, or a product

35 write a letter inviting/thanking a guest speaker

36 compare and contrast, for example, two types of energy, birds, or chemical reactions

37 compare and contrast different species

38 evaluate a guest speaker presentation

39 invite persons to
  a attend a science fair
  b judge an exhibit
  c conduct a demonstration
  d be interviewed in a class

40 respond to oral questions in complete sentences

41 explain factors that could have affected an unsuccessful experiment

42 keep a weather diary

43 create a time capsule of artifacts for the year A.D. 2000

various educational purposes are required at least once a week in all academic areas. Students are encouraged to write with clarity, brevity, exactness, logic, and with appropriate wit and grace. All teachers in the school system participate in Project Write. Guidelines for the program are shared, and inservice training sessions are conducted for the staff. An important point of this program is that each teacher and administrator is encouraged to believe that he or she can make a real difference in helping to improve students' writing competency.

Among the many different strategies and techniques developed as part of this program are lists of writing activities that could be used in each area of the curriculum. For the science classroom, these activities are listed in Table 2 (see pp. 86–87). Even though this is an extensive list of activities, Project Write is open-ended. Many activities involving a particular set of circumstances at the local level could easily be incorporated.

Project Write also involves local community members who come into the classroom to discuss the writing skills needed in various careers. For example, a local scientist might visit a science classroom to discuss why a scientist must write with precision and to explain the differences between scientific writing and other types of writing. The scientist might also show that writing style depends upon the intended audience: scientist-to-scientist, scientist-to-public, and scientist-to-student communications all require different writing skills.

Project Write places strong emphasis on the development of thinking, reading, and oral language skills. Its strength also lies in its applicability at any level in the science curriculum, K–12.

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Does School Science Enhance Language Literacy?

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A society that depends upon technology for its economy and its survival cannot afford to ignore science as a basic. Yet a significant aspect of the science educator's task has become convincing the public and fellow educators that science is an important part of a basic program in the elementary schools. [2]

One way to incorporate science into the basic elementary school curriculum is to integrate scientific content and processes into an already recognized basic area of the curriculum, language arts—reading, writing, speaking, and listening—through a technique known as the Language Experience Approach.

The Language Experience Approach to teaching the language arts is a recognized one among educators. The child experiences a phenomenon or an event, then uses language to share it with others and to record it for his own use at a later time. Studies have shown that students tend to read more quickly and with more comprehension when they read material that (1) is a part of their background, and (2) is written in a language that they understand. Language experience proponents say it simply: "What he can say, he can write; what he can write, he (or others) can read." [1]

Elementary teachers know that young children are in a stage of development where they need concrete experiences in order to build concepts and to form a background for later learning. Children cannot understand abstractions until they have a concrete experience base upon which to build. This is where science fits easily into the language experience approach to instruction. Young children are curious by nature. The activities of science appeal to this curiosity and provide the child with something concrete, stimulating, and interesting to talk about, read about, write about, and hear about in order to learn more. Through activities that encourage exploration and excite curiosity, the child is challenged and learns to meet and respond to challenge. When schools exchange this type of learning for rote or "programmed" learning, they cut off enthusiasm and the desire to learn which should be a lifelong trait.

How do we as science educators implement a language experience in the elementary curriculum? The question is easier to answer in theory than to put into actual practice. Lesson development is not difficult. Preparing teachers becomes the hurdle to clear. We must help teachers to realize that science is not a difficult area for them to teach. We must show them that simple, easy-to-conduct activities such as planting seeds or measuring air and water temperatures are real science, and that they do not need scientific jargon or detailed knowledge to do activities with children. Science educators must be willing to take their time, energy, and knowledge into the field and work not only with teachers, but with school administrators, supervisors, and other area specialists such as reading specialists. Convenient directions for science activities need to be gathered and/or developed and placed in readily accessible locations along with the materials needed for carrying out the activities.

At first, many teachers need much encouragement, but once they begin to feel secure, most become as enthusiastic and excited as their students. Inservice, college level classes and workshops on the language experience approach are ways teachers can be introduced to and encouraged to try out the approach. Many teachers might benefit from a live-with-kids demonstration or from actually attempting the experience for themselves. Group sessions for developing lesson plans are also helpful. Whatever approach is used, it must be done with enthusiasm and with the expectation that there will be follow-up in the classroom.

The skills needed to translate science activities into language experience are already used by most elementary teachers. These skills consist of discussing or questioning what was done, then putting the ideas into some written form. A sample of the language activities which might evolve from a science activity could include

- making word lists of the words used or needed in the activity
- writing directions or stories about what the children did and what happened, emphasizing accuracy and sequence
- producing individual booklets which could be used as text or references by others

The implementation of a program of language experience through science activity would exclude neither the basal text nor a sequential skills development program. It would, in fact, expand and enrich such a program by providing for more extensive reading and writing experiences, more oral language, and an increased listening, speaking, reading, and writing vocabulary.

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Do We as Science Teachers Influence Political Or Policy Decision Making?

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Today we are faced with a challenge to increase both the quality and quantity of science education in order to help all students develop the scientific and technological literacy they need to be successful in and contribute to our present and future highly technical society. To obtain sufficient public support to meet this challenge, we must modify our fundamental argument for science education to include pocketbook issues. We have a professional responsibility to help the general public to realize that "there is an economic argument for public investment in education in general and for mathematics and science education in particular, especially in light of the country's productivity decline." [6] The quality and quantity of education have been important in determining future growth. [3] Productivity, employment, and economic strength are clearly related to the quality of our educational system. [5,8] The report of the Policy Conference on Economic Growth and Investment in Education emphasizes education as a principal factor of production: "Economic growth is generated not only by real capital in the form of tools and machinery, but also by men. And just as technological improvements increase the efficiency of machinery, so education increased the efficiency of manpower." [1]

Scientists, engineers, economists, government leaders, and educators agree that our present level of science and mathematics education in the United States is inadequate to meet present and future individual and societal needs. "Scientific and technical literacy is increasingly necessary in our society, but the number of our young people who graduate from high school and college with only the most rudimentary notions of science, mathematics, and technology portends trouble in the decades ahead." [6] Hurd speaks for all when he warns, "A majority of high school graduates will become members of the fastest growing minority group in the U.S., the scientific and technological illiterate." [4]

Promoting Public Awareness

In the U.S., the general public usually elects the policymaking school boards that must agree to significant changes within the schools. Thus, board members usually reflect the positions, desires, and demands of the general public. To increase the quality and quantity of science education in the schools to the extent needed, major policy change within school districts is required. This in turn requires the support of the general public.

The general public must be informed of the severe individual and societal consequences of inadequate science education in a highly scientific and technological society. They must know that the achievement level of high school graduates is declining at a time when an increasing number of jobs require more science and technical knowledge. The general public must understand that there is a direct relationship between the amount of education and employment, productivity, and the standard of living. They should be warned that the U.S. "stands poised at the brink of an education and manpower training crisis that will make our emergence as a world scientific and technological power akin to the maiden voyage of the Titanic." [6]

For education to respond to this crisis, it must have support. Parents, the general public, and the young people in our schools all must assume greater responsibility for developing an adequate science education.

To promote a broadly based public awareness of the need for adequate science education, we need a national public information campaign. We must make a convincing case for the link between science education and standard of living, as measured by effective citizenship, productivity, and employment. We must convince the general public that science education is essential for *all* students. We must create an intense public demand for science courses for *all* students in grades K through 12.

The public information campaign should be solidly based on the general public perception of the purposes of education:

> For over 200 years the central purpose of public education has been to develop citizens capable of informed and responsible participation in democratic processes. This purpose implies that certain knowledge, skills and attitudes are needed by citizens to sustain and improve the social order. [2]

Public education, linked directly to societal needs, must reflect societal changes. The rate of societal changes is rapid during some periods of time and reaches plateaus at other times. Ours is a time of rapid change and demands corresponding, intensive action.

Expanding NSTA's Political Influence

Over the past two years, NSTA has made a strong effort to influence federal legislation related to science education. NSTA past presidents Donald McCurdy and Sarah Klein each testified before the House Committee on Science, Research and Technology; the Senate Committee on Labor and Human Resources; and the Senate Appropriations Committee, Subcommittee on HUD-Independent Agencies. They spoke on behalf of the needs of science education and made specific recommendations for what should be accomplished.

This testimony was aided by a newly developed data-gathering system which uses a stratified random sample of science and mathematics teachers in the U.S., as well as samples of school administrators and placement officials. The process has produced some startling findings and should be expanded to produce an evolving data base tuned to the pulse of science education. Accessed via computer, it could provide a broad range of information on the health of science education.

NSTA must continue to extend and enhance its political influence on the national and local levels of government. If NSTA develops a reputation for being accurate, it will soon be looked upon as an appropriate and authoritative source of information relative to science education. Federal agencies and private foundations will rely upon this information in making important judgments and funding decisions.

NSTA also needs a system for disseminating information about Washington's legislative proceedings. Because there are so many committees and subcommittees on Capitol Hill, the task would be impossible for any one person to handle alone. However, with its sabbatical program NSTA is in a position to obtain relatively low-cost manpower which could be assigned this responsibility. The Association should investigate a cooperative arrangement with other scientific groups to share this responsibility and the resulting costs.

NSTA leaders who are interested in working with their elected representatives on legislation and policy matters should be identified, and organized into a network adequately representing all parts of the U.S. Information that NSTA received via the network could be used to update regional as well as national lawmakers on matters affecting science education policy; perhaps by means of a newsletter prepared and distributed monthly or quarterly.

Those who agree to participate in the network would be assigned the responsibility for establishing liaison with their congressmen or appropriate staff member in the congressional office; the unique organization of every congressional office would require some investigation to determine the most efficient method for channeling information. Important position statements prepared by NSTA on matters such as the "Teaching of Nonscience Theories" could be distributed to appropriate offices through the network. Soon NSTA could be known as the major voice for precollege science education.

A plausible activity for NSTA in the future is a congressional fellowship program, perhaps patterned after the one conducted by the American Chemical Society (ACS). The goals of the ACS program are:

1. to provide an opportunity for scientists to gain firsthand knowledge of the operations of the legislative branch of the federal government
2. to make available to the government an increasing amount of scientific and technical expertise
3. to broaden the perspective of both the scientific and governmental communities regarding the value of interaction between these two groups

Obviously these goals would have to be modified somewhat to meet the needs of the science education community.

Politicians are constantly confronted by people and organizations attempting to influence the decision-making process. NSTA must find a way to make its voice unique and authoritative, but also join with other organizations in supporting the common good. The greater the constituency of any group, the greater the political influence. As we collect valuable evidence pointing to a course of action, it behooves us to share this information with our colleagues in other scientific organizations.

At present, only a handful of members in The Congress have a background in science. We have a big and important job to do. Overcoming congressional indifference on matters of science and science education will not be easy. The suggestions in this paper will require a lot of work and dedication, but we will be accomplishing these goals not only for ourselves or for the science education community, but for the country as a whole.

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Part III

A National Laboratory For Science Education

Part III

A National Laboratory For Science Education

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Primary responsibilities of school science include helping students understand the results of scientific research; assisting them in their understanding of the interaction of science and society necessary for such discoveries; and helping them recognize the mutual interaction, support, and constraints that science and society have upon each other. But science education is not confined to the classroom. It is also concerned with interpreting science to the rest of society, and with helping scientists understand society.

Such a view of science education requires broader goals for school science: analyzing and understanding science as a means for satisfying personal needs; considering major societal issues of a given time; providing career awareness over a wide spectrum of career possibilities.

Since science education is itself a scientific discipline, it must have a base of scholarship. A new focus on research and development in science education is imperative. This research and development focus must respect the scientific discipline constraints while using related

research findings and procedures. This new research effort must be designed to affect public understanding of science as well as public ability to deal as citizens with matters pertaining to science and technology.

But new research and development requires more than money—it must involve time in people's schedules. Most science education researchers today have a multitude of training responsibilities, service commitments, and administrative tasks so that they will not be able to respond adequately to infusion of massive new funds. Nor can the situation improve with funding for researchers and developers who are unacquainted with science education or the public needs.

A. A NATIONAL LABORATORY FOR SCIENCE EDUCATION

A national laboratory for science education is envisioned as an important solution to the critical problem associated with Americans' low level of scientific and technological literacy. Such a laboratory—perhaps located in our nation's capital—would parallel the several laboratories that exist in the various other fields of pure and applied science and would establish science education as a legitimate discipline with specific goals and a definable research base.

Five features of such a national laboratory for science education are proposed as essential: a K–12 school, think tanks, a development arm, a research agenda, and a communication network.

1. *K–12 School.* The national laboratory for science education would include students at a variety of ages and levels. One component would be a traditional K–12 school with students at a variety of levels of development, academic potential, and interest in science/technology. The staff would include some key permanent staff while relying heavily upon rotating staff—many to come from colleges, universities, and schools on internships or sabbatical leave from their home institutions. This laboratory school would be free of the constraints often imposed by a host institution. It could seek out students and could capitalize upon ideas, experiences, and research conducted nationally. The emphases upon rotating staff, identification of problems, the infusion of new explanations and new models for testing them would enable renewal, intellectual vigor, and impact upon science teaching practices throughout the nation.

The laboratory would not simply concentrate on gifted students or on those with special interests in science and/or science career aspirations. Science magnet schools are often single purpose schools focusing upon enrichment and acceleration for students already directed to science and science-related careers. In a sense, these single-purpose schools are a detriment to solving the problem of an appropriate education for all citizens in a scientific/technological society. Children of all ability levels, interests, and races need to be included in a typical mix of Americans for the school to work to maximize relevant learning for *all* children.

2. *Think Tank Opportunities.* The laboratory should include groups that function as think tanks. The laboratory would provide a place for

thinking, contemplating, and debating; it could provide a place for creating conceptual design studies, as well as for planning tests to evaluate new ideas.

3. *A Development Arm*. The national laboratory in science education should have a development arm as well. As information is produced, prototype materials could be developed for trial in other settings, such as schools, museums, and television. The development arm could be an important ingredient as new theories for curriculum and instruction were developed. Such theories arise from observed successes, failures, and trials.

4. *A Research Agenda*. In a well-managed program of science education research, an essential feature is an infrastructure that brings the products of research to bear on science education policy and practice. Conversely, this infrastructure ensures that the goals of the research program reflect the information needs of policymakers and practitioners. The reasonableness of a proposal is established on the basis of need and the quality of the research plans. The delineation of need for a program of research includes descriptions of the success of past research efforts, projected knowledge requirements of the field, and a discussion of the value of the products of research. The quality of the research plan is determined in part by how it minimizes or avoids the problems of past programs of research with similar goals or administrative characteristics.

An important contribution to our understanding of the problems of research planning and evaluation is the description of the many faces of social research as described in the National Research Council's report, *The Federal Investment in Knowledge of Social Problems*. [3,4] The authors of this report redefine research and development as knowledge production and utilization, and they describe a variety of activities under these two headings: *knowledge production*—research on problems, the collection of statistics, evaluations of programs, and demonstration projects aiding the formation of policy; and *knowledge application*—demonstration projects aiding the implementation of policy, the development of materials related to problems, and efforts to synthesize, disseminate, or use knowledge of problems. [3]

There are many differences among types of research activities listed, including the specificity of practical return expected on the investment in the research and the time frame for the expected practical return. Thus, what is commonly called basic research is viewed as long-range research on problems. Basic work that investigates the nature of science learning, for example, will not—and should not be expected to—produce demonstrable results in the short term. [5] However, the results of other knowledge production activities, such as research to collect statistics, should be clearly demonstrable in the short term.

Another important difference in knowledge production activities is the function to be served by the knowledge produced.

Program-supporting activities offer information to meet the short-run, limited, and well-specified requirements of operating programs.

Policy-forming activities offer information that could help in making policy for a longer period of time.

Problem-exploring activities offer a deeper understanding of problems that may help to define policy options, even if no specific problem or policy needs were initially in view.

Knowledge-building activities enlarge the resources of knowledge or method, with applications to the understanding of problems, the forming of policy, or the operation of programs that are varied, difficult to forecast, and typically long run. [5]

A more thorough analysis of knowledge production and utilization activities with respect to science education research could be expected to inform debates about the value of research; to guide an assessment of the effectiveness of past research efforts; and to inform the planning of research efforts. The distinctions among research activities illuminated by this analysis allow planners to ask questions such as: What portion of research should be devoted to knowledge production and knowledge utilization activities?

To the science educator, the breadth and depth of the documentation and analysis proposed here for a science education research program might seem unnecessarily extensive. For the most part, science educators regard research activities as intrinsically valuable and argue that science education research has had demonstrable effects on teaching practice. However, if a major program of research is to be instituted and maintained, the science education community must be prepared to enlist the support of others. We must be ready to counter the arguments of the critics of educational research in general and of science education research in particular. The field must be ready to provide policymakers with the information necessary to justify the allocation of resources to research and to provide government research managers with specific recommendations, both for the substantive research agenda and for the mechanisms by which research programs can be effectively managed. The attainment of these objectives requires that we be well prepared.

5. *A Communication/Dissemination Linkage or Network*: The results of the laboratory efforts could be released as national reports for others to use, to test further, and to tailor for local needs. The national laboratory could be used to communicate the outcomes of conferences and meetings; the results of research, the products of development, and the experiences of the staff. Such communication would provide direction for science education while serving as a direct link between research and practice.

This communication network might take several forms. As illustrated in California, *Regional Teacher Centers* could be one link. California has recently enacted an Investment in People Program to improve science, mathematics, and computer education in grades K-12. [2] Most of the money put aside for the program will be used to set up and run 15 regional teacher education centers; to provide for staff development, and to fund exemplary instructional development projects. In these centers it will be possible to focus on program objectives—that is, how to teach to objectives, with much teacher sharing of ways to overcome problems that arise. The most effective staff development seems to happen when the inservice program is shaped by teaching/learning objectives rather than by professed deficiencies in teacher background, motivation, or other personal characteristics. Teachers who see themselves as generally "not ready" to teach science are unlikely ever to feel ready.

Another linkage system could be the establishment of *science resource centers*. These centers would be geographically and demographically distributed in order to provide services to all children; and could be housed at existing regional facilities such as Cooperative Educational Services sites, college/university campuses; museums/science centers, or industrial parks.

A science resource center would be manned by a permanent staff large enough to carry out the directives of a science advisory board composed of parents; teachers, school administrators, scientists; and science educators as well as representatives from industry, business; and government. The responsibilities of such a board would include

a. clarifying the goals and priorities of science education among parents, future employers; school administrators, and teachers [6]

b. identifying the programs and teaching methods, the outcomes of which are congruent with the goals [6]

c recommending services which would promote the stated goals

d. suggesting and coordinating evaluations to measure the effect of specific programs toward mastery of stated goals

e. providing guidelines for a vigorous, ongoing public relations program

f. identifying and cataloguing available regional science resource materials (hardware and software)

g. coordinating a mini-grant program to encourage community/parent/teacher initiative in implementing innovative, inquiry-oriented science projects

The science resource center staff would implement the priorities and goals of its advisory board through such activities as

- presenting a series of lectures and hands-on science demonstrations for parents and children
- involving community representatives in the design, preparation, and dissemination of hands-on inquiry science kits for use by students at home or in the classroom
- involving regional agencies in the design and construction of hands-on conceptual displays in science to be used by community organizations (Scouts or community centers, for example) or by teachers in the instruction of inquiry-oriented science
- providing workshops to prepare parents, senior citizens, and other interested community members to serve as science resource aides in the implementation of inquiry-oriented science projects
- providing inservice, Chautauqua-type short courses in science for parents and teachers [1]
- providing scholarships to encourage attendance by parents and teachers at state, regional, and national conferences for science educators
- coordinating a team approach to classroom research of science concepts and methodology
- providing recognition and reward to teachers, parents, industrial representatives, science consultants, and lawmakers who have demonstrated significant leadership in the field of science
- coordinating a public relations program to publicize goals, accomplishments, concerns, and even the ultimate favoring of serendipity of science instruction

A key feature of these centers would be the nurturance of a cadre of master teachers of science. These teachers would have a special interest and training in the sciences. The group of specialists would be detailed to give assistance to the classroom teacher in the planning and implementation of science study units.

A third potential linkage might be through *comprehensive centers* focused on teacher education. We know that school science, more than any other curricular area, is multidimensional. To be complete, the science curriculum must emphasize three components: concepts in the biological, physical, and Earth sciences; investigative problem solving; and the interactions of science, technology, and society. Students learning science must be involved in developing and assimilating science knowledge in developing process competence, including mathematical application; and in making value judgments. Teachers must manage a variety of materials and equipment, often including live specimens and hazardous chemicals; and must conduct valid demonstrations and investigations. Administrators must give strong support to provide professional time and money in excess of that required in other programs.

Traditionally, the responsibility for implementing and maintaining this complex program has rested primarily with individual classroom teachers, who have been provided with limited resources and limited interaction with colleagues working in other science courses or other levels of science teaching. Even though a support system can be provided through departmental organization or specialized curriculum coordinators, this system has rarely been successful.

A comprehensive center, focused on teacher education, would have two main objectives: (1) to help schools, through the education of their instructional, resource, and supervisory personnel, in developing their capacity for self-improvement in science and mathematics education, and (2) to assist the efforts of colleges and universities in developing, as part of their regular activities, more effective programs for the preservice and inservice education of science and mathematics teachers. The residual effects of such comprehensive programs are worthy of consideration. Although initial objectives will be somewhat different, it can be expected that a cooperation that did not previously exist will be established between governmental agencies, higher education institutions (including community colleges), and the public and private school systems.

B. CONTRIBUTIONS OF A NATIONAL LABORATORY IN SCIENCE EDUCATION

A national laboratory in science education could provide a link to the larger community and to other professionals in education. Adult education could be involved, especially since current research indicates that such experiences are more successful than school-based ones in resolving scientific illiteracy. The connection with administration, curriculum experts, business officials, health professionals, counselors, and teachers of other disciplines could be studied.

Models of excellence could be defined, developed, publicized, and packaged for transportation to other settings. The exemplary situations could be identified, as well as the process involved in transporting materials and approaches. Perhaps more than any other, the need in science education is for the identification of excellence from a variety of perspectives, a description of such exemplars, a review of their development, and a study of the support system necessary to maintain excellence.

Recognition is one of the most potent motivators. Recognition of excellence could stimulate use of proven techniques and approaches rather than many of the other correctives for science teaching tried and tested by NSF between 1955 and 1981, such as the production of new courses; the isolated improvement of subject matter preparation mostly by teachers (as badly as this is needed); or the procurement of new and more laboratory supplies and equipment.

Establishing a national laboratory for science education is the most important single action we could take to alleviate the problem of Americans' low level of scientific and technological literacy. More research conducted in traditional settings and translated in old ways will not solve the most pressing problems in our time. A permanent national laboratory could provide the prestige, the needed time and mix of researchers and practitioners, the communication mechanism, and the person-power to meet the extraordinary challenges of achieving a well-educated, scientific/technological society today.

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Appendix

NSTA Position Statement on Science–Technology–Society: Science Education for the 1980s

Preamble

Science and technology influence every aspect of our lives. They are central to our welfare as individuals and to the welfare of our society. All around us are examples of the importance of science and technology for production of food, water, shelter, clothing, medicines, transportation, and various sources of energy. There are an increasing number of science- and technology-related societal problems as well as increasing societal benefits. Science and technology are central to our personal and cultural welfare *and* to many societal problems. We must insure appropriate science education for all citizens.

However, the quantity and quality of science education for all people are not commensurate with the status of science and technology in society. When one would expect budgets, time spent on science-related subjects, and support for science education to be increasing, they are decreasing. At the same time these factors are declining, societal problems continue to require an understanding of science and technology. The burden of response rests heavily upon the shoulders of *all* persons associated with science endeavors—scientists, engineers, classroom teachers, other educators, and school administrators. Many of the problems we face today can be solved only by persons educated in the ideas and processes of science and technology. A scientific literacy is *basic* for living, working, and decision making in the 1980s and beyond.

There is a crisis in science education. The following science-technology-society problems demand immediate attention:

- understanding of science and technology are central to our personal and national welfare, yet public appreciation of science education has declined;
- increasing numbers of individual and societal problems which have an impact on the quality of life are related to science-generated technology;
- as the impact of science and technology on society has increased, the support for science education has decreased;
- compared to its recent past the United States has fallen behind in the production of scientific and technological goods and services; and
- women, minorities, and handicapped persons are underrepresented in nearly all professional and technical roles in science and technology.

Declaration

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 attributes listed below help to describe a scientifically literate person. Each attribute should be thought of as describing a continuum along which the individual may progress. The progress of the individual's science education should be equated with progress along this continuum.

The scientifically and technologically literate person:

- uses science concepts, process skills, and values in making responsible everyday decisions;
- understands how society influences science and technology as well as how science and technology influence society;
- understands that society controls science and technology through the allocation of resources;
- recognizes the limitations as well as the usefulness of science and technology in advancing human welfare;
- knows the major concepts, hypotheses, and theories of science and is able to use them;
- appreciates science and technology for the intellectual stimulus they provide;
- understands that the generation of scientific knowledge depends upon the inquiry process and upon conceptual theories;
- distinguishes between scientific evidence and personal opinion;
- recognizes the origin of science and understands that scientific knowledge is tentative and subject to change as evidence accumulates;
- understands the applications of technology and the decisions entailed in the use of technology,
- has sufficient knowledge and experience to appreciate the worthiness of research and technological development;
- has a richer and more exciting view of the world as a result of science education; and
- knows reliable sources of scientific and technological information and uses these sources in the process of decision making

Recommendations for K-12 Grade Levels

Elementary School Science

Science should be an integral part of the elementary school program. It should be used to integrate, reinforce, and enhance the other basic curricular areas so as to make learning more meaningful for children.

A carefully planned and articulated elementary science curriculum should provide daily opportunities for the sequential development of basic physical and life science concepts, along with the development of science process and inquiry skills.

Elementary science should provide opportunities for nurturing children's natural curiosity. This helps them to develop confidence to question and seek answers based upon evidence and independent thinking. Children should be given an opportunity to explore and investigate their world using a hands-on approach, with instructional materials readily available.

The focus of the elementary science program should be on fostering in children an understanding of, an interest in, and an appreciation of the world in which they live.

Middle/Junior High School Science

The middle/junior high school science curriculum should be designed to accommodate the needs and learning styles of the early adolescent. Students should be provided with daily opportunities to explore science through reading, discussion, and direct learning experiences in the classroom, laboratory, and field.

Middle/junior high school science should contribute to the development of scientifically literate persons and not simply prepare them for the next science course. National studies have shown that often middle/junior high school science is designed to prepare students for high school biology with no emphasis on physical science. In addition, studies show that fewer than one half of the junior high students going on to high school take chemistry and physics. Therefore, it is imperative that an important thrust of middle/junior high school science be toward the physical and Earth sciences.

Middle/junior high school students should continue to develop science process skills and content. Middle/junior high school science should emphasize the *application* of both skills and content to the students' personal life situations and enable students to begin examining societal issues that have a scientific and technological basis. Middle/junior high school students need to *apply* what they have learned soon after their instruction to insure the lasting value of the experience.

High School Science

The high school science curriculum should enable students to further develop their scientific and technological literacy. Courses incorporating well-designed laboratory and field work help to meet this need.

A balanced core of two years of science should be required of *all* students, consisting of one year of life science and one year of physical science—both taught in a science-technology-society context. The courses should provide students with opportunities to develop skills in identifying science-based societal problems and in making decisions about their resolution.

Students interested in exploring or preparing for careers in science, engineering, or technical fields should have the opportunity to take additional discipline-based courses in advanced biology, chemistry, physics, and Earth sciences. These courses should be planned and sequenced to take advantage of the students' increasing command of mathematics.

Time on science learning

- Lower elementary level (grades K-3): a minimum of 1½ hours/week of science should be required.
- Upper elementary level (grades 4-6): a minimum of 2½ hours/week of science should be required.
- Middle/junior high school level (grades 7-9): a minimum of 1 hour/day for at least 2 full years of science should be required of all students.
- Senior high school level (grades 10-12): a minimum of 1 hour per day for 2 full years of science should be required. The courses should represent a balance of physical and life sciences.

Emphasis on programs for all students

- In elementary, middle, junior, and senior high school grades, science education programs should provide basic concepts for all students. Opportunities should be available for students with diverse interests and commitments, including students with exceptional interests and talents in science.

Emphasis on science education for the adult general population

- Schools should provide educational opportunities in science for all the adult population in their community.
- Colleges, universities, and national organizations should increase emphasis on science education for adults through public lectures and seminars.
- The important contributions of out-of-school education programs such as museums, TV, planetariums, and zoos should be recognized and utilized by all those involved.

Emphasis on the professional development of science teachers through inservice opportunities

- Colleges, universities, and other agencies should develop teacher education and inservice education programs that are consistent with this policy statement.
- School districts should provide opportunities, encouragement, and recognition for teachers who maintain a high level of professional competence.

Emphasis on laboratory and field activities

- Elementary level laboratory and field activities should stress the development of basic inquiry skills
- Middle junior high school level laboratory and field activities should stress the application and extension of inquiry skills as a means of obtaining knowledge and resolving problems.
- High school level laboratory and field activities should emphasize not only the acquisition of knowledge, but also problem solving and decision making.

Science instruction matches students' cognitive, physical, social, and emotional development

- Schools should provide objectives, content, and instructional strategies that are appropriate to the student's stage of mental, moral, and physical development.
- Varying strategies and materials should be provided at all grades to accommodate students with various levels of learning skills and mental development.

Emphasis on science-related societal issues

- Elementary level, a minimum of 5 percent of science instruction should be directed toward science-related societal issues.
- Middle, junior high school level: a minimum of 15 percent of science instruction should be directed toward science-related societal issues.
- Senior high school level: a minimum of 20 percent of science instruction should be directed toward science-related societal issues

This NSTA Position Statement was adopted unanimously by the Board of Directors in 1982.