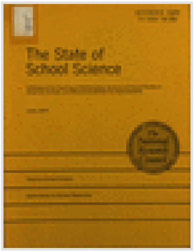

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THE STATE OF SCHOOL SCIENCE

A Review of the Teaching of Mathematics, Science and Social Studies in American Schools, and Recommendations for Improvements

Panel on School Science
Commission on Human Resources
National Research Council
2101 Constitution Ave., N.W.
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NOTICE

The project that is the subject of this report was approved by the Governing Board of the National Research Council, whose members are drawn from the Councils of the National Academy of Sciences, the National Academy of Engineering, and the Institute of Medicine. The members of the Panel responsible for the report were chosen for their special competences and with regard for appropriate balance.

This report has been reviewed by a group other than the authors according to procedures approved by a Report Review Committee consisting of members of the National Academy of Sciences, the National Academy of Engineering, and the Institute of Medicine.

ACKNOWLEDGMENTS

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The Panel is appreciative of the interest and support of Dr. F. James Rutherford, Dr. Alphonse Buccino, and Dr. Linda Ingison of the National Science Foundation.

Within the National Research Council, the Panel received valuable counsel and assistance from the Commission on Human Resources, especially from Dr. Harrison Shull, Chairman of the Commission, and Dr. William C. Kelly, its Executive Director, who participated in the meetings and joined in the discussions, and from Dr. Richard Crane and Dr. Lloyd Humphreys who served as Commission reviewers for the report.

The assistance of Dr. Douglas Lapp, Science Specialist for the Fairfax County (Virginia) School System, who served as a consultant to the Panel in its meetings and in the drafting of its report, was especially helpful.

Members of the staff of the Commission on Human Resources who assisted the Panel included Mrs. Shirley Davis, Administrative Associate, and Mrs. Lynn Dotson who supplied secretarial support.

To all of these persons, the Panel expresses its warmest thanks.

SUMMARY

During the 1950's and 1960's a national effort to improve pre-college education resulted in the development of new courses and teaching materials for instruction in elementary and secondary school mathematics, science, and social studies, and resulted also in the offering of a large number of institutes to increase the knowledge of school teachers and to help them learn to use the new courses and materials effectively.

The 1970's brought a great reduction in the number of institutes for teachers and a substantial decline in usage of the new courses and materials. The National Science Foundation, which has played a leading role in the whole effort toward improvement, sought to determine the current status of teaching and learning in elementary and secondary schools, and to reassess its own responsibility for pre-college education. To that end, NSF commissioned three national studies of the status of pre-college education, and then asked eight national organizations to review those three studies and to state current needs as they saw them. This report is one of the eight responses to that request.

Survey data, firsthand observation, and other evidence from the three studies commissioned by NSF describe a troubled American school system. Declining enrollments, financial stringency, the unsatisfactory performance of many pupils and graduates, pressure for greater accountability, disagreements over educational policy -- these and other forces have affected the teaching of science and mathematics as they have nearly every aspect of the nation's schools.

Nevertheless, there are good students, eager to learn. Good teaching is to be found. Many teachers wish to improve their knowledge and skills and to have better texts and teaching materials. The first three chapters of this report describe the conditions under which these teachers work, the variability, the trends, and the problems as reported in the three NSF studies and as indicated by other reports and evidence.

Drawing upon the findings of the three NSF studies and other information, the Panel on School Science of the National Research Council's Commission on Human Resources considered the current needs for improving education in science and mathematics and offers the following recommendations:

1. We recommend the establishment of a number of Science and Mathematics Teaching Resource Centers, each to

serve a large school system or a group of neighboring smaller systems. Each Teaching Resource Center would offer some or all of the following services:

In-service training programs related to the science and mathematics courses being taught or to be introduced in the school systems involved.

Construction, maintenance, repair, and distribution of kits of materials required to teach those courses.

Expert advice to teachers to help them learn to use new science and mathematics instructional materials and techniques, and to help them with their individual teaching problems.

2. We recommend increased support for the NSF program of funding the design, experimental testing, and revision of new courses in science and mathematics and their associated teaching and learning materials.

3. We recommend support of an NSF program of institutes for teachers, both to increase their knowledge of subject matter and to improve their skill in teaching the new courses that will be developed in the future, whether the development of those courses is funded by public or by private sources.

4. We recommend the development of additional science and technology centers of the kind that now exist in a number of cities. Furthermore, we recommend the strengthening of cooperative arrangements between these centers and nearby school systems to increase the extent to which the centers provide planned supplementation of the programs of the associated schools, and to increase their general value to children and adults who wish to learn more about science.

5. In order to give women and members of racial or ethnic minority groups greater opportunity to become interested in and to prepare for careers in scientific and technical occupations, we recommend that scientists and engineers work with their local school systems to provide special lectures and classes; tours of local scientific, engineering, and technical facilities; opportunities to meet with appropriate role models; and other experiences intended to increase their motivation and to overcome their disadvantages in securing the education necessary for scientific and technical careers. In addition, we recommend that efforts be made to identify gifted but economically disadvantaged students early in their schooling, so as to ensure that they will be afforded adequate opportunities to prepare themselves for admission to scientific and technological programs in college.

6. We recommend vigorous efforts at local levels to combat the overemphasis currently given to scores on standardized tests of achievement in comparing the performance of schools, classes, and individual pupils. Because the tests most generally used for these purposes give emphasis to the more elementary and routine abilities necessary to meet "minimum competency" requirements, they constitute only a part of the basis upon which schools and pupils should be judged. In addition, in order to make available more desirable tests with which teachers can appraise the performance of their pupils, we recommend the creation, for each major subject, of a large bank of test items, of varied types, and covering a wide range of skills and knowledge of the field. These test banks should be openly available to any teacher, school administrator, parent, child, or anyone else who is interested. Open availability of the entire bank of test items should improve the quality of test items and will give teachers latitude in selecting the test questions that match their educational objectives.

* * * *

Finally, we recommend that scientists take the lead in evaluating these and other recommendations for the improvement of science education at the pre-college level, and in developing the specific programs and activities necessary to implement the recommendations that seem most promising. Scientists will have to accept responsibility for leading the whole effort, for it is not likely that anyone else will.

INTRODUCTION

Beginning in the 1950's, several groups of scientists and mathematicians set out to achieve major improvements in the teaching of science and mathematics in the nation's schools. Congress responded quickly and generously by providing financial support for the National Science Foundation's Course Content Improvement Program, and for hundreds of institutes to enhance the knowledge and teaching effectiveness of thousands of teachers.

These cooperative efforts produced a rich variety of carefully prepared and well proven materials for teaching science[1] at all ages from kindergarten through grade 12. All over the country some teachers, particularly at the high school level, are making good use of at least parts of these materials and some of the innovations have been imitated in texts prepared under more traditional arrangements. Some teachers are helping their students learn how to ask questions and search for answers instead of simply relying on what the textbook says. And many teachers are better trained than they would have been without the benefit of attendance at a National Science Foundation institute for teachers. In short, the teaching of science in grades K-12 is on a higher plane than it was when the Course Content Improvement Program started.

Yet there has also been considerable slippage. Many of the innovative teaching programs are being used less widely than they were. Some of their ideas and techniques have been watered down as they have been transplanted into new settings and adapted by new authors.

Science is not alone in having difficulties; the whole educational system is in trouble. The inability of many students to read and write as well as expected is a frequent complaint at all school levels from the middle grades to college. Criticisms of the schools and of some educational innovations have induced a defensive reaction that encourages a "back to the basics" emphasis on the three R's and allots correspondingly less attention to science. Tax revolt, flight of some students to the suburbs or to private schools, and declining enrollments have restricted the funds that might have been used to overcome some of these difficulties.

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[1]Unless the context or wording indicates a narrower meaning, *science* is used in this report, as it is in many reports of the National Science Foundation, to include mathematics, the natural sciences, and the social sciences.

Aware of these troubles and aware also of the declining usage of the innovative teaching programs that had been developed under its auspices, the National Science Foundation commissioned three studies of the status of teaching of mathematics and the natural and social sciences in American schools. The Research Triangle Institute of North Carolina conducted a national survey of school administrators and teachers. The Ohio State University, with help from the Social Science Education Consortium of Boulder, Colorado, searched and summarized the literature on the teaching of mathematics, the natural sciences, and the social sciences. The University of Illinois carried out case studies of 11 selected and widely distributed high schools and the lower schools from which each drew its students. All three of these studies were expected to result in status reports; their authors were not invited to make suggestions for improvement or change.

Following receipt of these three studies, the National Science Foundation invited the National Academy of Sciences "to submit a proposal outlining an approach to summarizing relevant findings (of the three studies) and developing needs statements from the point of view of the membership". Simultaneously, similar requests were addressed to seven other organizations that were expected to view the status of the teaching of science and mathematics from the points of view of their constituencies.

Judged on the basis of the Panel members' other knowledge about American schools, these reports provide a clear and representative picture of the current status of precollege education in science and mathematics.

The statistical survey conducted by the Research Triangle Institute yielded useful information from a representative sample of teachers, principals, and curriculum supervisors. The Panel found the information regarding course offerings, enrollments, and current usage of federally-funded curriculum materials to be the most valuable. It is unfortunate, however, that this survey did not provide statistical information that was more relevant to some of the serious questions raised by the NSF case studies.

The literature reviews seemed to be an adequate and fair review of much of the existing literature concerning educational practices and needs in science, mathematics, and social studies. For the Panel's purposes, however, these literature reviews were less useful than the other two studies.

The NSF case studies, like all such studies, concentrated on an in-depth analysis of some particular school settings.

There is no way of telling how representative the eleven school districts selected are, but the case study approach did allow the investigators to present detailed descriptions of a series of specific problems that are certainly not uncommon in many other American schools.

The three studies will be referred to so often in this report they need a standard form of reference. When all three are meant, they will be called the three NSF studies. The national survey conducted by the Research Triangle Institute will be called "the NSF statistical survey" and will be cited as (Weiss, 1978). The literature search was in three volumes. When referred to separately, they will be identified and cited as follows: "the science education literature review" (Helgeson, Blosser, and Howe, 1977); "the mathematics education literature review" (Suydam and Osborne, 1977); and "the social science education literature review" (Wiley and Race, 1977). When all three volumes are meant, the collective reference will be to the "NSF literature review". The case studies and their analyses will be referred to as "the NSF case studies" and will be cited as (Stake and Easley, 1978).

Responsibility for reviewing these three studies and preparing this report was assigned to the National Research Council's Commission on Human Resources, which appointed an ad hoc Panel on School Science for the purpose. Members of the panel were:

Leallyn B. Clapp, Department of Chemistry, Brown University

Johns W. Hopkins, III, Department of Biology, Washington University

*Grace M. Hopper, Captain, United States Navy

*Gordon Millar, Vice President Engineering, Deere and Co.

John A. Moore, Department of Biology, University of California, Riverside

David Page, Departments of Education and Mathematics, University of Illinois, Chicago Circle, Chicago

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*Captain Hopper and Dr. Millar did not attend either meeting of the Panel. Dr. Colin Hudson of Deere and Company attended both meetings as an observer and made valuable suggestions.

James Perkins, Department of Chemistry, Jackson State University, Jackson, Mississippi

Gerard Piel, Publisher, Scientific American

Sylvia D. Roberts, The Spence School, New York City

David Z. Robinson, Carnegie Corporation of New York

John G. Truxal, College of Engineering and Applied Science, State University of New York at Stony Brook

Dael Wolfle (Chairman), Graduate School of Public Affairs, University of Washington

Jerrold R. Zacharias, Education Development Center, Newton, Massachusetts

Douglas Lapp, Science Specialist for the Fairfax County (Virginia) School System, served as consultant to the Panel.

The first three chapters following this introduction were written by Dr. Douglas Lapp. They review the three NSF studies and on a number of points compare the findings of those studies with information from other sources. These chapters analyze the data and observations provided by the three NSF studies to answer the following questions: (1) What emphasis do science, mathematics, and social studies receive in the curriculum of the elementary schools? (2) What constitutes the curriculum in science, mathematics, and social studies in the nation's secondary schools? (3) What factors currently appear to be adversely affecting the quality of pre-college instruction in science, mathematics, and social studies?

The remainder of the report is the work of the Panel members. Its recommendations are based upon the findings of the three studies, other reports reviewed by the Panel, and the collective experience of the Panel members.

THE ELEMENTARY SCHOOL CURRICULUM

Allocation of Instructional Time

The NSF statistical survey indicates that 25 percent of the states and 40 percent of the school districts in the nation set guidelines for the minimum amount of time to be spent on each subject in the elementary grades. In districts that have such guidelines, for grades one through three, the average recommended minimum times are 30 minutes per day for mathematics and approximately 20 minutes per day each for science and social studies. In grades four through six a minimum of 30 to 40 minutes of daily instruction is recommended for each of these subjects (Weiss, 1978, p. 22).

The elementary teachers surveyed indicated that they "typically" spent about 20 minutes each day on science and 20 minutes on social studies in grades K-3, as compared to 40 minutes on mathematics and 95 minutes on reading. In grades 4-6, upper elementary level teachers estimated that they usually spent about 30 minutes each day on science, 35 minutes on social studies, 50 minutes on mathematics, and 65 minutes on reading (Weiss, 1978, p. 51).

The above figures for elementary science do not differ radically from previous estimates; summarizing data from several independent surveys, Helgeson et al. concluded that about 60 minutes per week were devoted to science in grade 1, increasing to 110-140 minutes per week in the upper grades (1977, p. 32). For mathematics, the surveys summarized by Suydam and Osborne (1977, pp. 52-53) indicated that approximately 20 percent of the six-hour elementary school day has generally been allocated to mathematics instruction, a considerably larger amount of time than that reported by Weiss.

In the NSF case studies, Stake and Easley indicate that the teaching of science had a very low priority in most of the elementary schools visited.

> Most schools we studied had some written policy about what and how elementary science should be taught, but what actually was taught was left largely to individual teachers. By and large, the elementary teachers did not feel confident about their knowledge of science, especially about their understanding of science concepts. Even those few who did like science and felt confident in their understanding of at least certain aspects of it often felt that they did not have the time nor material resources to develop what they thought would be a meaningful program. As a consequence, science had been deemphasized at the elementary school level, with some teachers ignoring it completely.

> When and where science was formally taught, the instructional material was usually taken directly from a textbook series. The method of presentation was: assign - recite - test - discuss. The extent to which the emphasis on reading and textbooks pervaded the elementary science program is illustrated by an episode observed in an elementary life science class where the teacher opened a recitation period with the question: How do we learn? A chorus of students replied: "We learn by reading..."
>
> Other than the fairly common practice of learning science by reading from a textbook series, the selection of what was to be read and the actual time spent on reading science varied greatly from teacher to teacher. In most of our school systems, no district-wide elementary science program was identified (Stake and Easley, 1978, pp. 13:5-13:6).

Social studies instruction also took a back seat to instruction in the "basic skills" of reading and computation in the elementary schools studied:

> As a content area, social studies was found to be subordinate to reading and mathematics in the elementary curriculum. At each of the sites there was some kind of social studies curriculum, but teachers and principals readily admitted that instruction in this area was of much lower priority than reading or math. It had about the same priority as instruction in science. Social studies lessons were seen to be given more time than science by most K-6 teachers, perhaps because they were more knowledgeable about social studies than science (Stake and Easley, 1978, p. 13:28).

Use of Federally-Funded Curriculum Materials in Elementary Schools

Local school district personnel responding to the NSF statistical survey indicated that 31 percent of the districts claimed they were using one or more of the federally-funded elementary science curriculum materials. In social studies, the figure was 25 percent, while only 8 percent of the districts indicated use of any federally-funded mathematics materials. These data are compared with usage prior to 1976 in Table 1.

TABLE 1

Percent of School Districts Using One or More of the Federally-Funded Elementary School Curriculum Materials in Each Subject

Subject	1976-1977	Prior to 1976-1977
Science	31	26
Mathematics	8	37
Social Studies	25	24

Source: Weiss, 1978, p. 79.

Teachers were also asked to indicate which federally-funded curriculum materials they had actually used in the classroom. The most commonly used federally-funded curriculum materials in each discipline are shown in Table 2, with the corresponding percentages of districts and teachers who indicated use. The reader will note that there is often considerable disagreement between the usage figures reported by school district personnel and the information supplied by teachers. Weiss suggests that the data obtained from teachers are likely to be more accurate, since the respondents for school districts may not have been fully cognizant of the programs actually used in the schools and because not all schools in a given school district use the same programs (1978, p. 82).

It should also be noted that the usage figures in Table 2 cannot be used to calculate meaningful subtotals for science, mathematics, and social studies, since school districts and teachers commonly use materials from more than one federally-funded project in a given category. Furthermore, only the most commonly used federally-funded curriculum materials are listed in Table 2.

Table 3 tabulates the percent of teachers who were using at least one of the federally-funded curriculum materials during 1976-1977, by subject and grade range.

TABLE 2

Use of Selected Federally-Funded Curriculum Materials
In Elementary Schools

Curriculum Material	Percent of School Districts Using Selected Materials		Percent of Teachers Using Selected Materials			
			K-3		4-6	
	Using in 1976-1977	Used Prior to 1976-1977	Using in 1976-1977	Used Prior to 1976-1977	Using in 1976-1977	Used Prior to 1976-1977
K-6 Science						
Elementary Science Study (ESS)	15	13	5	7	9	14
Science - A Process Approach (SAPA)	9	10	4	10	9	13
Science Curriculum Improvement Study (SCIS)	8	8	11	16	12	16
K-6 Mathematics						
Developing Mathematical Processes (DMP)	1	3	1	3	3	4
ERC Mathematics (Greater Cleveland)	0	8	2	22	1	8
Individualized Mathematics System	4	11	4	7	3	9
Individually Prescribed Instruction	2	3	1	3	2	7
School Mathematics Study Group (SMSG)	0	18	0	4	0	9
K-6 Social Studies						
Concepts and Inquiry (ERC)	2	2	2	4	2	4
Elementary Social Science Education Program Laboratory Units (SRA)	12	3	3	14	6	5
Family Man (Minnesota)	1	2	1	4	1	1
Man: A Course of Study (MACOS)	3	3	0	0	2	5
Materials and Activities for Children (MATCH)	-	-	1	1	3	5
Our Working World	8	16	5	15	2	10
Taba Program in Social Science	2	2	1	2	1	3

Source: Weiss, 1978, Appendix B, pp. 22-25, 36-40.

TABLE 3

Percent of Elementary School Teachers Using One or More of the Federally-Funded Curriculum Materials in Each Subject (1976-77)

	Science	Mathematics	Social Studies
K-3	20	8	11
4-6	27	10	12

Source: Weiss, 1978, p. 83.

The 1976-77 usage figures shown in Tables 1, 2, and 3 are lowest in mathematics. The use of a federally-funded elementary mathematics program was reported by only 8 percent of the school districts and by less than 10 percent of the teachers. However, these figures may be somewhat misleading since the intention of many of the developers was to have their "innovations" incorporated into commercially-developed textbooks and this has occurred to a limited extent.

Although the NSF statistical survey identifies the most commonly used mathematics textbooks, no attempt was made to analyze their content. However, the Educational Products Information Exchange (EPIE) Institute did make such an analysis in the National Survey and Assessment of Instructional Materials (NSAIM), which was completed in 1976. This EPIE Report (1977a, p. 22) indicated that the ten most-used materials in mathematics (K-12) were clearly traditional programs, quite similar to each other in instructional design. They were also traditional in the way in which they were developed. Of the ten most-used materials, six were marketed by the same publisher. Among the 32 most popular mathematics materials listed in the EPIE Report, only one was the result of nontraditional development; this development was federally funded. This mathematics material ranked 24th, and was cited by only 2.4 percent of the EPIE survey's respondents. The EPIE evaluators came to the following conclusions:

> Of the remaining 31 materials in the first group, at best two could be considered to have even a modicum of an R&D base. This is not to say that R&D-based materials are necessarily the "best" or the "right" materials for every classroom, but it is to say that they are more likely to perform as promised when used as directed with an appropriate

> student population. By R&D-based materials, we refer to materials built upon an empirical data base, as opposed to conventional wisdom, and developed through continuous feedback loops that insure that once obtained data hold steady over time. A traditionally developed material uses little more than "conventional wisdom", that is, usually the manuscript is written by a publishing company's editor, who often is a former teacher, and it receives as "input" critical readings by those who are listed as authors and suggestions from sales representatives and production staff members (EPIE Institute, 1977a, p. 22).

In the case of social studies, although the EPIE survey concluded that most of the ten most-used social studies materials were fairly alike, there were some innovative materials in the group (EPIE Institute, 1977a, p. 23). The NSF statistical survey also revealed that some federally-funded social studies materials were among those that were most commonly used in the elementary grades (Weiss, 1978, p. B-46).

The NSF statistical survey's estimates of teacher usage of the three NSF-funded elementary science programs are lower than those which have appeared in earlier studies. Using data from state reports through 1975, Helgeson et al. (1977, p. 18) estimated that Science Curriculum Improvement Study (SCIS) materials were being used in schools in which 17 percent of the K-6 students in the nation were enrolled; Elementary Science Study (ESS) materials were in use in schools which contained 12 percent of the students; for the Science, A Process Approach (SAPA) program the figure was 20 percent. The discrepancy between these estimates and the NSF statistical survey data is probably due to the phenomenon mentioned earlier, that state and district supervisors often do not know which materials are actually being used in teachers' classrooms. Also, even though a few teachers in a given school may be teaching one of the new elementary science programs, this does not guarantee that all students are receiving such instruction.

During the 1970's several publishers produced "hybrid" elementary science texts which incorporated some of the emphases of the three NSF-funded elementary science programs (Hausman, 1976). The authors of the NSF science education literature review commented on the impact of these materials:

> It is evident that the content and activities of these (hybrid) materials is different from the textbooks of the 1950's. Curriculum guides and teacher guides produced by states and local school

> districts since 1972 are closer in emphasis to the NSF projects and recent "hybrid" materials than to the textbooks of the 1950's (Helgeson et al., 1977, p. 18).

However, the NSF statistical survey's data on textbook usage suggest that the second generation "hybrid" materials have not captured a significant fraction of the elementary science textbook market (Weiss, 1978, p. B-44). The four most commonly used elementary science texts listed in the NSF statistical survey utilize for the most part a didactic approach to science, in which most of the learner's time is spent reading and listening (EPIE Institute, 1977b).

THE CURRICULUM IN SECONDARY SCHOOLS

Science, Mathematics, and Social Studies Requirements

Most school systems questioned in the NSF statistical survey have established standards as to the minimum amounts of grade 9-12 instruction in science, mathematics, and social studies required for high school graduation. These requirements are summarized in Table 4.

TABLE 4

Percent of School Districts Requiring Minimum Amounts of Grade 9-12 Instruction in Each Subject

	Less Than 1 Year	1 Year	More Than 1 Year	Unknown
Science	2	54	33	11
Mathematics	4	47	33	16
Social Studies	2	5	74	20

Source: Weiss, 1978, p. 25.

In general, graduation requirements are significantly greater in social studies than in science or mathematics; approximately three-fourths of the districts reported that they require more than one year of social studies, compared to one-third of the districts in both science and mathematics. (Note that 20 percent of the districts surveyed did not answer this question for social studies, while 16 percent omitted the answer for mathematics and 11 percent for science, possibly because they have no requirements in the subject.) After reviewing state social studies requirements, Wiley and Race (1977, p. 34) determined that two or three years of social studies are usually required at the senior high school level.

Most districts (86 percent) require one or more specific courses in social studies; the courses most commonly required are United States history, American government, and world history. Less than half of the districts require specific courses in math or science. When specified, such science course requirements typically include general science, biology, or physical science; specific math course requirements are typically general mathematics or elementary algebra (Weiss, 1978, p. 26).

Course Offerings (Grades 7-12)

In the NSF statistical survey, the most commonly taught science, mathematics, and social studies courses in grades 7-9 and 10-12 were ascertained from teacher questionnaire data. The results are shown in Table 5.

At the junior high school level (grades 7-9), it will be noted that four courses (general science, earth science, life science, and physical science) account for 86 percent of the science classes. General mathematics and algebra together account for 87 percent of the mathematics classes, and American history and "social studies" account for 52 percent of the social studies classes.

For grades 10-12, biology, chemistry, and physics together account for 74 percent of the science classes; algebra and geometry together represent more than two-thirds of all 10-12 mathematics classes. In the case of social studies, numerous elective courses together account for as many classes as American history and world history, which together account for 37 percent of the 10-12 social studies classes.

Data collected by the NSF statistical survey do not lend themselves to calculations of the percentage of high school students who take a specific course prior to graduation. However, a smaller scale survey, conducted as a part of the NSF case studies, did collect some pertinent data. In this survey, 361 high school seniors were asked to indicate the science, mathematics, and social studies courses they had taken *previous to their senior year* in grades 9, 10, and 11. The results are tabulated in Table 6.

It is curious that earth science was not included in the questionnaire given students; the topic of earth science courses seemed to have been generally neglected in the NSF case studies, even though earth science courses represent 25 percent of the science classes taught in grades 7-9 (Weiss, 1978, p. 63).

Physics is not included in Table 6 because it is usually taken in grade 12, making the survey results for this subject not very useful. For the same reason, it is likely that the percentages listed in Table 6 for most upper-level courses (including chemistry and calculus) would be higher if a survey had been taken at the end of the senior year so that good estimates could have been made for all courses taken through grade 12. It is unfortunate that neither this NSF case studies survey nor the larger NSF statistical survey provided such estimates.

TABLE 5

Most Commonly Offered Science, Mathematics, and Social Studies Courses

Grades 7-9 Course	% of Classes	Grades 10-12 Course	% of Classes
Science			
General Science	30	Biology	40
Earth Science	25	Chemistry	19
Life Science	16	Physics	15
Physical Science	15	Advanced Biology (2d year)	5
Biology	6	Other Courses	21
Other Courses	8		
Mathematics			
General Mathematics	64	Algebra	38
Algebra	23	Geometry	30
Remedial Mathematics	4	Advanced Mathematics and Calculus	7
Other Courses	9	Consumer/Business Mathematics	6
		General Mathematics	5
		Other Courses	14
Social Studies			
American History	34	American History	27
Social Studies	18	World History	10
State History	7	Psychology	7
Civics	6	American Culture/ Contemporary Issues	7
World Geography	6	United States Government	6
Other Courses	29	Economics	5
		Other Courses	38

Source: Weiss, 1978, pp. 63-64.

Taken at face value, the data in Table 6 indicate that approximately 90 percent of high school students take biology, algebra, and American history in grades 9-11; three-fourths of the students take geometry, about two-thirds take general science, and approximately one-half take chemistry. These percentages are all somewhat unreliable. They are not in good agreement with what one would intimate from Table 7, and the students polled were not a nationally representative sample. Nevertheless, unless course enrollment patterns change radically, it would appear that these six courses represent the most appropriate targets for future high school curriculum development efforts aimed at improving general public literacy in science, mathematics and social studies.

TABLE 6

Percentage* of 12th Grade Students Who Had Completed Specific Courses in Grades 9-11

Course	% of Seniors	Course	% of Seniors
General Science	62	Advanced Algebra	38
Biology	87	Calculus	2
Chemistry	46	American History	94
Ecology	10	American Government	33
Basic Math	46	Psychology	14
Algebra	88	Sociology	12
Geometry	74	Economics	23

*Unweighted percentages

Source: Stake and Easley, 1978, p. 18:26.

Course Enrollment Trends

Science. The NSF case studies and the associated survey of science curriculum supervisors both suggested that a decline in science enrollments might be occurring in secondary schools. In particular, the NSF case studies observers noted declining enrollments in chemistry and physics. Reasons given by school system personnel for this apparent decline included reduced graduation requirements, more competition from other elective courses, the fact that these subjects could be picked up in junior college, if needed, and the perception of high school students that the content of physics and chemistry is not "relevant" (Stake and Easley, 1978, p. 13:4).

The Condition of Education, 1978 reports that in 1976 the size of the 14 to 17 year-old population in the nation began to decrease (National Center for Educational Statistics, 1978, p. 5), following a large increase in the size of this age group during the previous two decades. The peak in the growth of the student population in grades 7, 8, 9 occurred in 1972-73. The authors of the NSF science education literature review assert that the subsequent decline in total enrollment has affected the number of junior high school students taking science, but that the percentage has remained about constant since 1973 (Helgeson et al., 1977, p. 24).

Summarizing both national statistics and state data, the same authors note that general science was the science course most commonly taken by students in grades 7, 8, and 9 in the 1950's. Since then, there has been a decline in general science enrollments as that course has been increasingly replaced by life science, physical science, and earth science in grades 7, 8, and 9. There has been an especially sharp rise in earth science enrollments, and a resulting shortage of qualified earth science teachers in many states (Helgeson et al., 1977, p. 24).

In the 1960's, courses in physical science began to be offered at the eighth, ninth, and tenth grade levels for students who did not take chemistry or physics, or as preparation for these courses. About half of the schools were offering these general physical science courses in the 1960's, but since 1970 the percentage of students enrolling in them has declined (Helgeson et al., 1977, p. 29).

Course enrollment statistics collected by the National Center for Educational Statistics (NCES) 1972-73 survey indicate that the percentage of high school students (grades 9-12) registered in any science course increased from 48 percent in 1949 to 66 percent in 1960-61, and increased slightly further to 67.2 percent in 1972-73 (Ostendorf and Horn, 1976, p. 14). State data reviewed by Helgeson et al. (1977, p. 26) indicate a small reduction in the percentage of high school students taking science courses during the period 1974-1976.

The numbers of students enrolled in selected science courses according to the NCES surveys are listed in Table 7. Biology, usually taken in grade 10, is the last science course taken by about half of the students. The NSF science education literature review indicates that in most states over 80 percent of the students enroll in a biology course sometime during their high school program (Helgeson et al., 1977, p. 26).

Helgeson et al., without citing a source of data, state that chemistry enrollments showed a small percentage of enrollment gain in the 1960's and early 1970's, but that since 1971 the percentage of students enrolled in chemistry appears to have declined slightly. In addition, their report states that the percentage of enrollments in physics increased slightly in the 1960's and early 1970's, and has decreased since 1971-1972 (1977, p. 28).

TABLE 7

Total Enrollment in Grades 7-12

1961	1973	Percent Increase
11,700,000	18,500,000	59%

Number of Public School Students in Grades 9-12
Enrolled in Specific Science Courses in Selected Years

Course	1961	1973	Percent Change
General Science	1,826,087	1,096,020	-40%
Biology	1,776,306	2,868,352	+61%
Physiology	65,953	109,588	+66%
Earth Science	76,564	558,654	+630%
Chemistry	744,820	1,028,591	+38%
Physics	402,317	583,105	+45%

Source: National Center for Educational Statistics, 1976, p. 8 and Helgeson et al., 1977, p. 27.

However, the percent change calculations shown in Table 7 indicate that although enrollments in high school chemistry and physics courses did increase, they did not keep pace with the larger increase in the total secondary school student population during the period 1961-1972.

Percentage enrollments in advanced science courses (second-year biology, chemistry, and physics) and science electives such as physiology, anatomy, zoology, botany, oceanography, and ecology have increased during the last five years. Such science electives seem to be absorbing significant numbers of students who opt not to take chemistry and/or physics. Advanced or second-year biology courses have shown the largest percentage gains; it appears that as many as 3% of the students in grades 10,11, and 12 are enrolling in such courses (Helgeson et al., 1977, p. 29).

Mathematics. In 1949, 65% of the secondary school students in grades 7-12 were enrolled in a mathematics course. This figure increased to 73% in 1960, and then decreased slightly to 71% in 1972-73 (Ostendorf and Horn, 1976; Wright 1965).

Commenting on the effects of the secondary-level mathematics curriculum efforts during the period 1955-1975, the National Advisory Committee on Mathematics Education (NACOME) Report (1975, p. 6) notes that there were increased offerings in 1960 in advanced general mathematics, plane geometry, advanced algebra, trigonometry, and advanced mathematics courses such as calculus, probability and statistics, and analytic geometry. The 1972-73 NCES survey data revealed that almost as many students were taking a second course in algebra or algebra/trigonometry as were taking elementary algebra and that over 260,000 high school students were studying calculus or other advanced-level mathematics courses, four times the 1960 figure. The 1972-73 NCES survey thus indicated that changes had occurred in the mathematics curriculum for a targeted but narrow sample of secondary mathematics students; changes for students who were not as interested in mathematics were less pronounced (NACOME, 1975, p. 5).

Summarizing the results of several more recent surveys, the NSF mathematics education literature review concluded that the mathematics enrollment pattern has been relatively stable in recent years, but that some declines have been noted. In New York State, for example, enrollment has declined slightly year by year during the period 1971-76 in the introductory mathematics and algebra courses generally taken by most high school students, although the enrollment has increased in ninth grade "basic mathematics" (Suydam and Osborne, 1977, p. 44).

Social Studies. Citing a study by Gross the authors of the NSF social studies education literature review examined social studies course enrollment trends from 1961 to 1973; these data can be found in Table 8, which shows the percentage change in enrollment for the most commonly offered social studies courses.

TABLE 8

Total Enrollments in Grades 7-12

	1961	1973	Percent Increase
	11,700,000	18,500,000	59%

Number of Public School Students in Grades 9-12
Enrolled in Specific Social Studies Courses in Selected Years

Course	1961	1973	Percent Increase
Civics	733,000	449,000	-39%
Problems of Democracy	380,000	298,000	-22%
World History	1,471,000	1,541,000	+ 5%
World Geography	595,000	736,000	+24%
U.S. Government	780,000	1,306,000	+67%
U.S. History	1,994,000	3,464,000	+74%
Economics	293,000	592,000	+102%
Sociology	289,000	796,000	+175%
Psychology	140,000	590,000	+323%

Source: Wiley and Race, 1977, p. 35 (after Gross).

It can be seen that enrollments in U.S. history and U.S. government grew a little more rapidly than total enrollment during the 1961-1973 period, but that enrollments in world history and world geography grew less rapidly. The enrollment decreases in some courses were apparently redirected to new social studies offerings, particularly elective courses in the social sciences such as psychology and sociology (Wiley and Race, 1977, pp. 35-36).

Use of Federally-Funded Curricula

The NSF case studies investigators did not find much evidence of the laboratory-oriented NSF science curriculum projects in the schools, nor did they identify any remnants of the "new math" programs developed with NSF support. In social studies, no traces were found of the High School Geography Project, Project Social Studies, the Anthropology Project, etc. (Stake and Easley, pp. 13:7, 13:23, 13:29b).

Whether or not these observations are accurate or are representative of the situation in the rest of the schools in the United States is open to question. It is possible that at least some of the observers utilized by the NSF case studies may not have been equally familiar with the previous NSF curriculum development efforts in all subject areas, and therefore may not have recognized any residue of impact. Nevertheless, their impressions are discouraging.

The NSF statistical survey did obtain estimates of the percentages of school districts and teachers who indicated use of specific federally-funded materials during the 1976-77 school year, and also obtained information on the use of these materials by districts and teachers in prior years. The results for the most commonly used materials are summarized in Table 9.

Again, as was the case at the elementary level, the figures for mathematics may be misleading, since most federally-funded mathematics materials were developed with the intention of incorporating the innovations into commercially-developed text books. It is unfortunate that neither the NSF statistical survey nor the NSF case studies made an attempt to assess the impact of any specific innovations of the secondary level mathematics curriculum development projects.

Table 10 indicates the percent of secondary school teachers in each subject and grade range who were using at least one of the federally-funded project materials. (Note that only the most commonly-used federally-funded materials are listed in Table 9.) Comparing these data with Table 3, it will be noted that secondary school teachers were much more likely than elementary school teachers to be using one or more of the federally-funded materials.

Table 10 also indicates that the percentage of science teachers using federally-funded materials was greater than the percentage of mathematics or social studies teachers. Slightly more than half of all grade 10-12 science teachers were using at least one of the federally-funded curriculum materials during the 1976-77 school year. It is difficult to reconcile this information with the previously cited observations of the NSF case studies.

It is important to note that Table 9 does not give data about the percentages of teachers teaching a given subject who were using the materials. However, analysts did

TABLE 9

Use of Selected Federally-Funded Curriculum Materials
(Grades 7-12)

Curriculum Material	Percent of School Districts Using Selected Materials		Percent of Teachers Using Selected Materials			
			Grades 7-9		Grades 10-12	
	Using In 1976-77	Used Prior to 1976-77	Using In 1976-77	Used Prior to 1976-77	Using In 1976-77	Used Prior to 1976-77
Science						
BSCS Green	19	30	3	14	17	30
BSCS Yellow	16	31	5	14	13	31
BSCS Blue	8	11	6	11	5	16
Chemical Bond Approach	2	3	0	2	2	5
CHEM Study	15	19	1	5	7	14
ESCP	10	12	10	22	4	10
IPS	25	21	9	23	7	29
ISCS	12	11	12	19	2	6
PSSC Physics	11	18	1	4	4	14
Project Physics	12	9	1	4	10	14
Mathematics						
IMS	2	4	3	7	1	3
Modern Coordinate Geometry	3	3	3	6	5	13
SMSG	2	18	7	26	6	31
Social Studies						
American Political Behavior	12	11	3	6	7	12
Carnegie Mellon Project	10	11	2	4	4	12
High School Geography Project	4	7	2	4	3	7
Sociological Resources for the Social Studies	7	7	1	3	6	10

Source: Weiss, 1978, pp. B-21, B-23, B-25, B-37, B-39, B-41.

make some rough estimates of this kind and determined that approximately half of all biology teachers were using at least one of the BSCS materials; approximately 40 percent of all physics teachers were using either the Project Physics Course or PSSC Physics or both; and approximately 25 percent of the chemistry teachers were using either CHEM study materials or the Chemical Bond Approach, or both (Weiss, 1978, p. 82).

TABLE 10

Percent of Secondary School Teachers Using One or More of the Federally-Funded Curriculum Materials in Each Subject by Grade Range (1976-77)

	Subject		
	Science	Mathematics	Social Studies
7-9	33	10	12
10-12	52	11	22

Source: Weiss, 1978, p. 83.

The data collected by the NSF statistical survey indicate that a number of the federally-funded materials were used more extensively by teachers in previous years than in 1976-77, particularly SMSG for K-12 mathematics; PSSC physics, CHEM Study chemistry, and several of the BSCS program materials in 7-12 science; and Our Working World in K-6 social studies.

Tracing the use of the PSSC physics program, Helgeson et al. (1977, p. 28) note that the major physics text in use in the late 1950's was Modern Physics (Holt). Introduced in 1958, PSSC gained in acceptance until the early 1970's, at which time the peak usage was about 35 percent of the students enrolled in physics. Since the early 1970's, the use of PSSC has been declining, as reflected in the NSF statistical survey results. Project Physics, introduced in 1969, accounted for approximately 22 percent of the students studying physics in 1975. However, Modern Physics continued to be used by over 40 percent of the students throughout this time period (Helgeson et al., 1977, p. 29).

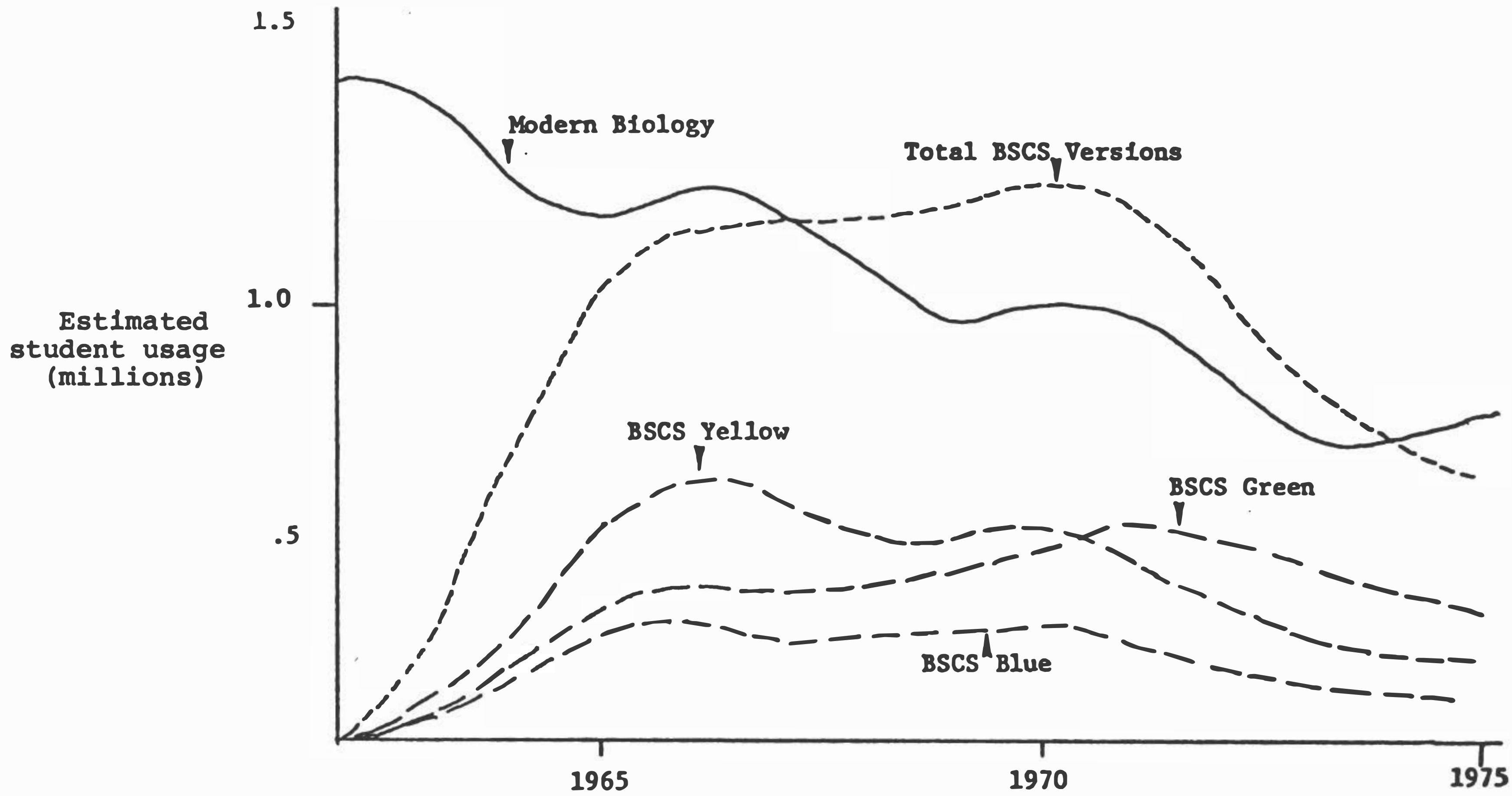
The situation in chemistry was similar. In the late 1950's most high school chemistry students were using Modern Chemistry (also published by Holt). Of the two NSF-funded high school chemistry projects, the Chemical Bond Approach (CBA) never was used by a large number of schools, but the CHEM Study text received considerable acceptance during the 1960's. The use of CHEM Study materials peaked in the early 1970's at about 30 percent of the students taking chemistry; this was followed by a decline during the last four years. Helgeson et al. suggest that this decline was due primarily to the availability of other texts that incorporate many of the CHEM Study approaches. However, the Modern Chemistry text, like the Holt physics text, has continued to be widely used. Helgeson et al. (1977, p. 28) report that in 1974 about 50 percent of the high school students studying chemistry were using this text.

In biology, the major text used during the 1950's was also one published by Holt, Modern Biology. Prior to 1963, it was reputed to occupy 80 percent of the high school biology market (Quick, 1978, p. 118). The three BSCS biology programs (the green, yellow, and blue versions) were widely adopted by school systems during the 1960's. In the early 1970's, about 40 percent of the students studying biology were using one of the three BSCS versions; about 35-40 percent were using the Modern Biology text. More recent data, as well as the NSF statistical survey, indicate that there has been a decline of from 5 to 8 percent in the use of the BSCS materials in recent years (Helgeson et al., 1977, p. 26). Figure 1 provides a picture of these trends in biology textbook usage.

A number of observers have stressed that recent declines in usage of federally-funded innovative materials need not cause much concern, since many of the ideas and approaches of these innovative materials have been incorporated into "conventional" textbooks (Weiss, 1978, p. 78; Helgeson et al., 1977, p. 28). Quick, in her recent study of the secondary impacts of the curriculum reform movement, found consistent evidence that educational publishers had incorporated innovations of the federally-funded curriculum materials into their own commercially-developed programs. She suggests that the commercial success of the federally-funded programs created market pressures that encouraged publishers to incorporate some of the themes and approaches of the innovative materials (Quick, 1978).

Other observers are less sanguine than Quick about the impact of the federally-funded innovative programs on classroom instruction in schools that are now using commercially-developed texts. Many of these texts have adopted changes that are largely cosmetic, in order to reflect the "inquiry

Figure 1. Student usage of Biology Textbooks



Source: Quick, 1978, p. 119. Student usage was estimated by John G. Wirt of the Rand Corporation from sales data supplied by Holt, Rinehart, and Winston, Inc., New York, and BSCS, Inc., Boulder, Colorado.

approach" and other innovations of the curriculum reform movement. Most of these commercially-developed texts still lend themselves to being used to support a didactic approach to teaching in which the student's main role is to listen, read, and memorize.

However, the above data indicate that a substantial number of teachers do continue to use the inquiry-based curriculum materials developed with federal support, although they usually constitute a minority. Of greater concern is the rate at which this usage is decreasing, especially considering the absence of an effective mechanism to familiarize new teachers with the content and approach of the NSF courses.

FACTORS AFFECTING THE QUALITY OF INSTRUCTION

Evidence of a Decline in Student Performance

In 1977, after a 14-year decline, the average scores on the College Entrance Examination Board's (CEEB) verbal and mathematics tests reached a new low. The Scholastic Aptitude Test (SAT) verbal score average, which had been 478 in 1963, dropped 49 points to 429; the mathematics average score fell from 502 in 1963 to 470 in 1977. A CEEB panel investigating the decline estimated that about 70 percent of the decline prior to 1970 was due to an expansion in the diversity of the population of students taking the SAT. In 1952, only half of the young people in the United States were staying in school through the twelfth grade; this increased to two-thirds in 1964, and to three-fourths in 1970. The proportion going on to college was about one-fourth in 1952; this increased to one-third in 1964 and to almost half in 1970. The panel indicated that 55 percent of those taking the SAT in 1960 came from the top fifth of their high school classes; in 1972 this was true of only 36 percent (Wirtz et al., 1977, pp. 13-14).

However, since 1970 there has been only a limited amount of change in the composition of the test-taking group. The CEEB panel suggested that a number of other factors might have affected the scores, including: (1) a proliferation in the number of elective courses taken by high school students at the expense of more "basic" course offerings, (2) a "diminished seriousness of purpose and attention to mastery of skills and knowledge... in the schools, the home, and the society generally", (3) the competition for time between television and student's school work, (4) a decline in the role of the family in the educational process, (5) the effect of a "decade of distraction" between 1967 and 1975, (6) "an apparent marked diminution in young people's learning motivation".

Ironically, the CEEB panel laid some of the blame for the decline in SAT scores on a deterioration in student writing ability, brought about in part by the increasingly widespread use of easily scored multiple-choice tests (like the SAT) at all educational levels:

> Our firmest conclusion is that the critical factors in the relationship between curricular change and the SAT scores are (1) that less thoughtful and critical reading is now being demanded and done, and (2) that careful writing has apparently about gone out of style...We can't prove that learning how to write is related to a decline in scores

> on a test that requires no writing. Yet in our judgment this may be a significant factor. We suspect strongly that <u>expressing</u> something clearly and correctly -- especially in writing -- is thinking's sternest discipline.
>
> It seems clear that increasing reliance in colleges and high schools on tests requiring only the putting of X's in boxes contributes to juvenile writing delinquency. Students learn what they think they need to know... Our strong conviction is that concern about declining SAT-Verbal scores can profitably be concentrated on seeing to it that young people do more reading that enhances vocabulary and enlarges knowledge and experience, and more writing that makes fledgling ideas test and strengthen their wings (Wirtz et al., 1977, p. 27).

Although the "return to the basics" has shifted into high gear in school systems throughout the United States it is paradoxical that this activity has been accompanied in many school districts by an increased molecularization of the curriculum into disembodied learning objectives, the achievement of which is usually indicated by student performance on standardized or criterion-referenced multiple-choice tests. Too often, these tests emphasize the most superficial aspects of learning in the content areas, focusing on the recall of facts and information as opposed to an understanding of conceptual schemes.

More detailed information about student performance in specific disciplines has been provided by the surveys conducted in recent years by the National Assessment of Educational Progress (NAEP). The first NAEP mathematics assessment was conducted during 1972-73, and included six major content areas: numbers and numeration, measurement, geometry, variables and relationships, probability and statistics, and consumer mathematics.

Summarizing several interpretive reports on the results of the 1972-73 mathematics assessment, Suydam and Osborne (1977, pp. 201-203) indicate that student performance was reasonably strong in the areas of whole-number computation, knowledge of numeration concepts, analysis of one-step word problems, measurement concepts, and the recognition of basic geometrical figures. Weaknesses were evident in the areas of percent, the use of fractions, tasks involving estimation and measurement, problems involving geometrical concepts, and complex word problems.

Three NAEP science assessments have been conducted (in 1969-70, 1972-73, and 1976-77), to assess the science knowledge of nine-, thirteen-, and seventeen-year-old students. A considerable amount of controversy has been generated concerning both the kinds of questions included in the first two surveys and the way in which the results were reported to the public (Tolman, 1976). An attempt was made to revise the NAEP science test items and reporting procedures for the 1976-77 science assessment in order to remedy these problems.

A statistically significant decline in achievement on the test exercises was noted between the first and second science assessments for all three age levels. A further decline was noted for seventeen-year-olds in 1976-77; their average scores were lower on both biology and physical sciences exercises, although the decline was greater in the physical sciences. Nine- and thirteen-year-olds did not decline in achievement on biology exercises during the period 1969-1977, but both groups did decline steadily in achievement on physical science questions (NAEP, 1978b).

In 1971-72, the first NAEP social studies assessment was conducted. The following findings were highlighted in the report of this survey:

---Less than one-half of the seventeen-year-olds and adults in the nation understood how to use all parts of a simple ballot.

---Relatively few Americans could read or interpret tables, graphs or maps effectively.

---A large gap existed between the attitudes students professed to hold and the actions they indicated they would take in specific situations.

---Exercises involving the recall of specific information appeared to be the most difficult to answer for all age groups.

---Students generally had very little knowledge about the contributions of minority groups to our culture and history.

The 1971-72 social studies results also suggested that one's out-of-school learning experiences in social studies are often as important as what one learns in school (Wiley and Race, 1977, p. 212).

A second NAEP social studies assessment was conducted in 1975-76. This survey provided data on changes in social studies achievement between 1972 and 1976. The results revealed changes in social studies achievement that were related to age level: nine-year-olds showed no statistically significant change in performance while the achievement of thirteen-year-olds declined only slightly. However, the performance of seventeen-year-olds showed a significant decline between 1972 and 1976 (NAEP, 1978a). In this respect the results of the 1976 social studies assessment and the 1977 science assessment were similar, and suggest that special attention needs to be paid to changes in attitudes toward learning that may be occurring when students reach adolescence, and to the methods which teachers are using to deal with this problem.

Teacher Effectiveness in the Classroom

Teacher Qualifications

The NSF statistical survey determined that, considering science, mathematics, and social studies teachers as a group, the average number of years of teaching experience is 11.5 years, with only small differences among those responsible for different subjects or grade levels (Weiss, 1978, p. 137). Although many school systems are experiencing declining enrollments, union pressures and the desires of school system administrators to avoid grievances have led to the establishment of reduction in force policies based solely on seniority. As a result, it has generally been the younger teachers who have been dropped when personnel cuts became necessary. The more experienced teachers have been retained, sometimes by transferring them to different grade levels or sometimes to entirely new subjects.

Most secondary (levels 7-12) school teachers of science, mathematics, and social studies teach all of their courses within a single subject area. However, 13 percent of the secondary science teachers surveyed were teaching one or more courses for which they felt inadequately qualified, as did 12 percent of the social studies teachers and 8 percent of the mathematics teachers. Most such teachers indicated concern about their qualifications to teach courses within their general subject area; for example, a science teacher qualified to teach biology might have indicated a concern about being unqualified to teach earth science or chemistry (Weiss, 1978, p. 142).

At the elementary level, 49 percent of the teachers feel themselves to be "very well qualified" to teach mathematics, as compared to 39 percent in social studies, only 22 percent in science, and a high of 63 percent in reading. Most of the teachers felt at least "adequately qualified" to teach all these subjects, although 16 percent of the elementary teachers felt that they were "not well qualified" to teach science, the only subject in which more than 6 percent of the teachers so indicated (Weiss, 1978, p. 142). However, state science supervisors and elementary school principals considered inadequate teacher preparation in science, as well as a lack of teacher interest in science, to be a serious problem in their schools. In addition, state mathematics supervisors rated inadequate teacher preparation to be a serious problem in K-6 mathematics (Weiss, 1978, p. 161).

In the past, the NSF provided a considerable amount of support for in-service training institutes to help teachers to improve their knowledge of subject matter and teaching skills. Almost half of the grade 10-12 science teachers, and 40 percent of the mathematics teachers at this level, have attended one or more of the institutes, conferences, or workshops sponsored by NSF. Attendance rates at such NSF activities were substantially lower for junior high school science and mathematics teachers (grades 7-9) and much lower for elementary school teachers, averaging less than 10 percent for science and 5 percent for mathematics. Only a few of the social studies teachers surveyed had attended NSF institutes or workshops; this is not surprising since NSF sponsored a relatively small number of such in-service training activities in the social sciences (Weiss, 1978, p. 69).

Although the teacher-training institutes supported by the National Science Foundation were attended by significant numbers of teachers, half of the science, mathematics, and social studies teachers surveyed in 1977 indicated that they needed assistance in the use of manipulatives or hands-on materials in implementing the inquiry approach (Weiss, 1978, p. 148). Undoubtedly, this group included many experienced teachers who have been reassigned to teach subjects outside of their field of expertise, as well as new graduates from colleges of education who are currently receiving very little training in the use of specific inquiry-based course materials. The NSF case studies reported that many teachers and administrators felt that the NSF institutes should be extended to the many teachers who have not had a chance to benefit from them (Helgeson, Stake, and Weiss, 1978, p. 19:25).

Unfortunately, there are not as many opportunities as there once were for teachers to improve their knowledge of subject matter and their teaching skills. Local school systems do not have the resources or capabilities to support such activities; the limited staff development funds that are available are usually targeted on efforts to implement competency-based accountability schemes. Since in the past such training was most effectively provided in the context of course-specific NSF institutes, the Foundation's current inability to support such activities poses a serious problem.

Laboratory Instruction and the Inquiry Approach

The research scholars and teachers who worked together in the NSF Course Content Improvement Program were critical of the encyclopedic approach of the textbooks of the time and of the procedures by which facts were presented, facts were learned, and facts were regurgitated in class and on examinations. Instead, the developers of the new courses strove to create teaching materials that would foster better understanding of ideas and principles. They placed emphasis on what is called the inquiry approach, which provides opportunities for students to "discover" key concepts and relationships through hands-on experiences. Thus laboratory instruction was designed to play an important role in the NSF-supported curricula, especially in the sciences. There are many reasons for such an emphasis.

First, laboratory work provides personal experiences for students. Some of the programs were designed so that important information had to come from the lab. The development of an idea in the textbook would stop at a critical point, requiring the student to search for the answer in the laboratory. Students were expected to be able to answer some important questions on the basis of their own observations and experiments.

Second, laboratory experiences provided information that is almost impossible to convey in a textbook. Printed words and static illustrations cannot capture the complexity of the behavior of microorganisms in a droplet of pond water or of the ways in which waves passing through two narrow apertures interact to produce interference patterns.

Third, the laboratory requires activity of students in a time when many young people lead increasingly passive lives. For some young people, the dissection of a frog or the qualitative analysis of an unknown substance will be one of the most challenging things they have ever done in their lives.

Fourth, scientific observations and experiments frequently show the limitations and uncertainties of scientific procedures. All copies of the same book present the same "correct" data and answers. Observations and experiments may not and, when the results are different, an inquisitive student and a stimulating teacher will search for the causes of the different results. That search will lead to a deeper and more reliable understanding of the phenomenon.

Last, most students find that laboratory work is fun. The seemingly endless pattern of classroom recitation or busy work is broken by this opportunity to be independent, to be active, and to discover.

However, the use of laboratory instruction and the inquiry approach in the schools appears to be diminishing. Although the use of manipulatives or laboratory materials is much more common in science classes than in mathematics or social studies classes, only 48 percent of the (K-12) science teachers surveyed indicated that they used them once a week or more in their classes, 9 percent of the K-12 science classes never use laboratory materials, and 14 percent do so less than once a month (Weiss, 1978, p. 107). Although the use of laboratory materials is more common at the secondary level, the NSF statistical survey revealed that 26 percent of the level 10-12 science classes and 38 percent of the level 7-9 science classes do not have laboratory activities as often as once a week (Weiss, 1978, p. B-62).

In some schools, this reduction in "hands-on" learning experiences can be attributed to a lack of laboratory facilities and equipment, since the diminishing proportion of school district funds allocated to instructional supplies and equipment is causing critical shortages of laboratory apparatus in many school systems. This problem has been exacerbated by the termination of categorical National Defense Education Act support for the purchase of science equipment and the improvement of laboratory facilities. The NSF statistical survey revealed that shortages of science supplies and equipment were identified as a major problem by over one-third of the secondary school science teachers and by over half of the elementary teachers of grades 4-6 (Weiss, 1978, p. 135). The situation at the elementary level is encapsulated in this comment by a science coordinator quoted in the NSF case studies:

> Even though state law says teach science as a lab science, with so little money you have to teach it from the textbook. At the elementary level many teachers cannot teach science and many do not try (Stake and Easley, 1978, p. 13:61).

A second factor which must be considered as a possible cause of the infrequent use of laboratory instruction is the decreased opportunities during recent years for teachers to attend NSF institutes focused on specific laboratory-centered courses. The NSF statistical survey indicated that science teachers who had attended one or more NSF-sponsored institutes were considerably more likely than other teachers to be using manipulative materials once a week or more (Weiss, 1978,

p. 107). Because laboratory-centered courses are more difficult to teach, the problems which inevitably arise when an untrained teacher attempts to use inquiry-based materials often lead to the adoption of a textbook-centered approach which makes fewer demands upon the teacher.

However, even if teachers have been adequately trained and provided with sufficient laboratory equipment and supplies, forces still remain that tend to discourage placing an emphasis on hands-on learning experiences. The educational climate in the schools, with the current focus on accountability schemes and basic skills, has tended to attach great importance to student performance on standardized achievement tests or criterion-referenced competency tests. Because complex ideas and relationships are difficult to test in a multiple-choice format, a heavy system-wide emphasis on multiple-choice testing has the unfortunate result of elevating the importance of simpler and less meaningful instructional objectives and of diminishing the importance attached to the learning of concepts and relationships.

Teachers and principals are under pressure to allocate more and more instructional time to the kinds of achievement measured by the tests, and to neglect those aspects of student learning that are not so well measured by the tests. Principals and teachers who advocate learning through experience find little to sustain them in such an environment.

The Educational Climate in the Schools

The diminished emphasis on laboratory instruction and learning through experience is thus indicative of a more pervasive problem in the nation's public schools. The whole climate under which teachers are working is less favorable to the pursuit of excellence than it was in the latter part of the 1950's and most of the 1960's.

Science and the development of critical thinking skills in social studies and mathematics have assumed a low priority in the thinking of school administrators. An increased emphasis on the "basic" learning skills, such as reading, arithmetic, and spelling, is preempting time previously available for the study of science, social studies, and mathematical concepts, especially in elementary schools. The NSF case studies observers found that in most schools natural sciences, mathematics other than basic arithmetic, and social science inquiry were seen as having a rather limited value for the student body at large, and that providing a strong K-12 program in science for those students who will become the nation's future scientists was not a high priority in most school systems (Stake and Easley, 1978, p. 12:1).

The NSF case studies observers also found much apathy among students. In some schools, a lack of academic motivation was revealed by low attendance rates and the refusal of many students to attend school on a regular basis. Other students displayed their apathy towards school through passive noninvolvement in classroom activities. After budget problems, the problem most frequently cited by public school teachers was student apathy, lack of motivation, and absenteeism (Stake and Easley, 1978, p. 18:89).

The NSF case studies described many of the schools as not being intellectually stimulating places in which to work. Few school principals have a good academic background in science or mathematics; this makes it difficult for them to help teachers to develop effective science and mathematics instructional programs. School administrators have increasingly had to become managers and interpreters of the school bureaucracy, rather than educational leaders. School system superintendents, primarily preoccupied with the details of institutional management, are not acting as educational spokesmen, but instead are responding primarily to perceived community and governmental pressures.

This is not the set of conditions one would choose as the environment in which to mount new efforts to improve science and mathematics education. However, many opportunities remain to cooperate with that nucleus of teachers who retain the spirit of the course content improvement program and to expand their numbers. Many teachers would take advantage of a revived program of NSF institutes and many say that they want access to knowledgeable resource people who can help them with their teaching problems in science and mathematics. Scientists and research scholars in all fields need to address this problem, and to find ways in which they can cooperate to provide the educational leadership that is so critically needed.

THE CURRENT NEED

That volunteer citizen initiative can secure substantial and constructive change in the classrooms of America was generously demonstrated by the impact of the National Science Foundation's Course Content Improvement Program. Some 53 different curriculum-development projects were carried through by volunteer groups of university scientists and experienced teachers. Beginning with the Physical Sciences Study Committee of 1956, the effort spread to the life sciences, chemistry, mathematics, and the social sciences, principally for the secondary school years but also including new programs and materials for the elementary grades. By the mid-1960's, improvements in the preparation of entering freshmen compelled upgrading of the science curricula in the colleges. In 1978, nearly a decade after the main initiative had been spent, more than half the high-school science teachers surveyed were still using "at least one" of the materials thus developed, as were 22 percent of the teachers in the social sciences and 11 percent of the teachers of mathematics. The cumulative cost to the taxpayer of this movement in American education came to just under $1 billion, most of it spent for teacher institutes that brought teachers back to college for refresher courses in their subjects as well as introducing them to the new curricular materials. It would be difficult to find a better bargain in the federal government's shopping list over the past quarter century.

The effort that started in the 1950's was motivated by fear that the United States was falling behind in international competition and by the conviction that it was necessary to increase the number of young people preparing for careers in science and technology.

Now, the disarray in American elementary and secondary schools again asks for the concern and the constructive intervention of all responsible citizens. Much evidence indicates that far too many young men and women are leaving high school with less than adequate capacity to read, write, and do simple arithmetic. Such findings have enlisted many citizens and educators in a nationwide "back to the basics" movement, with a resulting narrowing of the educational program in schools all across the country.

From the preoccupation of the popular culture with the paranormal, the psychic, the mystic, and the occult, it is apparent that an alarming number of American adults cannot tell sense from nonsense. Mathophobia and the associated incapacity to make rigorous quantitative connections and distinctions afflicts altogether too large a fraction of the adult population. In the context of single purpose pressure groups in contemporary politics, wishing displaces thinking; none of these groups accepts the real-world constraint that allows the attainment of each good only in a trade-off against some other good. The American people share no common body of knowledge and understanding on which to ground a reliable consensus on such urgent public issues as energy and the arms race. Too many Americans find themselves coping with life in today's largely man-made environment with relatively as much ignorance and superstition as forerunners in the pristine environment of nature.

The situation argues for literacy in science as an objective of American education fully as urgent as basic skills in the three R's. An educated citizen ought to have not only a general acquaintance with contemporary knowledge about inanimate and living nature but, more important, a disposition and capacity to frame questions and find answers. One must be able to recognize relevant evidence, make quantitative assessments of rate and scale, and think in rational accordance with objective reality. Some methods of teaching science can contribute to the development of this kind of critical, rational approach to problems; and a reasonably accurate but not detailed understanding of major scientific principles and of the methods and limitations of scientific work -- what we here call scientific literacy -- can help one to understand and cope with many types of problems.

To assert the priority of scientific literacy is not, therefore, to attempt to impose upon American education the aims of yet another single-purpose pressure group. On the contrary, it is a call on American society to redeem its promise to its children: that is, to fulfill their right to the best education society can provide.

That right is implicit in the very institution of democratic self-government. A self-governing society must be made up of self-governing citizens. What is wanted in the citizen is autonomous intelligence, disciplined to seek and face the truth, and capable of the independent judgment that stands up both to wishful thinking and to arbitrary external authority.

The liberating objective of scientific literacy cannot be accomplished by a one-time effort, not even one as prolonged as the course content improvement effort. What is required is the permanent, sustained, and increasing commitment of the American scientific community to enlarge its presence in the nation's classrooms. A practical and feasible program to this end, one that will reach a substantial and reasonable number of classrooms and children in a reasonable time, is spelled out in what follows.

There is not now as much public interest in improving the quality of education as there was during the early post-Sputnik years and many scientists may now be less willing to take time away from their regular duties than were eager to volunteer in the 1950's and 1960's. Even so, we expect that university and industrial scientists and engineers, and others qualified to help, will make themselves available for the effort, which will range from curriculum development, to the instruction of classroom teachers, to the development of regional resource centers, and to helping teachers in the classroom. That such talent and time are available, providing there is assurance the effort can be effective, was demonstrated by the story of the science-curriculum reform movement of the 1950's and 1960's.

It is also expected that the National Science Foundation will correspondingly restore elementary and secondary science education to its priorities, and will have funding available to respond to proposals, subject to the usual critical standards of peer review. Additional funding will be necessary from other sources, for while NSF can be a leader, it should not be expected to provide all of the necessary money. We make no estimate of the total cost of the following recommendations. Those costs will be variable, depending upon how widely the recommendations are adopted. But even at full implementation, annual costs would be substantially less than one percent of the $100 billion per year that federal, state, and local governments now spend on elementary and secondary education.

RECOMMENDATIONS

Rationale

The Panel's recommendations are based on three considerations:

- An analysis of the alternative goals of pre-college education in science and mathematics.
- Lessons learned from experience with the new courses and curricula of the 1950's and 1960's.
- Evidence from teachers as to what they need in order to teach more effectively.

The Goals of Science and Mathematics Education

There are four main goals for the teaching of science and mathematics:

1. Knowledge is a value in itself. It need serve no immediately useful purpose other than to expand the world view of the individual learner.

2. Knowledge may be useful by helping the individual to live in greater health and happiness, and even to survive better in a competitive society.

3. Important economic and social values are involved. Citizens with knowledge of science and mathematics are necessary for a healthy economy and for future progress; and intelligent action on many public issues depends upon understanding their scientific and technical content.

4. The education may be preparatory to a professional career in science or one of the technical professions.

The major NSF-supported curriculum studies were initiated primarily to deal with the fourth goal, to help increase the nation's scientific manpower. Because there were at the same time a number of other measures to that same end, it is impossible to say just how much the Course Content Improvement Program contributed to the growing numbers of scientists and engineers. But it is clear that their number did increase greatly and that the new courses developed under NSF auspices did provide improved learning materials for a significant number of students who were interested in careers in science and mathematics. Moreover the high visibility of the new courses drew added attention to their disciplines.

Because the new curricula were designed for precollege students, and especially for high school students, they could only be introductory, and not fully professional. Thus for a large group of students, including many who were not headed toward scientific or technical careers, they served the other goals as well. They did so to varying degrees.

The first goal -- learning for the sake of learning -- was met with considerable success. The science curricula were modern, laboratory based, and inquiry-oriented. They were sophisticated and demanded considerable mental work from the student. They were indeed mind-expanding for students who were motivated, able, and disciplined, and who were fortunate in having a skillful teacher and a well-equipped laboratory.

The second goal -- knowledge useful for one's own well-being -- was met less successfully. As an example, the biological sciences can offer much of importance to one's health and happiness: an understanding of nutrition, disease and its prevention, and behavior. Yet the Biological Sciences Curriculum Study courses did not deal with these areas in a substantial manner; there were other messages that seemed more pressing to the authors. A second example is provided by the new elementary school mathematics. It may have introduced young pupils to the field of mathematics in a manner thought befitting by mathematicians, but it did not succeed in encouraging students to become "friendly with numbers" and it left some of them unable to do the simple calculations of adult living.

The third goal -- an informed citizenry -- was probably the least successfully met. It is unquestionably difficult in one school year to give students an understanding of the basic scientific concepts in a field and also to provide enough relevant information to enable them as future citizens to deal intelligently with difficult political, economic, and social issues. But progress can be made; students can begin to develop critical standards that will help them to sort out and appraise the technological claims and advice they receive through the popular media. This task has not been given sufficient attention in past curriculum development efforts and needs to be readdressed.

In summary, goals two and three -- knowledge useful for one's own well being and knowledge useful for good citizenship -- now need more emphasis than they received in the 1950's and 1960's.

Lessons of the Past

In planning future programs, we should take advantage of the experience of the past two decades of curriculum reform. That experience has demonstrated that even the best curriculum materials will not be adequately utilized unless attention is paid to the following issues:

1. Teachers must be provided opportunities and incentives to acquire the comprehensive training necessary for the successful utilization of the new materials and techniques.

2. Principals should be provided opportunities to gain understanding of the new programs, for they are key agents for educational change or for maintaining the status quo.

3. New course materials should be introduced in a fashion that encourages honest exchange of views between teachers and the exponents of curricular innovation.

4. Mechanisms of long-term materials support must be established so that teachers can obtain the instructional materials and apparatus needed for the new courses. In the past, obtaining materials has presented a serious obstacle to the successful adoption of elementary science programs, for many of those programs utilize a large variety of expendable materials. Although commercially-prepared kits have been purchased by many school systems, elementary teachers, in particular, have found it difficult to order in advance all of the materials required to refurbish those kits so they may be used again.

5. Resource personnel should be available to provide continued expert advice and moral support to teachers and principals when problems arise. The three NSF studies indicate that most school systems are not sufficiently staffed with supervisory personnel to perform this task. Such supervisory personnel as exist are usually so fully occupied with administrative functions that they seldom have opportunities to work with the large numbers of teachers for whom they are responsible.

What Teachers Need

Many teachers want help. They want to teach more effectively. They want better equipment that will help their students learn from observation, manipulation, and trying things out -- from educative experience as well as from reading and discussion. They want to strengthen their own understanding of science and mathematics. And they want access to experts to whom they can turn for help on their teaching problems (Weiss, 1978, pp. B-93-B-116; Stake and Easley, 1978).

The percentages of teachers expressing each need varied considerably, depending on the subjects taught and the age level of the pupils involved, but in total, large numbers of teachers said they wanted improvement in each of the following areas:

- Opportunities to learn about new teaching materials.
- Access to current information in their fields.
- Opportunities to learn new teaching methods, especially regarding the use of "hands-on" materials and the implementation of the discovery or inquiry approach.
- More permanent equipment, such as microscopes or balances, and better maintenance of equipment.
- Ability to get consumable supplies such as chemicals, dry cells, and duplicating masters quickly and as needed.

* * * *

The teachers who want these improvements are to be found in many school systems. They are sometimes a minority within their own school system, but in total, there are many of them. Because the teachers who want these kinds of help are widely scattered and because no central education authority exists under the American system, the remedies have to be decentralized. Because the kind and amount of help teachers want or are able to accept varies, delivery has to be on a basis of voluntary participation.

Thus, what seems to be called for is not a uniform and centrally planned revision of the whole school system or a set of uniform changes, but rather a set of opportunities that can be grasped by those teachers who are eager to improve. Because not all teachers will want to take advantage of such opportunities, the recommendations involve services that can be made available to motivated teachers regardless of what their immediate colleagues or the teachers in neighboring systems decide to do. If these recommendations are put into effect, many teachers will be helped, and their pupils will reap the benefits of better education in science and mathematics.

Science and Mathematics Teaching Resource Centers

The findings of the three NSF studies indicate that teachers, principals, and superintendents all attest to a need for more assistance with the local implementation of course improvement programs in science and mathematics. Such assistance could be best provided by creating a network of science and mathematics teaching resource centers throughout the nation. These centers could provide a variety of supporting services to science and mathematics teachers who want to improve their teaching. The centers could conduct in-service training programs based upon locally identified needs; provide low-cost kits of science and mathematics instructional materials to teachers from participating school systems; and provide expert resource personnel to help teachers learn to utilize new science and mathematics instructional materials and techniques.

Two successful prototype science teaching resource centers already exist in the United States. In Spencerport, New York, the Science Center for Instructional Materials and Processing (SCIMAP) is currently serving approximately 1,000 teachers and 25,000 elementary school students in the Genessee Valley. The SCIMAP assembles elementary science kits and sponsors in-service training workshops for teachers from 17 small independent school districts. The SCIMAP operation is one of the services provided by the Board of Cooperative Educational Services of Monroe-Orleans Counties, New York. Participation in the SCIMAP science programs is voluntary; financial support is derived from the local participating school districts and the New York State Department of Education, with the state paying the larger share.

A larger Science Materials Center was established in 1970 by Lawrence Watts, Superintendent of Schools of Fairfax County, Virginia. The Fairfax resource center is operated and supported by the Fairfax County School System (the twelfth largest school system in the nation). It provides teachers with a variety of in-service training programs and with classroom kits of science teaching materials, beginning at the kindergarten level and extending through high school. At the elementary school level, it provides science kits and teacher training services for 2,400 teachers and 60,000 children.

Similar large-scale prototype support centers do not currently exist for mathematics teachers. However, because the problems of in-service training and instructional materials are similar in science and mathematics, it seems likely that a joint effort would be feasible.

One of the functions of the science and mathematics teaching resource centers would be to provide in-service training for teachers of science and mathematics in response to needs identified by local school systems. At the elementary school level, such locally-based teacher-training efforts are urgently needed if significant improvements are to be made in the teaching of science and mathematics.

Past efforts to institute significant improvements in science and mathematics curricula at the elementary level have often foundered, due to seemingly unmanageable problems of scale. Although it was possible to retrain a significant fraction of the nation's 15,000 high school physics teachers by holding summer institutes for several years at several universities, it has not been practicable to set up institutes to train over 1 million elementary teachers. Strategies involving the training of a token number of elementary school teachers during summer institutes, with the hope that they would return to their school districts to "spread the word", were at best wishful thinking.

The three NSF studies indicate that a much greater teacher-training effort will be needed if significant improvements in the teaching of elementary school science and mathematics are to be achieved. The large number of elementary school teachers who must be reached points to the need for developing locally-based institutions which could focus on this task. The proposed science and mathematics teaching resource centers could assess local needs by arranging periodic meetings with key teachers, principals, and curriculum supervisors; organize meetings of parents and teachers to discuss recent developments in the teaching of science and mathematics; provide in-service workshops on science and mathematics instructional programs and methods; enlist the help of experts to speak on topics of special interest to teachers; and arrange for staff members to visit local schools periodically to ensure close communications with schools served by the centers.

A second important function of the proposed science and mathematics teaching resource centers would be to provide low-cost kits of science and mathematics materials to teachers from participating school systems. The need for this service is especially great at the elementary school level, since most elementary schools are poorly equipped to teach science and mathematics.

It is generally agreed that science and mathematics at the elementary school level are best taught through the utilization of concrete "hands-on" experiences to develop key concepts (Hausman, 1976, p. 13; National Advisory Committee on Mathematical Education, 1975, p. 18). However, the logistics of supplying "hands-on" instructional materials to elementary school classrooms on a large scale has presented a serious obstacle to the implementation of activity-centered programs in both science and mathematics. Most school systems have not been able to develop effective mechanisms to supply instructional materials other than textbooks to elementary school classrooms. The problem has been one of scale, and also of costs. Even though the developers of the elementary level course content improvement programs usually attempted to make use of materials that would be relatively inexpensive to purchase, the marketing costs associated with the commercial production of elementary science and mathematics kits has raised the price to a prohibitive level for many school systems.

Another obstacle has been the problem of maintaining kits of instructional materials in a ready-to-teach condition after their initial purchase. Because significant amounts of expendable materials are frequently used in many of the new programs, some provision must be made to refurbish the kits each term; both to replace the expendable items and to inventory, clean, and repair non-expendable items.

The two existing science resource centers in New York and Virginia have demonstrated a practical solution to these problems. Personnel at these centers manufacture most of the science apparatus used in the elementary schools. These pieces of science apparatus, as well as packages of expendable materials, are assembled into kits that are loaned to teachers at participating schools. Considerable cost savings result from employing high school students to carry out many of the manufacturing operations necessary to assemble simple elementary science and mathematics apparatus, such as microscopes, balances, circuit boards, and trundle wheels. Additional savings are made by purchasing supplies in bulk, directly from manufacturers, and by reprocessing kits of instructional materials after each use so that they can be used by several elementary school classes each year.

Even when overhead and administrative costs are included, the science kits produced by these centers cost substantially less than those available from commercial suppliers. For example, a "Small Things" microscopy kit for a class of 32 students cost the Fairfax Science Materials Center $68 to prepare, compared with $202 for the least expensive commercial version. A large part of this saving resulted from the use of a simple elementary microscope manufactured by the Fairfax Center at a cost of 52 cents. (Seven thousand of these simple microscopes were manufactured by high school students during two summer vacations.) The least expensive comparable microscope available from commercial suppliers would have cost over four dollars. In total, the first 4,000 science kits produced by the Fairfax Science Materials Center cost the school system $211,000 instead of the $420,000 they would have cost commercially.

An added benefit can accrue by linking the provision of instructional materials support to the in-service training provided by a science and mathematics teaching resource center. Although past experience suggests that in-service training programs are most effective if teacher participation is voluntary, it is feasible to limit the availability of some kits of instructional materials to teachers who have attended an in-service training workshop designed to acquaint them with the effective use of the materials in the kit. Such an arrangement can help motivate teachers to become involved in in-service training programs who would not otherwise respond to appeals to upgrade their teaching skills. In addition, teachers often adopt a more serious attitude toward the utilization of new instructional materials if they must make an effort to qualify to receive them.

Although most essential for the elementary school level, similar teacher-training and materials-support services would also be of considerable assistance to junior high school science and mathematics teachers. After the elementary school teachers, junior high school teachers comprise the group which is most numerous and least adequately prepared to teach science and mathematics.

The science and mathematics teaching resource centers could also help improve the quality of teaching at the secondary level, both by working within the constraints of existing curricula and by providing opportunities to acquaint local decision-makers and teachers with the options available for improving the curriculum. The resource centers would provide an ideal site for the introduction, adaptation, and dissemination of supplementary science and mathematics teaching materials. It might also be possible for the resource center to collaborate with university science faculties to sponsor summer institutes for science and mathematics teachers that would be closely tied to the needs and interests of local school systems.

Initially, a limited number of prototype centers might be started in locations where the essential local cooperation and support could most readily be found. It might be possible to attach some such centers to existing institutions, such as science and technology centers or universities. However, because some teacher-support institutions established in the past have become bogged down in bureaucracy and enmeshed in struggles over control, it will be important to plan the science and mathematics teaching resource centers so as to lessen the probability of such problems ensuing.

Due to declining enrollments, school systems in many parts of the country have space in school buildings that is no longer needed for classroom instruction. It might be possible to locate some science and mathematics teaching resource centers in such unused space. However, it is important that a resource center be independent of day-to-day school system management concerns, so that it can concentrate entirely on serving the teacher-support purposes for which it is being established. Ideally, a science and mathematics teaching resource center should be a quasi-independent, cooperative enterprise, governed by a board with representation from local participating school systems, and the local university and industrial scientific research community.

In areas with many small school systems, a science and mathematics teaching resource center might be operated in conjunction with the other services sometimes offered by an "intermediate school district", such as the Boards of Cooperative Educational Services that exist in New York State and the SCIMAP center in Spencerport, New York. Eventually, it would be advantageous for groups of resource centers to be loosely associated into regional networks which would allow them to share capabilities and to undertake collaborative efforts.

The findings of the three NSF studies suggest that the proposed science and mathematics teaching resource centers would be enthusiastically supported by teachers, principals, and school system superintendents. Each new center would create a focus for the professional development of teachers; establish a mechanism by which teachers could have a voice in curriculum and materials design; and provide them with innovative instructional materials and moral support.

RECOMMENDATION 1: We recommend the establishment of a number of science and mathematics teaching resource centers, each to serve a large school system or a group of neighboring smaller systems. Each teaching resource center would offer some or all of the following services:

In-service training programs related to the science and mathematics courses being taught or to be introduced in the school systems involved.

Construction, maintenance, repair, and distribution of kits of materials required to teach those courses.

Expert advice to teachers to help them learn to use new science and mathematics instructional materials and techniques, and to help them with their individual teaching problems.

This recommendation is addressed to individual school systems and clusters of neighboring systems, since such a resource center will be unlikely to succeed unless the local community wants it to succeed. Money, of course, is also needed. The resource centers in Genessee Valley, New York and Fairfax County, Virginia operate their science materials support programs for elementary schools at a yearly cost of four to six dollars per student, depending upon the grade level and the number of new science units that are introduced in a given year. This cost represents less than one-half percent of the total annual per pupil operating cost. Nevertheless, for 25,000 pupils an annual outlay of $100,000 to $150,000 would be required. Most of this cost should come from local school budgets, and we hope enough communities will develop teaching resource centers to give the idea a thorough testing under a variety of community and organizational patterns.

However, federal assistance to help with the initial costs of establishing and outfitting resource centers will be needed to encourage a substantially larger number of school systems to establish such facilities. Such centers should also be eligible for federal support for special programs, such as institutes or other special in-service teacher training programs. Continuing operating costs, however, should come from local resources and should be considered as a part of the normal cost of operating the school system.

New Courses and Learning Materials

The continued advance of human understanding on the frontiers of science requires continued revision and development of the science curriculum. The yield from research is not new "information" to be packed into young heads; it is, rather, changes in understanding. Better understanding sometimes requires not a new chapter in a textbook, but new textbooks and new ways of teaching. That task calls for the continued engagement of university scientists; through their collaboration with teachers, the linkage of primary source to the classroom can be most directly made.

A continuing program of improvement is also desirable in order to do better what we tried to do before, but in a first effort did not know how to do very well. Funding agencies need to pay special attention to the following needs:

1. The new math did not work out satisfactorily in elementary schools, but the current reemphasis on building skills in the four basic operations of arithmetic is not satisfactory either. Most elementary school children not only continue to learn primarily computational arithmetic, they continue to be taught by rote with the same lack of emphasis on logical thinking that has already produced large numbers of adult mathophobes.

The NSF case studies reported little evidence of the use of hands-on materials and found that fun and excitement were absent from almost all elementary mathematics classes. Although it is now generally accepted that firmer mathematical foundations are laid if children's numerical thinking is closely related to concrete perceptual experiences, elementary mathematics programs with such an emphasis are not common in elementary schools in the United States.

Clearly, a renewed effort to improve the teaching of elementary school mathematics is a high priority need. However, in initiating new projects, great care needs to be taken to learn from the mistakes of the past, so as to develop elementary mathematics materials that can be readily understood by teachers and parents as well as students.

2. Well-intended efforts to make education "relevant" by developing totally new multidisciplinary or problem-centered courses have not been very successful due to the reluctance of schools and school systems to make radical alterations in the core curriculum. The NSF statistical survey found that, at the junior high school level (grade 7-9), four fairly traditional fields accounted for 86 percent of the science classes -- general science, earth science, life science, and physical science. Similarly, general mathematics and algebra accounted for 87 percent of the junior high mathematics classes. In grades 10 through 12, biology, chemistry, and physics comprised 74 percent of the science classes, and algebra and geometry more than two-thirds of all mathematics

classes. (See Tables 5 and 7.) Although these are the science and mathematics courses most commonly taken by secondary school students during the past decade, a disproportionately small percentage of the financial support has been allocated for their improvement. In the future, greater relative emphasis should be given to improving the courses that are taken by the largest numbers of students.

3. More attention needs to be focused on the development of science and mathematics materials appropriate to the needs of the average student, as distinguished from those students who are preparing for careers in science. In the past, it has been difficult for some course developers to appreciate the fact that not all students are interested in science for its own sake. Some courses have emphasized topics and activities that were of marginal interest to the average student.

Although it is not proposed that developers cease trying to involve students in the intrinsic delights of the pursuit of scientific knowledge, in the future an effort should be made to develop some course materials that have greater appeal to students who are not intensely interested in science.

The problem is particularly acute at the junior and senior high school levels, where there is a current need for a junior high school applied physical science course, an activity-centered earth science course appropriate to the abilities and interests of the average ninth grader, and a general education chemistry course that is less mathematical than CHEM Study or CBA chemistry.

The second and third goals of education stated on page 41 are knowledge for personal satisfaction and benefit, and knowledge for good citizenship and intelligent dealing with social issues that have a technical content. Courses aimed toward these goals are often more difficult to develop than are courses directed primarily toward knowledge as an end in itself, and many scientists are not as comfortable in trying to develop or teach them. In planning such courses, delicate steering is necessary to avoid the levels of rigor and scientific sophistication that scare some students away, and at the same time to avoid the mushiness of courses that are about but not of science, or that treat only the social aspects of a topic without giving students a better understanding of the underlying processes and principles. Developing courses to meet the second and third goals is not easy, but we think the effort is very much worth continuing.

4. There is a continuing need for the development of supplemental materials for the teaching of science and mathematics at all levels of the curriculum. Such supplemental materials can provide a focus for efforts to improve teaching, draw the attention of teachers to new ideas and teaching techniques, and serve as vehicles to add more timely and exciting activities to existing courses.

A need also exists to explore alternative mechanisms for distributing low-cost supplementary resource materials for teachers, such as resource guides, learning games, duplicator and transparency masters, and booklets for students on topics of special interest. Because supplementary materials for teachers comprise a relatively small market as compared to textbooks, their production is often not economically attractive to commercial publishers. Several branches of the federal government, including the Department of Energy and the U.S. Geological Survey, are already publishing resource materials for teachers in specialized fields. Consideration should be given to the utilization of this mechanism for the dissemination of some of the supplementary materials produced with National Science Foundation support. If such materials were to be placed immediately in the public domain, even wider distribution could be accomplished through local reprintings at regional science and mathematics resource centers.

Major curriculum development requires public funding for the familiar reason that the profit margins of textbook publishing do not generate the necessary capital. History shows that the inertia of the country's vast, pluralistic, independent, locally controlled school system, taken together with the high risk and intense competition in educational publishing, has tended to inhibit innovation and to promote uniformity at a safely mediocre level in the quality and content of textbooks and other materials sold by the textbook industry to the schools. Although many publishers were initially worried about "government interference", the responsible leadership of the industry came to welcome the curriculum-reform movement and to conclude that they, as well as the schools, had benefitted from it (BCMA Associates, 1975).

The NSF-supported curriculum-reform enterprises not only supplied fresh materials directly to the publishers that took over the distribution of their product but also made market breakthroughs that were sufficiently successful to stimulate competing publishers to update the content and enhance the appeal of their offerings.

This successful model of curriculum development needs to be revived and continued. The earlier effort was successful, in part, because the shock of Russian achievement in space motivated many able and prominent scientists to devote much attention to improving precollege instruction. There is now no single motivating factor comparable to Sputnik. But there is another kind of motivation to reinforce a sense of public duty: many scientists are greatly dissatisfied with the education of their own children.

> RECOMMENDATION 2: We recommend continuation and increased support for the NSF programs of funding the design, experimental testing, and revision of new courses or curricula in science and mathematics and their associated teaching and learning materials.

The cost of this recommendation will be of the order of $15 to $20 million a year, and should be provided by the federal government. During the 1960's, 77 elementary and secondary school curriculum projects cost a total of $93.8 million, or an average of $1.22 million each (National Science Foundation, 1970). They varied substantially in size and scope; some of the larger projects cost about $5 million each. If emphasis is placed on the core subjects that are taken by the largest numbers of students, if each of these courses is revised every five to ten years, and if there are always two or three alternative programs for each subject, one can estimate that some six to eight new projects would be started each year. At the average cost of the 1960's, corrected for inflation, we arrive at a figure in the $15 to $20 million a year range.

Institutes for Teachers

The new courses developed under NSF auspices are not as widely used as they were a few years ago (Weiss, 1978), and the learning techniques that characterized many of those courses -- the inquiry approach, hands-on student experimentation, and student-initiated discussion -- are not in common use in most schools (Stake and Easley, 1978).

There are probably several reasons for this situation. Certainly part of the problem is due to the fact that only short-term teacher-training efforts were made to solve long-term problems. Several studies have indicated that the NSF Institutes held prior to 1970 were generally successful; teachers who had attended such institutes were more likely than other teachers to be using curriculum materials developed with NSF support, to be emphasizing laboratory activities, and to be stressing a pupil-centered approach (Schlessinger, Howe, et al., 1973, p. 149). Nevertheless, in Fiscal Year 1971, NSF negotiations with the Office of Management and Budget resulted in a reduction of over one-third in funds for teacher-training institutes (from 33.1 million dollars to 20.1 million dollars). In explaining this change in priorities in 1971, Dr. William McElroy, the new NSF Director, stated:

> Up to now we have put roughly $460 million into the summer institutes for high school teachers and we think we have reached the maximum benefit from this approach. We think it is time to turn around and reexamine our whole approach... The major cutback is in summer institutes for high school teachers...40 percent of our high school teachers have now participated in one or more of these. Unfortunately, we don't have, but hope to know by the end of the year, how much further we can really go in reaching the football coach who is assigned to teach biology at the high school level (Crane, 1976, pp. 145-146).

As it turned out, the issue was not so much how to reach the "football coach who is assigned to teach biology" as it was to give the new teachers who continued to enter the schools an understanding of the specific content, rationale, and techniques required to teach the improved core curriculum courses developed during the previous fifteen years.

Each year, the schools have a significant turnover of science and mathematics teachers. In 1971, the average teaching experience of secondary school science teachers was between 10 and 11 years (Schlessinger, et al., 1973, p. 103). In recent years, this figure has increased slightly; in 1977 the NSF statistical survey found an average of 11.5 years of experience for mathematics, science, and social studies teachers, with no great differences among the three subject areas (Weiss, 1978, p. 137). Many of the 40 percent of the teachers who had attended NSF institutes prior to 1970 are no longer teaching.

Although declining school enrollments have now slowed the hiring of new teachers, declining enrollments have created new problems. When lay-offs are necessary, younger teachers with little seniority are the first to be terminated; they are often replaced by teachers with more seniority who have been transferred from other disciplines. In 1977, 13 percent of the secondary school science teachers in the nation were teaching courses they did not feel adequately qualified to teach (Weiss, 1978, p. 144).

For example, it is not at all unusual to find a former chemistry or biology teacher with no academic background in earth science assigned to teach that course. In such situations, teachers often abandon the more rigorous course materials in favor of alternative texts that stress reading about science, and place fewer demands upon the teacher. The classrooms of these teachers are generally distinguished by a lack of emphasis on laboratory work and a preoccupation with answering the questions at the end of each chapter.

Unfortunately, adequate opportunities have not been provided during the 1970's for retraining teachers who have been transferred to new fields. The 1971 reduction in funds for teacher institutes described by Dr. McElroy was followed by further reductions, and in 1975 all funding for NSF teacher training programs was suspended. In 1976, Congress restored $4 million for teacher institutes but restricted its use to institutes that are disciplinary in nature and not integrated with course development efforts. These are institutes of the original kind, those intended to help teachers learn more chemistry, more mathematics, or more of some other subject they teach. Although there has been some dissatisfaction with the extent to which these institutes actually increased the scientific knowledge of teachers attending them, there has been general approval of the objective.

Much more controversial has been a second type of institute. As new courses and materials were prepared by some of the curriculum projects supported by NSF, it seemed desirable to give teachers of those courses special training not only in the subject matter but also in methods of handling the laboratory and other special materials used in the new courses, and in how to use the discovery or inquiry method of teaching that some of these courses emphasized.

The second objective has been both confused and criticized. The purpose has sometimes been described as stimulating the adoption of new curricular materials that had been developed with NSF support, and when so described has been justified as increasing the effectiveness of the courses developed under the NSF Course Content Improvement Program. At other times, however, the same effort has been criticized as improperly interfering with course selection decisions that should be made at the local level. These course-specific institutes have also been charged with being unfairly competitive with private textbook publishers who do not have funds to support teacher training institutes.

Although both of these issues have been overemphasized in recent years by some members of Congress, there have been few complaints from publishers or school district officials. A 1975 report on the elementary and high school publishing industry indicates that, although the publishing industry was apprehensive twenty years ago when the NSF Course Content Improvement Program was initiated, most publishers now appreciate the need for course-specific institutes. The report explains:

> [Publishers] may not be equal to the challenge of new curriculum materials with their new approaches to teaching and learning and with content frequently not included in the teacher's undergraduate and graduate curriculum. The publishers' efforts to expand implementation beyond their present efforts is limited by the money available in school budgets. Many publishers are convinced that the programs they develop with a heavy investment of their own funds, as well as the programs developed by Study Groups and Councils, do not always live up to expectations because of the cost limit imposed on implementation (BCMA Associates, 1975, p. 21).

Moreover, the spectre of interference in local curriculum decisions is dispelled by the endorsement of NSF activities by many school superintendents. The NSF statistical survey found 58 percent of the superintendents agreeing that federal support has improved the quality of curriculum alternatives available to schools, 66 percent believing continued federal support for curriculum development to be necessary, and 77 percent believing that NSF should continue to help teachers learn to implement NSF-funded curricula (Weiss, 1978, p. 76).

Several changes in NSF policy had the effect of depriving many teachers of contact with the individuals who were most knowledgeable and most committed to the successful utilization of the new materials in the core areas of science. These changes included NSF's reluctance to fund teacher-training efforts by the groups responsible for developing the new materials; termination of some of the projects in the core areas before their fruition; and a switch in emphasis from the core subjects to interdisciplinary approaches and social studies. During the period when the largest numbers of teachers finally began to use the core curriculum materials developed with NSF support, most of the curriculum project personnel were dispersed, and could no longer respond to the problems encountered by teachers. This discontinuity also prevented project personnel from becoming significantly involved with the very real problems of large-scale course implementation; such experience could have provided the basis for substantive improvements in later revisions of the course materials.

Although there can be no substitute for subject-area competence, the NSF statistical survey revealed that large numbers of teachers indicated a need for additional assistance in obtaining information about new instructional materials (43 percent), learning new teaching methods (43 percent), implementing the discovery/inquiry approach (36 percent), and using manipulative materials (33 percent) (Weiss, 1978, p. 147). The dicipline-centered institutes that are now authorized may be able to meet some of these needs in addition to increasing teachers' knowledge of the discipline involved. But past experience has shown that there is no such thing as a "teacher-proof" curriculum. Unless adequate teacher training programs are provided when new courses are introduced, very little change occurs in the classroom save the substitution of one textbook for another.

Most of the major curriculum development groups have stressed that the approach used by teachers in the classroom is as important as the new course materials. Some projects have stressed that the success of their materials in the classroom is critically dependent upon the adoption of a new role by the teacher. Teaching science or mathematics with an emphasis on the quality of children's thinking is an alien experience for many teachers, and is not an easy task for anyone. Teachers who are not convinced of the need to change their approaches to teaching can and do sabotage even the best of the new programs.

The NSF case studies suggest that considerable attention needs to be given to the development of strategies to help teachers cope successfully with the practical problems created by the introduction of new teaching approaches and materials into their classrooms. Substantive and long-term teacher-training efforts are needed, both to update teachers' understanding of science and to address the specific problems and challenges that the new courses generate, such as the use of the inquiry approach, the development of questioning techniques that focus on the quality of a student's thinking, the management and use of manipulative materials, the orchestration of a multi-media approach, the evaluation of student achievement, and the maintenance of discipline in an activity-centered classroom.

Rarely are these skills adequately mastered in the pre-service education of teachers, partly because teachers usually do not know which courses they will be teaching until they are hired, and partly because theoretical discussions of pedagogy do not seem to have much impact on teachers before they have grappled with the realities of managing their own classrooms. The alternative is more effective in-service training programs, but local school systems do not have the capabilities, resources, or will to assume responsibilities for the in-service training of science and mathematics teachers, particularly at the secondary level. It is therefore important that the National Science Foundation resume support for institutes that can be course-specific, as well as for those that are primarily disciplinary in nature.

The charge of undue interference in local curriculum selection decisions need not arise, for NSF funding of institutes with the original emphasis on the upgrading of individual teachers would allow NSF to remain at arm's length from the adoption of specific programs by specific school systems. After a school system has decided to introduce a particular new program, special training for the teachers is essential regardless of whether development of the new program has been supported with NSF funds.

In addition to in-service training programs for teachers, more efforts should be made to develop summer institutes for elementary and secondary principals, focused on new approaches to the teaching of science and mathematics. Besides making principals more effective, such efforts might also enlist their support in recruiting reluctant teachers to participate in in-service training institutes.

RECOMMENDATION 3: We recommend support of an NSF program of institutes for teachers, both to increase their knowledge of subject matter and to improve their skill in teaching the new courses that will be developed in the future, whether the development of these courses is funded by public or private sources.

Although there has been much testimony to the value of the NSF institutes, it must be acknowledged that the leaders of some of the institutes were disappointed that they were not more effective. In planning for future institutes, attention should be given to overcoming the deficiencies reported in some of the past ones.

At peak level during the latter half of the 1960's, NSF was expending close to $40 million a year to support institutes attended by about 40,000 teachers a year. Nearly 90 percent of the institutes were for high school teachers, and the major cost was for stipends for the teachers who attended summer or year-long institutes. The part-time institutes attended by in-service teachers were considerably less expensive. For the future, there is no "right" number of institutes; the number will be determined by the normal political processes of balancing competing needs and opportunities, but we believe the program should have permanent, continuing status.

Non-traditional Educational Opportunities

Much learning goes on outside of schools and school lessons. The Panel had extensive discussions on only one of the non-traditional educational agencies -- the science and technology centers that now constitute the most rapidly growing segment of the museum world. But two others should be mentioned, for although the Panel did not consider them in detail they will have to be given careful attention in future efforts to improve science education.

One has resulted from recent revolutionary changes in electronic circuitry. The hand-held calculator is used by many thousands of students and teachers, to solve a variety of quantitative problems. Computers of increasing power and decreasing cost have added a new dimension to instruction in a range of subjects. Computer aided instruction has not fulfilled all the hopes of its advocates, but surely is not yet to be dismissed. When and how these powerful tools can most effectively be used in education is a topic of much importance in future studies of science education.

The other is television, which has clearly become an enormously potent force in American society. Most children watch and are influenced by it, and several studies have suggested that by the time they graduate from high school, many students have spent more time watching television than attending school -- 20,000 hours and more.

The Panel noted that in the past, TV science programs have not been popular with children (Holden, 1978) and that even the best programs have not been totally successful, particularly in involving the child actively, instead of as a passive spectator. Nevertheless, a major challenge and opportunity lies in using television, perhaps in unconventional ways, as a tool to improve science literacy. The Children's Television Workshop science series now being developed has attractive possibilities; the Panel would hope other innovative approaches can be found.

It is possible that new and cheaper technology might help in making children more active participants. For instance, it is likely that video discs will soon be available in classrooms so that video materials can be consulted readily and without help from teachers, just as books can now be used. Similarly, cheap hand-held video cameras and recording equipment could allow children to video-record their own science programs, the goal being not necessarily the finished product but rather involvement in the process of program preparation.

Television and the computer have drastically changed most people's lives in the past 25 years. However, the right strategy for their use in education, particularly in science education which depends heavily on active individual discovery and conceptual development, is not evident. Certainly much harm can be done by the misapplication of inappropriate technologies, and the glamour of sophisticated technologies often casts them in the role of a solution in search of a problem. The Panel would hope that in the future the educational value of these technologies will be assessed objectively, giving full consideration to both costs and benefits, so that their most appropriate uses in children's science and mathematics education can be identified.

Science and Technology Centers

Many a visitor has come away from a museum, a planetarium, a zoo, an aquarium, or a science and technology center with a new interest, or an enhanced understanding of some scientific process or phenomenon. These non-formal educational institutions differ in kind, style, and effectiveness, but in communities that are fortunate enough to have them they can be valuable resources to children and adults who want to know more about science and technology.

Their permanent and traveling exhibits and their specialized collections and facilities provide opportunities for experiences that are practically never available in schools. One can watch a polar bear, view science films, get a close-up view of a live octopus, sit in a space capsule, or examine artifacts from early civilizations and other cultures. And in a science and technology center -- much more than in the typical museum or zoo -- one can also manipulate, try out, and experiment with equipment specifically designed to facilitate learning through experience. As compared with school, the learning is less systematic, deliberately less formal, and more dependent on individual initiative and interest. At the same time, the experience can enrich the classroom fare, allow one to go more deeply into an interesting topic, and bring a topic to life through close study and manipulation of specific examples.

These benefits are available to those that seek them. Yet there has been surprisingly little research on what and how visitors to museums, zoos, and science and technology centers really learn. It seems clear that some visitors learn much. And attendance records and the number of repeat visits give evidence that many people value these institutions. The science and technology centers are especially popular; a 1974 survey by the National Endowment for the Arts found 38 percent of all museum visits to be to science and technology centers, as compared with 24 percent to history museums and 14 percent to art museums. Science centers had 36.5 million visitors in 1975 (Kimche, 1977; Roark, 1979).

Because of their popularity and flexibility, science centers can be very important contributors to increased science literacy of the American public. How their programs and exhibits can best contribute to this end is an area of educational research that merits much more effort than it has received in the past.

In addition to their classic, museum-like function of presenting interesting and informative exhibits, many of these institutions offer other educational opportunities. Examples include:

- Special lecture-demonstrations, given to school classes brought to the center for that purpose, or taken to the school by the center staff, together with a van load of demonstration equipment.

- Organized classes, a few hours a day for pre-school children; and short courses on photography, magnetism, geology, computer programming, and many other topics, taught at levels appropriate for designated age groups.

- Guided tours, work on projects that have educational value, a home and meeting place for amateur science clubs, and a variety of other activities, some for particular age groups and some designed to attract whole families.

- Internships for elementary or high school teachers who want to learn more about science education and how to make use of a variety of kinds of equipment, or for prospective teachers during their pre-service education.

Typically, the people who take advantage of any of these opportunities constitute a voluntary, self-selected group; people visit museums and science centers because they want to. Thus the students who make most use of these out-of-school opportunities are likely to be those who are most interested in science, for there they can pursue their interests to greater depth, in new directions, and at their own pace -- all more readily than is usually possible in the more structured atmosphere of the school.

This aspect is an asset that should be preserved, for under current priorities the abler and more highly motivated students are now often given less attention in school than their abilities and their potential contributions to society would warrant. At a science center, they can pursue favorite topics in more depth, work on science projects, and get expert advice more readily than in most schools.

At the same time, because these centers are located in cities, they can also provide inner-city youngsters with better opportunities to learn what the natural world is like than can be offered by the fenced-in blacktop surrounding a city school building. Some centers have already started special programs for this purpose, such as the events sponsored by the Oakland Museum to involve local community members and the "explainer" student intern program of the San Francisco Exploratorium. Science centers can play quite significant roles in providing alternative educational experiences for talented students from inner-city schools who do not have sufficient opportunities in school to pursue scientific interests. This concept will be discussed in more detail later, in the section entitled "The Needs of Special Groups".

In some communities, the local science and technology center may be the best organizational base for a science and mathematics teaching resource center of the type described earlier. A science center provides a degree of independence from the school system itself. The center's staff may include experienced and successful teachers and also practicing scientists interested in improving science education. And it may already have a variety of useful supporting services, such as shops, technicians, and graphic arts facilities. The decision is obviously a local and individual one, for many communities do not have a science and technology center. But in communities in which they do exist, their educational usefulness could sometimes be increased by enabling them to assume the additional role of a teaching resource center.

In a number of communities, the educational value of science and technology centers is already so widely recognized that they are being pressed to do more than can be supported by their over-strained budgets. All of their functions require money, and admission charges are never sufficient to meet expenses. Gifts from private sources or subsidies from public ones are essential. Contributions from business and industry, grants for special projects from private foundations and federal agencies with scientific and technical interests, and the new but still small sustaining grants from the federal Institute for Museum Services are all needed, and all helpful.

In some communities, the school systems of the region have found the local science and technology center to be so valuable that they regularly provide some support from school budgets. This is a relationship to be encouraged, for it gives both sides an on-going interest in developing the most educationally useful methods of collaboration between the formal school system and these non-school allies in improving science education.

> RECOMMENDATION 4: We recommend the development of additional science and technology centers of the kind that now exist in a number of cities. Furthermore, we recommend the strengthening of cooperative arrangements between these centers and nearby school systems to increase the extent to which the centers provide planned supplementation of the programs of the associated schools, and to increase their general value to children and adults who wish to learn more about science.

This recommendation does not call for action by the federal government. A number of cities have found means to develop science and technology centers; their number is growing; we hope it will continue to grow. But we are not recommending their establishment anywhere except where there is sufficient local interest and local financial support to get one started.

The Needs of Special Groups

Minority group members and women are seriously underrepresented in science and engineering. In 1974, minorities constituted almost 11 percent of the employed labor force, but occupied only about 5 percent of all jobs in science and engineering. Women, who made up almost 40 percent of the work force, comprised only 6 percent of the employed scientists and engineers (NSF, 1977, p. 6).

These disparities are so great as to show clearly the need for positive efforts to increase the opportunities for women and for members of minority groups. But citing the disparities does not mean that our objective is exact statistical parity of all groups in all occupational fields. Indeed the attainment of precise statistical parity in all fields would no doubt require the illegal use of race and sex as criteria for selection. In any event, the goal should not be statistical, but individual: any child who has the necessary interest and ability should not be denied access because of race or sex to a career in any field of science or any of the professions based on science.

Among the four generally identified minority groups, persons of Asian origin are statistically over-represented in science and engineering, and therefore do not need special attention in the context of this report. The other three -- American Indians and Alaskan Natives, Blacks, and Hispanics -- are all underrepresented. Of these three groups, Blacks are most numerous, have been most studied, and will most often be used as the illustrative minority group in the following discussion. In general, however, the special needs of Blacks are matched by similar needs of the other two minority groups, and also by those economically disadvantaged children in general.

Blacks constituted 15 percent of the 18-21 age group in 1974 and 10.7 percent of the total undergraduate population. But Blacks constitute only 6.9 percent of undergraduates majoring in the biological sciences, 5.9 percent of those majoring in engineering, and 4.6 percent of the physical science majors (Office of Civil Rights, 1976).

At the graduate school level, the numbers of minorities receiving doctorates in scientific disciplines are even lower. Blacks, Hispanics, and Native Americans account for almost 20 percent of the population, but in 1977 constituted less than 4 percent of the Ph.D. recipients in all science and engineering fields, including the social sciences. Women received 18 percent of the doctoral degrees in science and engineering in 1977 (National Research Council, 1978).

The situation means that as a nation we are not utilizing effectively many gifted young people, although technological innovation is widely recognized as a need focal to our economic health. A large fraction of the nation's corporate executives and more than half of the federal decision-makers (GS-18 and above) come from science and engineering backgrounds. It is unfortunate that more women and minorities are not receiving the scientific education that would improve their opportunities for upward mobility.

As children approach adolescence, the availability of role models becomes an important factor in their selection of future careers. Studies have shown that, although parents are listed by adolescents as the individuals most responsible for their career choices, associations with other adults holding specific occupations are second in importance (Pallone, Hurley, and Rickard, 1973). There is a need, therefore, to provide more women and minority group role models, if we are to encourage more adolescent girls and minority group students to consider careers in science.

Ways should be explored to increase the number of such role models on the science and mathematics faculties of secondary schools. However, minority group students and girls need contact with role models from scientific careers other than secondary school science or mathematics teaching. It is here that industry and university science and engineering departments can provide an important service by lending scientific personnel to work with minority youth and girls.

The Minorities in Engineering programs initiated throughout the country beginning in 1972 provide many examples of cooperative efforts involving local school systems, industries, and universities (Committee on Minorities in Engineering, 1977). With support from a number of industrial corporations and their foundations, these programs have focused on establishing local organizations that encourage interactions among secondary school personnel, college faculty members, industrial personnel, and community groups.

However, much remains to be done, not only in engineering but in other scientific fields. Until it is possible to improve significantly the quality of mathematics and science education for all disadvantaged children, particularly in inner-city schools, there is a need to develop an approach that will identify gifted but economically disadvantaged students early in elementary and junior high school and follow them through high school and college, so as to provide them with the support necessary to increase their opportunities for learning and their chances of success. There is much that could be done to help such students cross the academic hurdles in their path, such as the establishment of special schools or schools-within-a-school, the provision of summer enrichment camps in science and mathematics, the arrangement of part-time student apprenticeships with professional scientists and engineers, and the provision of special career-planning assistance for students and their parents.

If larger numbers of women and minority group members are to have careers in science and engineering, larger numbers of students must be put into good science and mathematics courses, enrolled in the college-preparatory programs in high school, and given the education that will qualify them for admission to scientific and technical programs in college. Effective actions of this kind should be the conscious and measurable objectives of programs to increase interest and motivation.

Even if many special efforts are made, the task will take decades. Success will require a national commitment lasting into the next century. The fact that the task cannot be accomplished quickly should not deter us from continuing on what must necessarily be a long-term effort.

> RECOMMENDATION 5: In order to give women and members of racial or ethnic minority groups greater opportunity to become interested in and to prepare for careers in scientific and technical occupations, we recommend that scientists and engineers work with their local school systems to provide special lectures and classes; tours of local scientific, engineering, and technical facilities; opportunities to meet with appropriate role models; and other experiences intended to increase their motivation and to overcome their disadvantages in securing the education necessary for scientific and technical careers. In addition, we recommend that efforts be made to identify gifted but economically disadvantaged students early in their schooling, so as to ensure that they will be afforded adequate opportunities to prepare themselves for admission to scientific and technical programs in college.

Accomplishment of these objectives will require widespread, decentralized, continuing effort on the part of many organizations and individuals. This recommendation is equally broadly aimed.

Accountability and the Use of Tests

The phrase "back to the basics" summarizes the most widely publicized recent campaign in education. Three quarters of the States of the Union have adopted some form of minimum competency legislation, legislation requiring students to pass certain tests before being promoted or allowed to graduate. Both the back to the basics movement and the minimum competency legislation are evidence of increasing public insistence that schools be held accountable for the performance of students.

This whole movement has been fueled by widespread complaints that high school graduates are not as well educated as they should be. Employers complain that new young employees with high school diplomas are illiterate. College English departments are having to shift more of their Freshman English classes to work on composition and remedial English instead of teaching literature courses (Gibson, 1978); publicity has been given to declining scores on the Scholastic Aptitude Test, and part of that decline has been related to the fact that "less thoughtful and critical reading is now being demanded and done" and "careful writing has apparently about gone out of style" in many schools (Wirtz, et al., 1977).

So the call arises for an end to social promotion, the abolition of frills and a reduction in the number of soft courses, for greater emphasis on the basics of reading, writing, and computation, for the use of standardized tests to determine whether students have attained minimum competency, and for increased accountability on the part of the schools.

The motivation for much of this concern is highly laudable. The public should be interested in its schools. There is room for much improvement in the curriculum. Reading and writing are basic and essential skills. Schools should be accountable for the effectiveness with which they educate the nation's youth. The trouble with accountability is not with the concept, but with the method by which student performance is measured and publicly reported.

If teachers know the tests that will be used to compare their pupils, their schools, and their own performance, of course they will emphasize in their teaching the skills and knowledge that are emphasized in the tests. Nothing else could be expected. Indeed teachers would be remiss if they did not help their students acquire the information and skills on which they will be judged.

It is therefore necessary to understand the methods by which pupils are judged, and to analyze the slogan "back to the basics", for that slogan seems to have different meanings for different users. As a reassertion of the primacy of the central core subjects in contrast with a variety of "fringe" or "soft" courses, it raises a question of educational philosophy on which there is continuing argument, and to which the answer often depends upon the particular students being considered.

As insistence on mastery of the facts, methods, and skills that are essential for competent performance, learning the basics of mathematics or other subjects has the same kind of solid justification that it does in learning to play basketball, or a musical instrument. Initially, reading, writing, and arithmetic are skill subjects. After the rudiments have been learned, they become much more than that, but for a beginning pupil much practice is required to master the basic skills. Because those skills are essential for other school subjects and for effective management of many aspects of adult life, the public is right in wanting to hold schools accountable for the ability of their students to read, write, and calculate with reasonable competency.

Reasonable competency may be all that can be expected of some students, but for others that level is not enough, particularly in the higher grades and especially for the more competent students. Thus loss results when back to the basics sets limits on what is to be learned, as it does when some subjects, such as science, are excluded from the definition of basic education which is used to allocate state funds to local schools; or when teachers and students are led to believe that there is no need to go beyond the level of minimum competency, as they are when promotion or graduation are determined by scores on tests of minimum competency.

It is this last interpretation, or implementation, of the back to the basics and minimum competency movements that we strongly oppose. When those movements set a low ceiling on expectations and opportunities, many of the children and society are deprived. Ralph Tyler provides an example of how the low ceiling of a minimum competency requirement affects schools:

> "In Florida, the National Education Association panel (which I chaired) heard criticisms that the eleventh grade testing program was resulting in an overemphasis in many high schools on elementary reading, arithmetic, and specific test items in order to ensure that students can pass the tests. As a result, high school subjects such as science, history, literature, music, and the arts have been neglected. Some of the teachers actually believed that the law now required them to narrow the curriculum to these minimum competencies...Many teachers interpreted the emphasis on basic skills to mean they must devote most of their attention to routine drill" (Tyler, 1979, p. 29-30).

An encouraging contrast to this report is the fact that some students now seem to recognize what has been happening; a recent survey conducted by Gallup Poll and the Kettering Foundation found many students saying that elementary school standards are too low and that classes are not sufficiently challenging.

In practice, the emphasis on minimum competency has led to over-reliance on tests of those aspects of the curriculum that can be most readily expressed in simple numerical scores. This tendency is reinforced by the already wide use of objective and nationally standardized tests of aptitude and achievement, and by the desire on the part of parents, the public, and school administrators to be able to compare this year with last year, or this school with that one.

Unfortunately, this emphasis on numerical measures that are easily obtained and easy to report undermines an important part of the schools' educational function, for the tests that best satisfy the desire for ease of administration and reporting are, in the main, designed to measure the simpler and more routine aspects of education: ability to perform the four fundamental processes of arithmetic rather than understanding of mathematical principles and reasoning; remembering the names of concepts rather than understanding their meaning; ability to recognize rules and principles rather than ability to interpret and apply them; ability to recognize parts of speech rather than ability to write literate English. Yet as a report from the Council for Basic Education emphasized, "without the thinking elements science teaching is stripped of its greatest appeal to children," and these "more subtle and often more important objectives of education" tend to be suppressed by the rigid application of accountability measures (Hausman, 1976, pp. 3 and 10).

It is possible to improve the examinations that are used to measure minimum competency and that should be done for they will no doubt continue to be used. But even at their best, they help establish a single standard for the granting of an educational credential, a standard that may be discouragingly high for some students and dispiritingly low for others. As stated earlier, there are important basic skills that students should be expected to learn, and it is appropriate to require demonstration of competency in reading, writing, and arithmetic computation. But measures of these skills should never constitute the sole basis for decisions concerning promotion or graduation of students or the evaluation of school curricula. Tests of these skills do not measure and do not purport to measure all that should be considered in making those decisions.

We, therefore, recommend that teachers be provided with a more desirable and flexible alternative: a large bank of carefully constructed examination items from which individual schools and individual teachers can select their own examinations (Zacharias, 1979). There should be such a bank or reservoir of test items in each subject or major area included in the curriculum: in the sciences, and also in foreign languages, social studies, the arts, and all the rest.

Each bank should cover a wide range, from the elemental and simple facts to the ideas, the concepts, the methods, and the more difficult and abstract aspects of the subject. Each item bank should include questions of several types. Some can be of familiar multiple-choice form, but other types would also be included. Essay or discussion questions are harder to score, but pedagogically more effective. In between multiple-choice and essay questions are open-ended questions that can be answered by a word, a phrase, a sentence, a computation, or a comparison. These items can be scored in a highly reliable manner; they can be phrased to require real understanding; they can be written in great variety; they serve more effectively as a basis for class discussion than do multiple-choice items; and they stand up better to public scrutiny.

Each bank should be large enough to provide very wide choice in selecting items to make up different examinations -- different in order to be appropriate for the wide range of schools and pupils that exist in the United States, and different so the same school or teacher can draw many examinations from the bank.

Moreover, and most importantly, the bank should not be secret. All of the test items should be publicly available, to teachers, parents, school children, to anyone who is interested. Unlike tests whose secrecy must be carefully preserved, there would be no danger in allowing students to examine the test bank. Within any field -- biology for example -- there would be so many different items, testing so many different aspects of biological knowledge, principle, and method that any teacher could say to a pupil "Go to it. If you can answer the questions in the biology bank you know enough biology to earn a high grade."[2] It may be desirable

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[2] Beginning in the 1930's, the University of Chicago faculty -- with help from the University's Board of Examinations -- constructed long, searching examinations that were the sole basis for grading in many courses. These examinations included some multiple-choice and other objective items, some to be answered by a word or phrase, and some that required longer answers. As soon as one of these examinations was used, copies were made available in the University Book Store for purchase by anyone interested. This system worked very satisfactorily. The faculty had to construct good examinations, ones they were willing to make public. Students had the opportunity to find out in advance what the faculty considered to be the content, scope, and appropriate examination for a course. The reasonableness of our proposal is supported by this favorable experience, but our proposal goes further in making the whole bank of items available from the start.

to add that under most circumstances the particular items from the bank that will appear on a given examination should not be announced in advance. The whole item bank should be open, but if the particular questions on which students will be graded are known in advance, students will be tempted to concentrate too exclusively on the answers to the selected items.

Open access to the whole test bank would force the people who construct the test items to do a better job. It is difficult to write test items that assess a student's ability to think clearly, to understand principles and relationships, to express ideas in clear, concise prose. It is more difficult to write such items than to write test items that depend on memory for facts, names, or word meanings, but it is not impossible. If all of the items are open to public inspection, and if the test bank is expected to cover the whole range of curricular objectives, the test writers would have to do a better job.

If all of the items are open to inspection, they are also open to objection by experts. Scientists could challenge any that involved faulty understanding of the scientific facts or principles involved. Representatives of minority groups could challenge any that seemed unfair to their groups.

The purposes of these test banks would be to improve education and to give teachers wider latitude in measuring what their pupils have learned than is possible with standardized tests. For other purposes, tests of other types are available. Employers and college admissions officers can continue to use standardized tests to aid in making their selection decisions. Educational and vocational counselors can continue to use the tests they find of value in their work. The National Assessment of Educational Progress will no doubt continue to use tests designed for its purposes. Tests for these uses are typically the same throughout the country, and care is exercised to keep the test items secret, at least until after the test has served its purpose.

But neither national standardization nor secrecy are necessary for tests used to assess progress during the school year, to help diagnose areas of strength or weakness, to use as starting points for classroom discussion or other forms of teaching, or to determine when a student is ready to move to the next level or block of material, or is ready for promotion or graduation. For these purposes, examinations consisting of questions selected from the appropriate test bank can give each school or teacher substantial latitude in selecting items with the content and at the level that are appropriate for that particular group of students.

RECOMMENDATION 6: We recommend vigorous efforts at local levels to combat the overemphasis currently given to scores on standardized tests of achievement in comparing the performance of schools, classes, and individual pupils. Because the tests most generally used for these purposes give emphasis to the more elementary and routine abilities necessary to meet "minimum competency" requirements, they constitute only a part of the basis upon which schools and pupils should be judged. In addition, in order to make available more desirable tests with which teachers can appraise the performance of their pupils, we recommend the creation, for each major subject, of a large bank of test items, of varied types and covering a wide range of skills and knowledge of the subject field. These test banks should be openly available to any teacher, school administrator, parent, child, or anyone else who is interested. Open availability of the entire bank of test items should improve the quality of test items and will give teachers latitude in selecting the test questions that match their educational objectives.

Much work would be involved in making up the thousands of items that would be needed for the item banks in all of the major areas of the school curriculum, and to pretest the items to determine their difficulty and uncover hidden ambiguities. Because the test items would be of quite varied types, more time would be required to score them than is necessary for tests that can be scored by machine. But offsetting these costs would be the large amount of time saved by not having to construct individual teacher-made tests and the advantage of having access to a large resource of reliable and well-tested items from which any teacher could draw examinations tailored to the particular needs and interests of a school or class.

IMPLEMENTATION

Successful achievement of the objectives of our recommendations will require leadership, cooperation between the scientific and educational communities, and continuing government support for private initiative.

Leadership

Most of the leadership must come from scientists and scientific organizations. The NSF studies indicate that leadership in this effort is quite unlikely to come from anywhere within the educational system. Only a small percentage of school superintendents and principals are primarily interested in science or mathematics. Teachers rate them low among available sources of help on problems in teaching science and mathematics. A maze of state and federal regulations and requirements forces them to be systems managers rather than educational leaders.

Some subject matter coordinators could serve as leaders, but the excellently qualified ones are few in number, and typically they are able to devote only about a fourth of their time to working with teachers on instructional matters.

The individual teachers who are interested are geographically scattered. Working on curricular reform and the development of innovative teaching materials is not generally rewarded in most school systems. Some of the specialized societies, such as the National Council of Teachers of Mathematics or the National Science Teachers Association, can be very helpful. But the major national association, the National Education Association, has lost most of its former interest in educational matters as it has become an aggressive labor union.

Thus, responsibility for leadership seems to lie in the hands of scientists and scientific associations. In the 1950's and 1960's most of the scientists actively involved in the curriculum projects came from academic institutions, and that will probably be true in the future. But there is also a rich source of talent among scientists and engineers in industry, and they may be of special value as greater emphasis is given to improving science learning for all students, whether or not they are going to college or whether they are likely to follow careers in the scientific and technical fields.

From wherever they may come, scientists will have to take the initiative. Many are not satisfied with the present performance of the nation's schools, and believe that improvement is possible and necessary. They now have the choice between doing the hard work necessary to provide leadership in bringing about the desired improvements or of resigning themselves to the expectation that those improvements will not occur.

Institutional as well as individual leadership will be necessary, and the National Science Foundation is the most experienced and appears to be the most appropriate institutional leader. Other federal agencies, school systems, and private foundations should help, as they have in the past, but a leading agency is required to focus the governmental interest and support.

One of the unknowns of the legislative future is whether Congress will vote to establish a new Department of Education, and if it does so, whether it will transfer the pre-college educational responsibilities of NSF to that new Department, as some of the advocates of the new Department propose. The case can be argued either way. Science education is part of education and should therefore be part of the new Department. Or, science education is part of science and should remain in close alliance with other scientific activities. If a new Department of Education is established, it may develop in such a way as to make the transfer seem desirable. But for the time being, we give more weight to two reasons for retaining responsibility in the National Science Foundation. One reason is the nature of the activities to be supported. The recommendations presented above will require individual decisions as to which proposals, among a number submitted, are most meritorious and can be supported. NSF has had much more experience in the support of individual projects selected as most meritorious by the processes of peer review than has either the Office of Education or the National Institute of Education. Indeed a substantial part of the Office of Education responsibility has been for programs in which funds are allotted by formula instead of on a selective basis.

The other reason concerns the personnel involved. Scientists, who will have to lead the whole effort, already have well-established working relationships with NSF. Moreover, because the interests of scientists in education are often closely linked to their interests in research, strong continuing relationships with NSF are altogether likely. For these historical and organizational reasons, we believe that the NSF should continue to be the federal agency with major responsibility for supporting efforts to improve science education at the pre-college level.

Cooperation

Leadership will come from scientists, but they should make greater efforts to enlist the active cooperation of the educational community than they did in the 1950's and 1960's. Specialists in education are needed and they can be of much help in getting improved programs accepted by the educational community. They can also be more directly effective in devising systems to reward teachers for using better materials and methods, and can help build into the education system the idea of a continuing effort toward improvement.

New curricular materials are generally more demanding of teachers than were the textbooks that preceded them. They call for greater understanding of subject matter, and require effective use of teaching skills that are not required by simple reading and recitation. But this is not what is emphasized in most schools of education. So far the schools of education have had relatively little involvement in the course improvement effort. Individuals, particularly specialists in science education, have been valuable members of many of the project teams. And some of the institutes for teachers have been sponsored by schools or departments of education. But the education profession did not initiate the major efforts to improve education in science and mathematics, and the initiators of that effort have not done enough to enlist the continuing cooperation of that profession.

Now, with clear recognition that a continuing effort is needed, the leaders of that effort should seek means of involving more effectively the deans and professors of education. In the long run, it is they who will determine whether new teachers enter their first positions reasonably well grounded in their fields and able to use teaching methods that help young students learn to think and develop rational abilities. The schools of education should inculcate the attitude that curricular improvement and the development of better materials and methods will be an expected and continuing part of each teacher's professional life.

Support for Private Initiative

Twenty years ago, NSF clearly distinguished the educational responsibilities of the federal government from those of the private sector and local government. Congress had recognized the need for federal assistance to the nation's schools, and NSF was authorized to use part of its funds for that purpose. But it would not try to control; instead, it would support "the activities of competent persons and groups in the scientific and academic communities in carrying out what those communities judge to be needed and proper. The

Foundation takes pains to avoid wherever possible the implication of endorsing or specifying attitudes, the nature of course content, or related items which are properly the province of the educational community. The initiative must derive from the academic community" (quoted from 1959 budget statement, NSF, 1975, Vol. II, p. 21).

In taking this posture, NSF was honoring the long and deep tradition that educational responsibility is reserved to private institutions and to state and local government. At the same time, NSF was honoring another deeply rooted American tradition, that voluntary private action is often the most effective way to accomplish major public purposes. In supporting research, NSF had already followed this course. It was accustomed to selecting the most promising proposals from among all those submitted, but it did not try to decide what problems should be tackled next or what methods should be employed. Scientists actively engaged in research were considered to be the best judges of those matters. And so it was with improvements in education; scientists and the educational specialists and teachers who were working with them were considered to be better judges than the NSF staff members of what should be taught to pre-college students and of how it should be taught.

For several reasons there has been appreciable backsliding from this position. Congress still pays tribute to the tradition of local autonomy, and in fact has reprimanded NSF when it thought some of the Foundation's implementation activities had gone too far in influencing school systems as to the curricular materials they should use. Congress itself has not tried to dictate what should be taught in the nation's schools, but it has come dangerously close in deciding some things that should not be taught. When some of the NSF-funded projects in the biological and social sciences encountered criticism in Congress as being value-laden or controversial, NSF was seized by anxiety. Both Congress and the General Accounting Office have warned NSF that it cannot avoid being responsible for the content and conduct of curriculum development projects, and that it should take a more active role in determining in advance what is needed in the way of educational improvement and then seek means of responding to those needs.

NSF has been immensely valuable in achieving many of the improvements in science and mathematics education of the past quarter century. Other federal agencies and some private foundations have also been involved, but NSF has clearly been the primary supporter of the whole movement. In large part its success has been due to the fact that it had the confidence of the scientific community, and it, in turn, was geared to provide financial support for the best ideas and proposals that were generated in that community. NSF was successful because it did not try to mastermind the whole effort and because it could pick and choose from among all the ideas emanating from the community of scientists and educators interested in the improvement of education.

Much experience tells us that the support of private interest and effort is often the most effective way to achieve a public purpose. But when private initiative is supported by public funds there is strong temptation for the provider of those funds to exert more and more control. Unless that temptation is resisted, the private initiative that started the whole effort is weakened, and is likely to be squeezed out. The fact that this tendency is wrong in principle and usually inefficient in practice is likely to be forgotten by a bureaucracy that is overly responsive to criticism. Nothing useful in education can expect universal approval. The response to criticisms must not be the typical bureaucratic remedy of stronger central control.

In looking toward the implementation of the recommendations made above, the tendency toward centralization and increasing national regulations should be resisted as vigorously and continuously as possible. The teaching resource centers we have proposed will operate in individual communities, some as parts of school systems and others under other organizational sponsors. Each should be planned, organized, and managed in terms of its local resources, opportunities, and customs. Similarly, as efforts are made to improve education in mathematics -- to achieve something better than the traditional emphasis on computation and better than the original versions of the new math -- it is surely teachers and mathematicians in the field, not staff members in Washington, who can best decide what to try and whether what has been tried has worked as effectively as it might.

What is called for is enlightened self-restraint on the part of the National Science Foundation, the Office of Management and Budget, and the Congress. All recognize the principle involved, but in day to day dealing with details staff members are always under pressure to take the "safe" course of increasing central control or adopting another national regulation. Yet principle should be made to prevail. NSF surely does not want authority over the substance of what is taught in the schools. Congress would not want that power to be held by any agency of the Executive Branch nor to arrogate it to itself. The proper role for NSF is to allocate public funds in the encouragement of the best independent initiative. Of course NSF must then see to it that those funds are honestly and competently used for the purposes intended. But decisions as to what educational improvements are most needed and how those needs can best be met are emphatically not decisions to be made by an agency of the federal government.

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