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ABSTRACT

This report is a result of evaluation of the status of science education in the United States with suggested recommendations for the future role of the National Science Foundation (NSF). The overriding theme of the report for the future is summarized as "to educate scientists who will be at home in society and to educate a society that will be at home with science." The first part of the report gives a background of science education improvement activities and their impact on various facets of economy and institutions. The second part is called "A Review of Course and Curriculum Development Support" initiated by NSF. The recommendations are listed in the third part and cover a broader area. Teacher Training, Educatonal Technology, Science Education Outside of the Classroom, Science and Public Policy, and Pre-College, Undergraduate, and Graduate Education are the areas for specific recommendations made in the report. Other areas covered are Policies and Operations, which deals with topics such as relationship between NSF and the U. S. Office of Education, and Use of the Talents and Resources of Nonacademic Organizations. (PS)

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Science Education—

The Task Ahead for the National Science Foundation

"To educate scientists who will be at home in society and to educate a society that will be at home with science."

Report of the Advisory Committee for Science Education

March 1970

NSF 71-13

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This is a year of debate on priorities of many urgent social needs and of slowly growing resources. The Federal Government has many competing demands for the support of pure and applied research and of education. The National Science Foundation has limited additional funds with which to support any increase in its present programs, or to support additional programs the Foundation initiates or others ask it to undertake. Any proposal for new initiatives must be made in the context of other thoroughly justified claims on the same money and talent.

We are quite convinced that the proposals advocated in this report are part of the solution and not simply an addition to the problem. Effective action to meet our social needs will often require the application of science and technology, and will often require the understanding and direction of many people, not themselves scientists, who know the power and the limitations of science and technology. It is to the broadening of this understanding, to the competence of this direction, that our recommendations are addressed.

Many of us on this Committee have shared in the excitement and appreciate the contributions of research; we also know the satisfactions of teaching young people who aspire to be scientists. For these things to continue to flourish and to make their social contribution we need "scientists at home with society and a society at home with science."

We suspect that, at the moment, not more than a small fraction of the Foundation's budget could be committed to the activities we propose without saturating the best of the ideas and people. A few years ago it would have been much less possible to find effective ways to enhance the scientific education of nonscientists. Now there are promising things to do, and if done, the next years should bring more. It is an essential task, and one which needs thought, support, and commitment now.

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FOREWORD

With its limited resources, the National Science Foundation's role in American education is ideally that of a catalyst and multiplier. As such the Foundation has had a profound effect on the growth and development of science education in the United States.

Innovations in curriculum, teacher education, and student support, now an accepted part of the educational scene, are directly attributable to the leadership and financial support provided by the Foundation.

Two fundamental precepts have guided and shaped the Foundation's science education activities since its inception 20 years ago: the education of professionals for careers in science and technology; and the qualitative improvement of science education for students at all educational levels.

These objectives remain. But recognizing the temporal character of past successes, when measured against educational and social needs, the Foundation initiated a comprehensive review of its educational program in late 1969.

The attached Report of the NSF Advisory Committee for Science Education to the National Science Board, with support papers from Drs. Greenberg and Platt, is a major contribution to this review process.

The Report stresses one overriding goal for the coming decade: "To educate scientists who will be at home in society and to educate a society that will be at home with science."

Among the recommendations in the Report are:

Increased emphasis on the understanding of science and technology by those who are not, and do not expect to be, professional scientists and technologists.

This charge has clear implications for curriculum and teacher education at both the secondary and undergraduate level. Focus in curriculum, for example, should shift, in part, from the traditional discipline orientation to interdisciplinary approaches centered upon problems faced by informed citizens. Revised teacher education—both pre-service and in-service—should provide not only a thorough grounding

in the scientific disciplines but an understanding of the instructional processes appropriate to the new curriculum and varying student audiences.

Creation of alternatives in the training of future professionals for careers in science and technology.

This goal implies a shift from the past emphasis, limited primarily to the research Ph.D., to the development of undergraduate and advanced degree programs for future purveyors and users of scientific knowledge.

Use of technology in education, particularly television and computers.

New tools now available make possible individualized approaches to education, a more efficient role for the teacher, a greater flexibility in educational activities outside formal institutions, and more rigorous scientific investigations of the whole educational process. Experimentation with these tools should be an integral part of the Foundation's support of education projects at all levels.

The Advisory Committee report has already influenced the Foundation's current and projected science education activities. For example: at the undergraduate level, NSF is supporting the development of instructional programs for technologists competent in the more pressing problem areas of our society—air pollution, power transmission, solid waste disposal, etc. At the graduate level, NSF hopes to initiate programs to support the creation of options in advanced degree programs, both master's and doctoral, oriented toward the teaching and application of science in technology-linked careers. At the pre-college level, support for individual student projects is being deemphasized in favor of approaches designed to integrate curriculum development with teacher education, with special emphasis on programs for supervisors and administrators to build capability for locally generated improvement.

Dr. H. E. Carter, Chairman of the National Science Board, has asked me to present the Committee's report to the scientific and educational communities for consideration. We hope the report will give rise to extensive discussion, and that you will write me of your views. Only through such comments can NSF be responsive to the current educational and social needs.

W. D. McElroy
Director

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PART I

Background

The National Science Board in 1969 asked the Advisory Committee for Science Education to evaluate the effectiveness of the Foundation's programs, to date, in science education, including in particular the course content improvement activities, and to make recommendations for the decade about to begin. The body of this report is devoted to these tasks. But we found ourselves wrestling with larger concerns; larger than the Foundation's programs in science education or the entire Federal commitment to education. We believe this is a time of major change and adaptation for education in the United States, not because a decade happens to be ending, but because methods which have served the Nation well for a century are not adequate to meet our future needs. We also believe that the National Science Foundation, by the competence gained in the last two decades, can have a particularly significant role to play in developing and exploiting new ways of meeting these needs.

Our life in the United States, as individuals and as a Nation, is shaped by an unprecedented development of science and technology. Most of our citizens have a standard of material living, a mobility, a choice of vocation and avocation, new in human history. This has come about because of the discovery and the exploitation of knowledge in which pure and applied research have been essential ingredients. The facts of this knowledge explosion are well known. What concerns us here is how this knowledge is made useful, how it is taught.

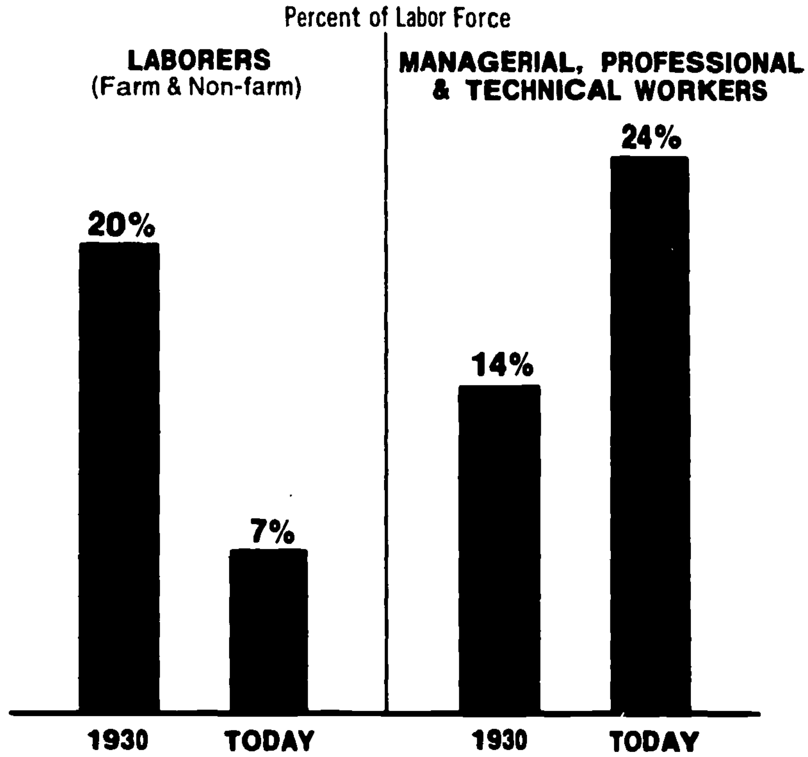
Three techniques have dominated our approach to education during the last century. We have made knowledge more useful to individuals and to our society by teaching more people, by teaching any one person longer, and by the growth of specialization. Yet, while we have been exploiting these techniques, the nature of our society has changed dramatically. Over the last 40 years the fraction of our labor force employed as laborers (farm and nonfarm) has decreased from 20 percent to 7 percent; the fraction in professional, technical, and managerial employment has increased from 14 percent to 24 percent; and the average per capita personal income, in constant dollars, has increased 103 percent. Formal education on a grand scale has been a precondition for this national transformation. (See Figure 1.)

As for teaching more people: The fraction of youth in the 14- through 17-year age bracket enrolled in secondary schools was 7 percent in 1890; in 1930 it was 50 percent; it now stands at 96 percent. Three-quarters of our young people now graduate from high school. In 1890 less than 3 percent of our college-age youth were in college. In the 1970's it appears half our college-age young people will have some post-high school formal education and one-quarter will earn the baccalaureate. (See Figure 2.)

As for teaching any one person longer: The average member of the labor force had less than 8 years of formal schooling in 1890, his present counterpart has over 12 years. For some professions we now require not only doctoral but postdoctoral educa-

FIGURE 1

IMPACT OF FORMAL EDUCATION ON SHAPE OF LABOR FORCE



AVERAGE PER CAPITA PERSONAL INCOME

(constant dollars)

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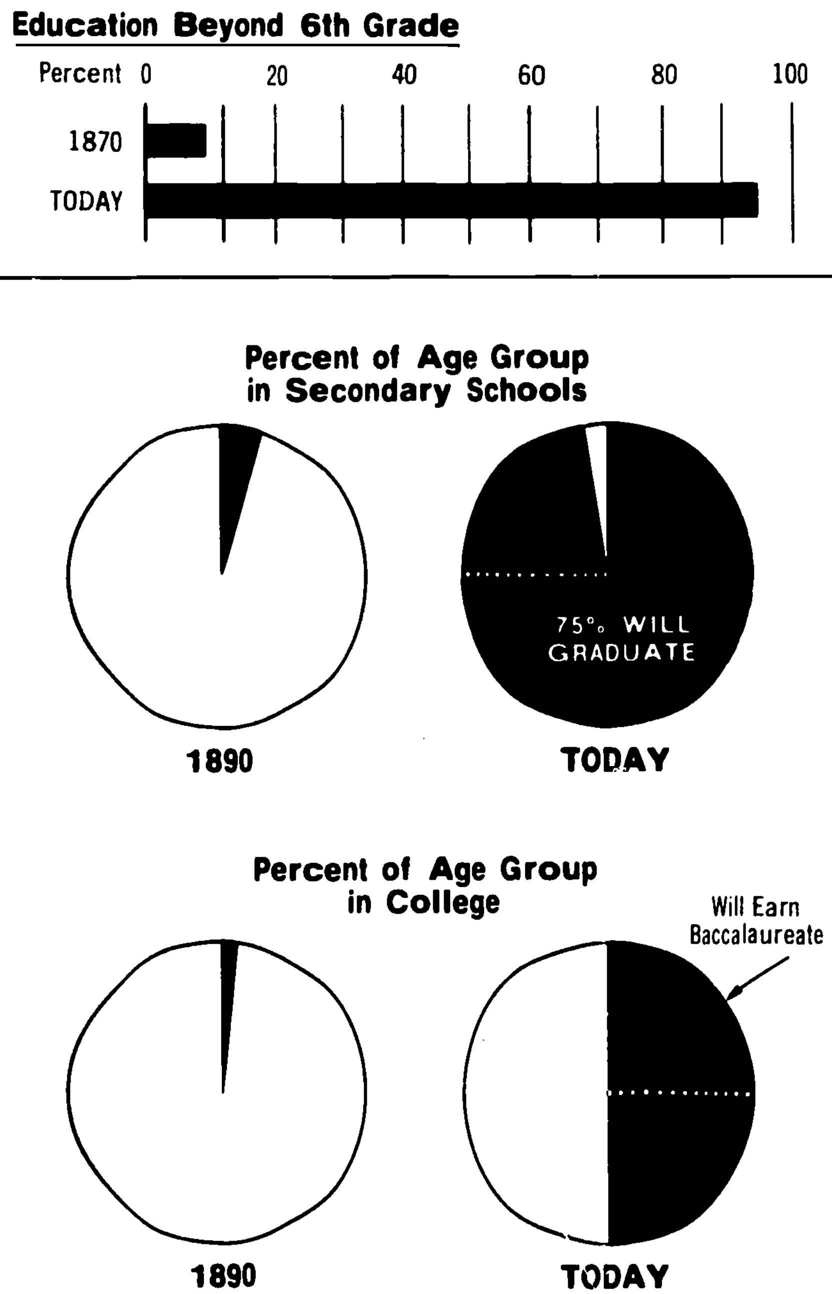
FIGURE 2

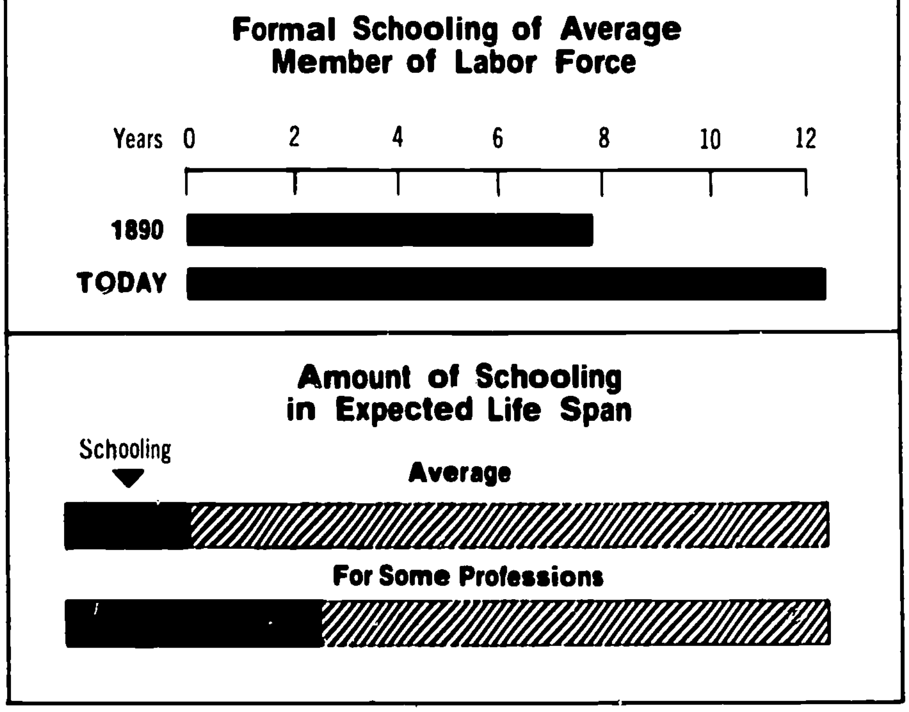
INCREASINGLY MORE PEOPLE ARE RECEIVING EDUCATION



tion, so the length of formal schooling exceeds 20 years. On the average, schooling requires one-sixth of the expected life span, and for some professions, one-third (Figure 3).

As for specialization: Each of us in his field can cite ample evidence. A doubling time of 10 years may be a plausible estimate for the number of specialties in many general areas of knowledge, for example, medicine, engineering, or law. (See Figure 4.)

FIGURE 3



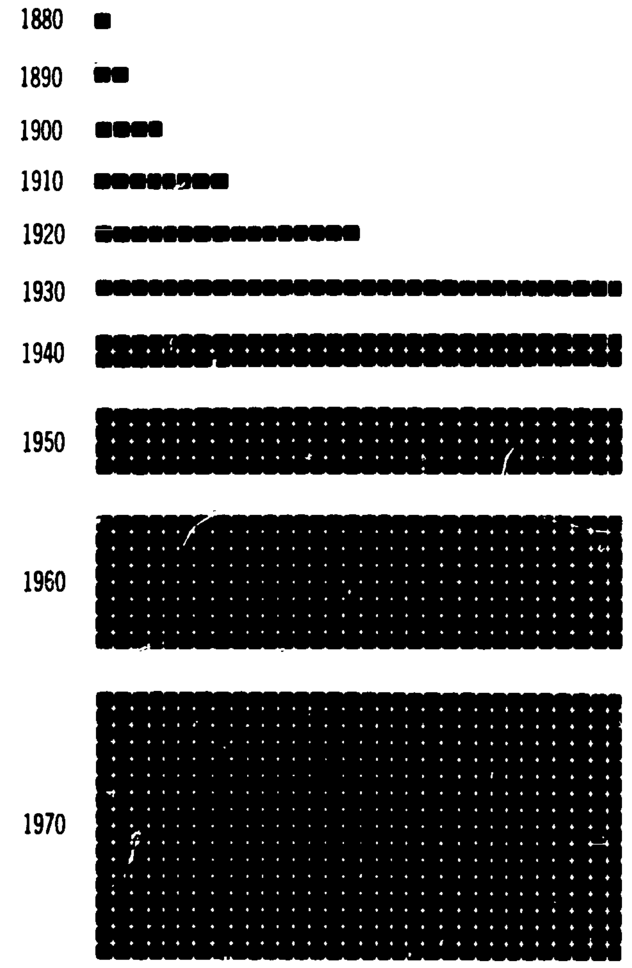
The challenge concerning us is that one cannot continue to exploit a growing body of knowledge by extrapolation of these techniques. We cannot teach more than 100 percent of the population at either secondary or collegiate levels. The fraction of the life span one can commit to formal schooling also has an upper limit of 100 percent. Moreover, as the growth of specialization increases the difficulty of communication between specialities, it undermines the end of all education—understanding and wisdom, two end-products never more in demand than now. In short, we need new approaches to learning and the dissemination of knowledge.

In fact, the primary challenge may not even be to exploit a growing body of knowledge, but to make more effective use of existing knowledge—to diffuse more broadly an understanding of the opportunities and the risks which current technology presents, and to cultivate more generally the rationality the methods of science bring to a decision.

All of us suffer from some alienation because of the growth of specialization.

FIGURE 4

Number of Doctorates Doubling Every 10 Years



That which we do not understand, we cannot control; and much of the work of our fellows is strange to us. We come finally to believe that no one is in charge!

But if some of us who have taught science feel we may be overspecialized, overprofessionalized, and out of touch with the nonscientists, what must those we are attempting to educate think? The perspective of the young cannot be comforting—much less gratifying—to any of us who have devoted our lives to science.

Their charges are many and varied, justifiable and unjustifiable, and—as always the case with the young—passionately made. "Science is immoral," they say, "technology is mindless, science and technology are dehumanizing," both "disregard democratic values." "Science exploits nature while rejecting the whole man." "The scientific-military-industrial complex threatens all humanity!"

These are debatable and unsubstantiated charges. But they are, nevertheless, becoming the belief of some of our ablest students and of a growing segment of the community at large. This perspective of the young offers us a challenge and a task we have, until now, chosen to put aside for another day, another budget, and a different set of priorities. The next decade will not be so tolerant. For if, in fact, we are exhausting the usefulness of teaching more people, teaching them longer, and teaching them more about less, we must reevaluate our assumptions.

We might begin by asking ourselves: What is the end of science education in an age of technology? The end of a scientific education should be the development of a person who uses the scientific method to understand a constantly changing environment, one who has learned to use disciplined observation and analysis to increase his understanding of *all* of nature. He may be primarily concerned with extending some particular forefront of knowledge, but he uses the same methods of observation and analysis to increase his understanding of all his physical and social surroundings. He thus has a philosophical conception of the place of science in the understanding and management of human affairs.

It is the diffusion of this conception—this mode of thought—which we feel is urgent national business. The full results of an improved, widely accepted general education in the sciences can be available only after decades. These results include more complete legislative and public understanding of problems of fundamental social concern such as the ecology, better ability to communicate between scientific specialties and between scientists and the rest of the community, and a wiser understanding of nonscientific issues by engineers and scientists. We believe this growth in communication, understanding, and trust *is* essential if we, as a people, are to respond constructively to the changes and the new equilibria the remainder of the century will force on us. But a bold start need not require decades. We have a growing concern of scientists for the problems of the larger society and a growing segment of the larger society—technicians, legislators, newscasters, and fishermen—who find they must understand more science to understand what is happening to their jobs, their environment, and the prospects of their children.

One may agree that a better understanding of science and technology is very important to the development of a stable society, and still ask whether or not this is the task of the NSF, or whether it can do much that is useful in this area. We believe that the Foundation can and should have much greater involvement in public understanding of science, and particularly in the promotion of general education in the sciences for the young nonscientist, during the coming decade. Certainly the local school systems, State departments of education, and many Federal agencies have responsibilities for improved general education in science. It is also true that no one has any very clear idea of what could best be done to improve the scientific and technical literacy of our citizens. But the Foundation has unique assets in exploring new approaches, developing new techniques, and helping others to understand how they can improve science education.

The national operating costs for primary and secondary education over the 12 years from 1957 to 1969 totalled $250 billion. During that same period the Founda-

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tion invested about $100 million in the improvement of course content at these levels–4 cents of every one hundred dollars. The result has been a more dramatic change in the teaching of science and mathematics–primarily for prospective scientists–than has occurred in any other 12 years of this century, in any area of instruction. There has also been more interest in the improvement of teaching–secondary, primary, and now college and university–on the part of university scientists than we had known previously, and a greater interest in subject matter and scientific skills on the part of teachers. The approaches and enthusiasm of these curriculum development activities in mathematics and science have stimulated parallel work in the social sciences and humanities, and have stimulated commercial as well as school interests. As a consequence of the work of these 12 years the Foundation has established a reputation for competence in the improvement of science instruction, and has accumulated a background of experience in how instruction can be improved.

Furthermore, the scientists and teachers who have had NSF support, and the staff and advisors of the Foundation, now have some promising leads on ways of improving teaching for the prospective nonscientist. There is still a great gap between the Schools of Education and the rest of most universities, and a greater gap between the scientific community and the faculties which prepare most school teachers, but the number of scientists concerned with bridging these gaps has increased.

These scientists, and their students who are candidates for doctoral degrees in science education (either through Schools of Education or science departments), can be supported whether they are working on new curricular materials, machine-aided instruction, or the introduction of quantitative thinking to educationally disadvantaged second graders. Now, more is known about learning theory and about ways of presenting scientific concepts to students whose cultural background or personality traits are not those of most scientists. In addition there is a growing amount of interest at the college and university level in attempting to introduce all types of students to an understanding of the impact of science and technology on our modes of thought, our physical and social environment, our economy, and our public policy. This interest can be fostered, and we may hasten the day when some of these concepts are familiar to the high school students.

We *can* learn to improve the teaching of science and technology to *all* our young people. We reassert the importance of catalytic activity in these areas. Our economy needs not only physical scientists, mathematicians, biologists, and logicians but also engineers, mechanics, hospital technicians, and computer programmers. A working familiarity with science and mathematics is increasingly important for most ways of making a living. And a willingness to explore the technological questions of public policy is becoming an essential qualification for responsible citizenship.

We appreciate that we are proposing the Foundation extend its educational interests more aggressively to include junior colleges and teachers colleges, and vocational as well as college preparatory programs. We urge the Foundation to do so. Clearly the Foundation will wish to limit its activities to projects with significant hope of improving existing methods, and to projects others will copy if they are found good. The Foundation should consider support of projects it may find to be more properly the

business of the Office of Education or of a State Superintendent of Public Instruction. It may be useful to have some projects of real excellence supported by the Foundation in areas of overlapping responsibility. The Foundation will find it is increasingly involved with such commercial organizations as textbook and equipment manufacturers or film producers, and we would urge development of policy and staff adequate to manage these involvements.

Much of the substance of this report, including the recommendations in Part III, concerns what can be called educational research and development. The subject of educational R&D and the need for basic scientific research in education has received much critical attention lately. We first call attention to a number of studies on this topic recently completed or now underway.

In July 1969 a report,[1] prepared by the Bureau of Research of the U.S. Office of Education for the Organization for Economic Cooperation and Development, cited 10 recent studies of policy and practice in educational research and development. As listed there,[2] "Two of the studies have been conducted by committees of the Congress. Four have been or are being conducted by groups internal to the Executive Branch of the Federal Government. Two have been sponsored by independent policy bodies, one by an individual, Francis Chase, under contract to the Department of Health, Education, and Welfare, and one by a nonprofit corporation using Foundation funds."

Of particular interest is an ongoing study being conducted by the Panel on Educational Research and Development of the President's Science Advisory Committee and the report[3] of the Committee on Educational Research of the National Academy of Education.

The PSAC Panel is concerned with the need for:

(a) Basic research in education.
(b) Involvement of social and behavioral scientists and other relevant intellectual groups in carrying out educational R&D and evaluating projects and proposals.
(c) Much more research directed toward learning and development in very young children.
(d) A program of experimental schools such as those in England.
(e) New and more scientific ways to evaluate educational programs.

The NAE report calls particularly for "disciplined" scientific research in education and the training of manpower for this kind of research and development.[4] The training program they recommend calls for:

(a) Full-time study for three consecutive years.

[1] *Educational Research and Development in the United States*, Bureau of Reesearch, Office of Education, U.S. Department of Health, Education, and Welfare, 1969.

[2] *Ibid.*, p. 226.

[3] *Research for Tomorrow's Schools: Disciplined Inquiry for Education*, Lee J. Cronbach and Patrick Suppes, editors. The Macmillan Co., 1969.

[4] *Ibid.*, p. 206.

(b) Participation in research beginning with the first year of graduate school with increasing responsibility.
(c) Thorough grounding in at least one academic discipline.
(d) Study of the educational process and institutions: social goals, historical developments, learning, etc.

Summarizing these and other studies, the OE document[5] concludes as follows:

"Regarding educational research, several consistent judgments and conclusions emerge across the reviews and evaluations. The need to adopt a more forthright posture regarding the support of basic science relating to education is present, balanced by the equally strongly stated need to focus educational research, and particularly development, on the solution of high priority educational problems.

"The latter, especially, requires much more explicit delineation and specification of R&D objectives. A third continuing concern is aimed at the present quality of the entire research and development enterprise in education. Calls for closer ties to the parent disciplines and the involvement of more individuals of high repute from the social and behavioral sciences emerge with regularity.

"A fourth continuing thread can be found in the judgment that educational research and development is clearly undersupported financially and in great need of more forceful, and more directed, manpower development policies . . ."

The conclusions reached by our Committee do not differ in the main from those reached by these other studies. However, the focus in the present study has been the NSF with its special qualifications for the selection and support of educational R&D programs. The staff, standards, procedures, taste, associations, reputation, tradition, and experience of the Foundation all place it in a position where it commands the confidence and respect of all sectors of the educational establishment.

Equally significant are the special qualifications of the "hard scientist" with whom the Foundation has primarily dealt. The methods, attitudes, knowledge, tools, and experience of the natural scientist all need to be brought to bear on the problems of educational R&D. The past and highly successful partnership of these scientists with the Foundation in scientific research provides a specialized manpower resource of paramount importance for the success of future educational R&D programs.

[5] *Educational Research and Development in the United States, op. cit.*, pp. 258-259.

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PART II

A Review of Course and Curriculum Development Support

One of the Foundation's earliest activities after it was organized was an investigation of the nature and status of science education in the United States in an effort to identify its most serious deficiencies. Among the most important identified was the gross inadequacy of instructional materials available to teachers. Textbooks were attractive, readable, but usually badly outdated in content. Many students were studying material already obsolete, unimportant, and in some cases frankly wrong. Also, good instructional films were scarce, as were other instructional materials besides textbooks, and even good ones saw little use.

As a result of this investigation, the Foundation in 1954 began to support the development and testing of new science, mathematics, and engineering courses, as well as new curricula, instructional units, and associated teaching materials. This effort has been a pioneering one for a Federal agency. It has also, in our view, been one that has produced singularly beneficial results for education.

Accomplishments

There are several ways of looking at what has been accomplished. One is to examine the magnitude of the support effort. Through fiscal year 1969 more than 400 projects at the pre-college and undergraduate levels have been supported at a total cost of approximately 142 million dollars (see Figure 5). Of this number, 393 individual activities carried out by means of grants to approximately 170 institutions (universities, colleges, scientific societies, research institutes, and educational groups) are described in the booklet *Course and Curriculum Improvement Projects* (NSF 66-22) and its Supplement (NSF 69-21). Of the 393 activities reported, 10 are listed as general projects, 77 as elementary and secondary school projects, and 306 as college and university projects. Under elementary and secondary school projects, 16 are classified as multidisciplinary, 8 as astronomy, atmospheric and earth sciences, 10 as biology, 4 as chemistry, 25 as mathematics, 5 as physics, and 9 as social and behavioral sciences. The classification under college and university projects is as follows: 18 multidisciplinary, 1 agriculture, 13 anthropology, 34 biology, 24 chemistry, 116 engineering, 2 geography, 9 geology, 27 mathematics, 2 meteorology, 48 physics, 9 psychology, and 3 sociology. Of the 393 reported activities, approximately 108 are active or were only recently terminated, and approximately 285 are inactive in the sense that financial support has terminated.

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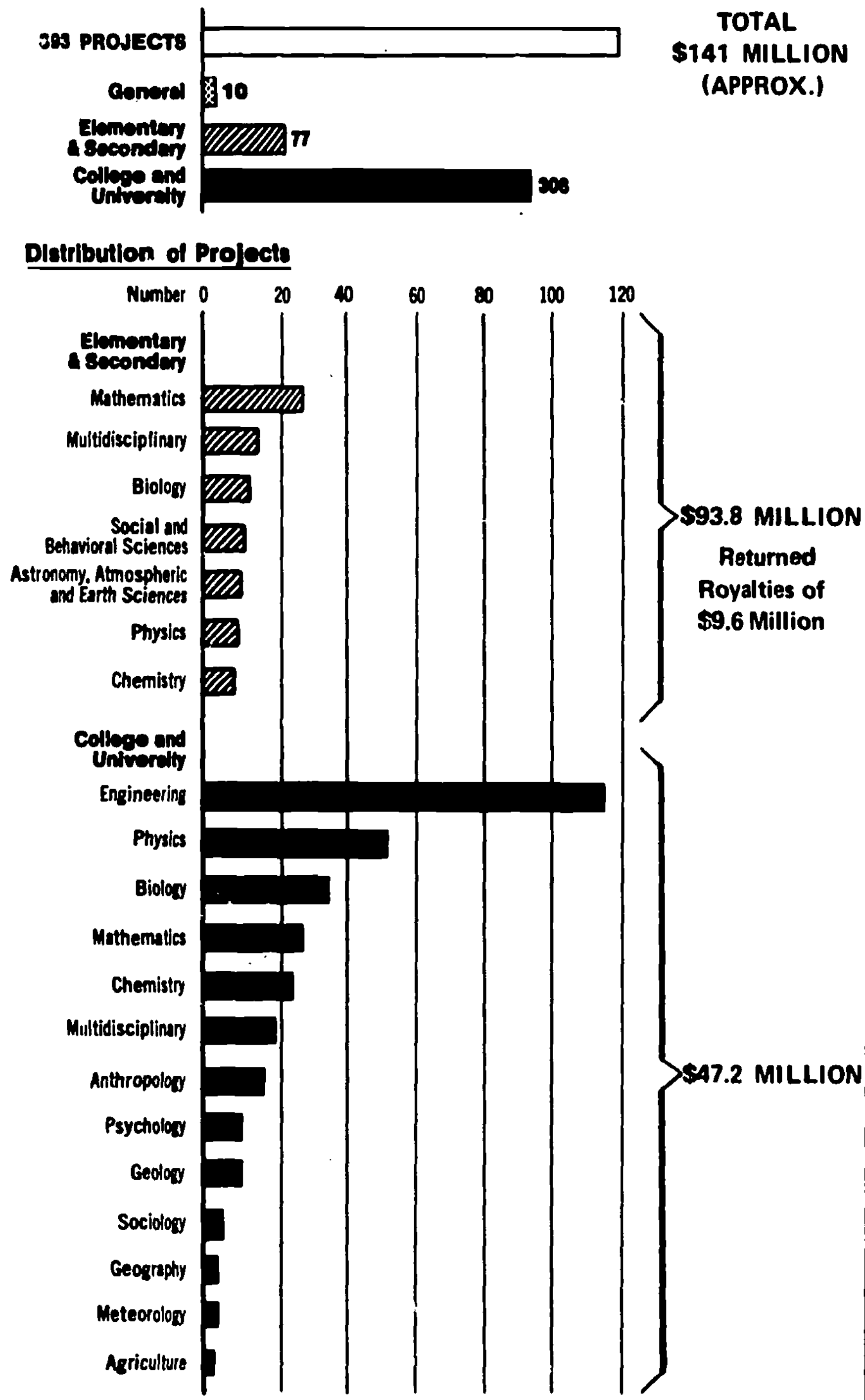
FIGURE 5

COURSE AND CURRICULUM IMPROVEMENT PROJECTS



But this is not the whole story of NSF support of course and curriculum efforts, since the projects described in the CCIP booklet and its supplement are limited solely to those administered by the Pre-college Division's Course Content Improvement Program and the Undergraduate Division's Science Curriculum Program (and by the precursor of these programs, the Course Content Improvement Section which handled projects at all educational levels). Through June 1969, at least 50 projects involving course or curriculum development at the graduate level have been supported by the Graduate Division's Special Projects program, and during the 2 years of its existence (FY 1968 and 1969) the Office of Computing Activities has supported approximately 50 computer-oriented projects having aspects of, or implications for, course and curriculum development. In addition, the Sea Grant Program, which has also been in existence for 2 years, has funded approximately 13 course and curriculum projects ranging from the technician (associate-degree) level through the graduate level.

Another way to look at the record of accomplishment is to measure the tangible output. The CCIP booklet and its supplement, while they are already somewhat out of date, give some idea of output at the pre-college and undergraduate levels. The information given in these publications is amplified by that given in the 72-page listing of *Released Textbooks, Films, and Other Teaching Materials* (NSF 68-24) and in the 21-page listing of *Translations and Adaptations of Instructional Materials For Other Countries* (NSF 66-P-28). NSF 68-24 lists approximately 1,500 items (ranging from pamphlets to a television course on "The New Biology" comprising 160, 30-minute films) available to students, teachers, and other interested persons. This number does not include special reports or preliminary versions of materials, which are numerous. Incidentally, as of June 30, 1969, $9,603,769 had been returned to the U.S. Treasury from royalty payments realized by pre-college grantees; no figures are available at the undergraduate level.

Utilization and Impact

What can be said about the use of materials developed under NSF grants? The concept of "use" at the undergraduate level does not have much meaning, partly because much of the emphasis here has been on coordination and stimulation of curriculum development efforts rather than on production of materials and partly because of pluralism in our colleges and universities. Some estimates, however, can be given for the secondary level. Of the 14,200,000 students enrolled in grades 9-12 in 1968-69, about 24 percent were using curriculum materials developed under NSF grants. This percentage represents an upper limit, since the project estimates are based on book sales, estimates of State educational agencies, and similar sources of information rather than a statistical survey of schools. Furthermore, some of the students take basic science and mathematics or social science during the same year. (See Table on p. 14.)

The figures do not appear unreasonable, however, when compared with those taken from a survey made by the State Department of Public Instruction in Delaware. A questionnaire was distributed in late 1968 to all 36 high schools in Delaware. Pertinent statistics from the report have been extracted and are illustrated in Figure 6.

ESTIMATE OF NUMBER OF SECONDARY SCHOOL STUDENTS USING CURRICULUM MATERIALS DEVELOPED UNDER NSF GRANTS IN THE 1968-1969 SCHOOL YEAR

Project	*Grade*	*No. of Students*
Biological Sciences Curriculum Study (BSCS)	10	1,500,000
Chemical Education Material Study (CHEMS)	11	500,000
Introductory Physical Science (IPS)	9	500,000
Earth Science Curriculum Project (ESCP)	9	250,000
School Mathematics Study Group (SMSG)	9-12	250,000
Physical Science Study Committee (PSSC)	12	225,000
Anthropology Curriculum Study Project (ACSP)	9-10	50,000
Chemical Bond Approach Project (CBAP)	11	50,000
Sociological Resources for Social Studies (SRSS)	11-12	30,000
High School Geography Project (HSGP)	9-12	11,000
Engineering Concepts Curriculum Project (ECCP)	12	3,500
Total		3,369,500

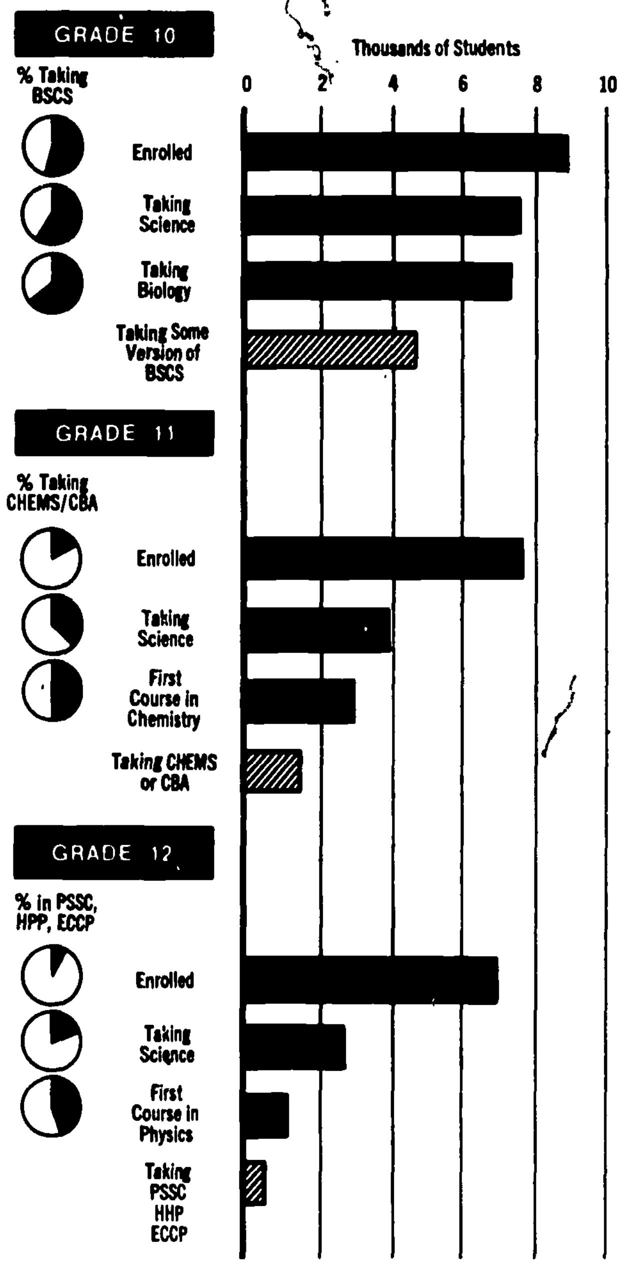
Finally we come to the question of impact. In getting some measure of this "immeasurable" we have relied on our own personal knowledge, the replies to our letter-questionnaire, the NSF staff interviews, and the comments of the experts who consulted with us. In addition, with respect to impact at the undergraduate level, we have also had the benefit of an evaluation study on four College Commissions carried out by the Planning and Evaluation Unit of the NSF Education Divisions. The general picture we have obtained of past efforts is given below.

All of the NSF-supported pre-college projects have been improvements over past efforts in that they have succeeded in introducing excellent content into all of the courses developed. As a result, more students now enter college with better preparation in natural science and mathematics than did a decade ago. Those teachers able to handle the materials now have a greater sense of "disciplinary professionalism" than before. There has also been some progress in helping school systems to improve their understanding of science resources for general education and to use them more intelligently.

High school textbooks resulting from NSF-supported projects have served as models for those produced under different auspices. BSCS provides a case in point. Prior to 1960, two biology texts were extensively used; one sold over 60 percent of the market and the other, 20 percent. In the 1956 edition of the more popular of the two, the word "evolution" does not occur in either the index or text; there is no material on human reproduction, population genetics, modern coverage of ecology, cellular metab-

FIGURE 6

NUMBER OF HIGH SCHOOL STUDENTS ENROLLED IN SCIENCE COURSES STATE OF DELAWARE, 1968-69*



Note: Although some students are taking CHEMS in grade 12 and PSSC in grade 11, making the total count somewhat larger than shown here, the essential picture is given above.

*Source: *The Status of Science Teaching in Delaware*, State Department of Public Instruction, Dover, Delaware 19901. June 1969.

olism or molecular biology, little physiology, no significant coverage of microbiology, nothing on race, and little cognizance of the modern developments in subject matter in the first half of the 20th century. The treatment of the material is quite elementary, and there is no laboratory work integrated into the text and little of the process of science or inquiry approaches. The 1969 edition of this same text shows accommodation in almost every instance along the paths developed by the BSCS.

From *The CHEM Study Story*[6] we quote the following: "It was found [in a May 1967 study] that of 10 new high school chemistry textbooks published between 1963 and 1967, five followed the general philosophy and content of CHEM Study with high fidelity. Three of the books were influenced somewhat by CHEM Study, as indicated by the inclusion of some up-to-date material on phases of matter, the mole concept, energy, rate and equilibrium characteristics of chemical reactions, and orbitals. Two of the ten were completely traditional in format and content."

Similar statements can be made about materials produced by other projects. Furthermore the high school materials generated by NSF grants have also had effects on texts prepared for more advanced students. For example, in *SMSG: The Making of a Curriculum*[7] it is stated: " . . . Recently published textbooks for courses in mathematics for teachers, almost without exception, refer to the influence of SMSG in their contents. The same is true of newer books on curriculum and on methods of teaching mathematics. . . ." Another example is given by the following preface to the college chemistry text *Chemistry, A Study of Matter:*[8] "The text examines various topics, building on and adding enrichment to many of those presented in CHEMS, CBA, PSSC and BSCS programs. . . . Some of the great scientific ideas discussed are a challenging, maturing extension of those presented in the new programs of CHEMS and CBA as well as of PSSC and BSCS. . . ."

Opinions vary as to which are the most successful of the NSF-supported projects, but it seems reasonable to conclude that some of the later starters, such as the Earth Science Curriculum Project, the Introductory Physical Science Project, the Engineering Concepts Curriculum Project, and the AAAS's "Science—A Process Approach" have been able to profit from the pioneering efforts—and mistakes—of the early starters. Less progress has been made in the social sciences and far less in interdisciplinary efforts to relate the natural sciences to each other, the natural to the social sciences, and mathematics to both. Nor has there been effective articulation in most cases between the grades and levels of education.

There seems little doubt that the benefits for bright, science-oriented, college-bound students have been appreciable. On the other hand, there are strong indications that the benefits for the less bright, disadvantaged, or even bright, nonscience-oriented students have been significantly fewer and perhaps even negative in the sense that the more difficult courses have "turned off" these students. Several reasons may be ad-

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[6] Richard J. Merrill and David W. Ridgway, W. H. Freeman and Company, 1969, p. 69.

[7] William Wooten, Yale University Press, 1965, p. 137.

[8] A. B. Garrett, W. T. Lippincott, and F. H. Verhoch, Blaisdell, 1968.

vanced for this differential effect, but an important one seems to be the fact that the prime movers of the projects have been university scientists and mathematicians with the desire (unconscious, at least) to further their own disciplines. Another reason is that the first products—PSSC, CHEMS, BSCS and SMSG—were specifically designed for the students then taking the established high school curriculum, a subgroup which, by and large, was made up of science-oriented college-bound students. It is not surprising that these courses have been more successful for the students for whom they were intended.

At the junior high school grades and below, the differentiation between poor and good students is no more evident in the use of the new curriculum materials than with any other materials. In these grades the target students are the entire student population, and the materials have been developed and tested in representative classrooms so as to be applicable for the entire student population insofar as that can be done. In the early elementary grades in particular the stage of the child's development as well as the subject matter has been, and must be, taken into account in selecting, organizing, and presenting teaching materials.

Role of the Teacher

The importance of the role of the teacher in achieving the maximum potential of new courses cannot be overlooked. Nor can the contribution made by NSF-supported institutes in equipping teachers to handle new materials. It is not our intention to go over the ground covered so well in *An Investment in Knowledge*,[9] the study of the first dozen years of the Institute Program. It might be well, however, to mention some of the findings reported by that study. For example, it is known that through 1965 approximately 150,000 "training opportunities" for teachers had been provided through institutes, and it is believed that about a third of the estimated 226,000 people teaching science and mathematics in 1964-65 had been to at least one summer institute. On the other hand, it was reported in a study conducted during the 1961-62 school year that more than half of the science and mathematics teachers in the Nation's high schools had not submitted an application to any institute during the previous 5 years. Despite this seeming underutilization of the institute mechanism for improving teachers and the failure of institutes to stimulate a genuine reform in their pre-service training, Dr. James B. Conant in his 1963 book, *The Education of American Teachers* stated that "the use of [NSF] summer institutes for bringing teachers up to date in a subject-matter field has been perhaps the single most important improvement in recent years in the training of secondary school teachers."

What about the specific relationship between course and curriculum improvement and teacher institutes? Some quotations from the Krieghbaum-Rawson study are of interest in answering this question. Dr. Jerrold R. Zacharias: "The National Science Foundation-sponsored PSSC summer and in-service teacher training institutes have been an essential part of the overall PSSC physics program. They perhaps more than

[9] *An Investment in Knowledge*, Hillier Krieghbaum and Hugh Rawson, New York University Press, 1969.

any other single influence have helped make the course immediately useful to teachers and students. . . ." Dr. George C. Pimentel: "I believe that chemistry teachers with strong background in content can teach CHEMS without too much retraining, but the average teacher probably would be well advised not to undertake this change without retraining. This is where the Summer Institutes play their vital role." Dr. Max Beberman: "Without the NSF Summer Institutes, any widespread inauguration of new curriculum reforms would be most difficult—if not impossible."

The opinions of our questionnaire respondents regarding the value of teacher institutes varied widely. One attributed a large part of the success of PSSC and CHEMS to good teacher training and the ready availability of the combination of texts, films, and laboratory equipment. Another found the quality of instruction in individual institutes to vary considerably and suggested a raising of standards even if that meant reducing the number of institutes and increasing the number of participants in the good ones. Others found institutes to be doing a good job in increasing the subject-matter knowledge of teachers, but a poor one in improving pedagogical techniques.

Impact on Higher Education

There are indications that a substantial number of institutions of higher learning have undertaken curriculum change in recent years and that others have either scheduled changes or are considering what changes should be made. What the impact of NSF-supported course and curriculum development has been in the midst of this ferment is somewhat difficult to determine, however. According to the results of the NSF evaluation study on College Commissions, the activities of the Commissions and changes in the secondary school background of the students are second in importance only to three traditional sources of influence on curriculum, i.e., changes in instructional staff, advances in research, and the requirements of graduate or professional schools.

The College Commissions and their impact could be discussed at considerable length. There seem to be differences of opinion with respect to the relative effectiveness of different Commissions, the relative value of the different methods they have used to inform, coordinate, and stimulate (newsletters, conferences, consultant services), and their relative effects on different types of institutions (small colleges, master's degree, and doctoral institutions). We believe we can safely state, however, that one of the most valuable effects of the Commissions has been to make the scientific societies—and the scientists they represent—more aware of their responsibilities in science education. Thus, the Commission on Engineering Education has been absorbed by the National Academy of Engineering, the American Institute of Biological Sciences and the American Chemical Society are carrying on projects spun off to them by CUEBS and ACCC respectively, and other societies have plans to continue the types of projects initiated by their corresponding Commissions.

While the College Commissions have perhaps represented the most visible type of project supported, it should be realized that expenditures on these eight groups have amounted to only about one-third of the total spent by the Foundation to improve courses and curricula at the undergraduate level. Other types of projects have made

solid contributions, some of which we shall mention by way of illustration. The Goals of Engineering Education project, partially because it has resulted in some controversial recommendations, is expected to have a profound—and we believe healthy—effect on engineering education. The Berkeley Physics Course and Laboratory, from which five volumes of text material have resulted, typifies those projects having a tangible output. The films on fluid mechanics produced by the Education Development Center epitomize what can be done in the area of educational films, thereby demonstrating that scientists and film makers can enter into fruitful cooperation. The BASIC language for computers is one result of a grant to Dartmouth College in which students have been taught the fundamentals of programming and the use of input-output stations to the Time-Sharing System. Attention has been given to the problem of science for the nonscience major by means of conferences and by the development of courses. One of these, the Integrated Course in Contemporary Science, developed at Berkeley, involves a unification of concepts from biology, chemistry, and physics; another, Physical Science for the Non-Scientist, developed at Rensselaer Polytechnic Institute, gives special attention to prospective elementary school teachers. Finally, a significant start has been made in the development of courses and materials for technicians by means of grants to the Wentworth Institute, the Polytechnic Institute of Brooklyn, the University of Illinois, and the American Chemical Society.

To conclude our discussion of impact at the undergraduate level, we would like to mention some of the deterrents to improving courses and curricula suggested by the respondents to the Committee questionnaire (not necessarily in order of importance): teacher qualifications and attitudes, inadequate facilities and equipment, the amount of time and energy required just to keep existing operations going, the vested interests of college administrators who are afraid of change, the prevailing view that what one publishes is more important than the quality of his teaching, and the common belief that failures in courses are due to the inadequacies of the students rather than to the lack of adequate teaching materials and adequate preparation on the part of the teachers. Presumably these factors and others have had a lot to do with the degree to which supported projects have been able to bring about meaningful reform.

We have not been able to get a measure of the impact of the very limited support NSF has been able to provide for course and curriculum development at the graduate level.

Overall Effects

Our questionnaire asked that the respondents evaluate both the size and quality of the overall impact of NSF's support thus far of science education activities (including more than course and curriculum development). Not all chose to do so but, for what it is worth, nine rated the *size* of the impact as "large," two as "between large and modest," one as "modest," and none as "not significant." With respect to *quality*, seven checked "highly beneficial," five checked "beneficial," and no one checked "not significant," "harmful," or "very harmful."

The respondents were also asked to give their opinions as to which educational activities have had the greatest beneficial effect, which the least, and the reasons why.

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It would not be fair to draw any general conclusions from the disparate comments that were made. However, of the seven respondents who had explicit answers to this question, six selected, as among the most beneficial activities, instructional program development (as opposed to teacher or student development), curriculum development, or the development of curriculum materials. Also mentioned as beneficial were projects emphasizing problem-solving or those emphasizing the unity of science, activities that allow students to learn in ways not available in typical programs, fellowships, funds for equipment purchase, and teacher institutes. (Some respondents listed more than one beneficial activity.) There were not enough nominations for "least beneficial" to be meaningful, but one respondent, who regards pre-college teacher development and graduate student development as probably having less of an impact in proportion to expenditure, gave as his reason that they frequently reinforce existing situations and are not tied in with other developments.

Summary and Conclusions

It has not been possible for us to quantify what has happened since the Foundation undertook the momentous step of becoming concerned with, and involved in, what kind of science and mathematics is taught in classrooms and laboratories throughout the United States (and indirectly throughout the world). But we have reached some conclusions about the worth of it all. These are based on some personal biases, to be sure, but they are buttressed by factual information, some of which has been given here, and by the opinions of others not on the Committee or the NSF staff. We would not go so far as to say, as one of our questionnaire respondents did, that "the NSF has done an incredible job for science education in this country. Far more and better things have happened than [in] any other place on earth directly as a result of its work." But we give high marks not only for effort but for accomplishment, and not only for the quality of materials produced but for the establishment of a fruitful new technique in which scientists and teachers work together in the development of materials. Much has been learned by those involved in any way with what has happened in the last 15 years, but much remains to be done, and that brings us to the next part of our report.

PART III

Recommendations

We assume in making the recommendations which appear below that—

(i) Science and technology have essential contributions to make in the formulation and solution of critical societal problems.
(ii) Understanding of (i) can and must be extended through education to all of the population.
(iii) The National Science Foundation can and must lead the way.

The recommendations require that the Foundation accord a higher priority in its overall program to science education. In the past, the emphasis in the Foundation's programs has been on educating future (or potential) scientists in science *per se*. The present and the future of society, including science itself, require that emphasis be placed in new directions; specifically, (a) the education of the nonscientist in science and the role of science at all levels of instruction, and (b) the education of the future scientist beyond his discipline to prepare him in skills and attitudes required to play a full role in relating science through technology to the needs of society.

The task for NSF is summed up in the charge written on the cover of this report: "To educate scientists who will be at home in society and to educate a society that will be at home with science."

This double commitment cannot be fully met without a significant increase in available funds. However, the nature of the commitment is such that it is anticipated that funds will be forthcoming that could not at the present time be obtained for programs aimed solely at the discipline-oriented training of future scientists.

GENERAL CONSIDERATIONS

In the following text, we make general recommendations for the Foundation in its support of educational R&D, i.e., recommendations not limited to any particular level of instruction.

Grants for Research in Science Education

One of the most prevalent and recurring themes in the Committee's investigation concerned the need for grants to educational research projects modeled on the more modest sized grants made by the Research Divisions of the Foundation. A growing number of scientists, senior and junior alike, have found a continuing interest in research in science education and seek support along traditional lines for themselves and graduate students. Both research in science education itself, and the training of specialists in science education at the doctoral level, appear to be highly desirable end products of this type of programmatic support.

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However, in the past, proposals for such projects have been at a disadvantage and have not, by and large, met with enthusiasm or support from the Foundation. There are several reasons for this. First, and most obviously, since the research is in science *education,* support from the Research Divisions has been ruled out. Second, the guidelines and criteria often employed in the Education Divisions in the past have favored projects with a "national flavor" where the production and implementation of educational materials was a prime objective. Such criteria would automatically exclude most individual research proposals in science education.

A third factor which has tended to act against the support of research-type proposals in science education derives from the high priority placed on "evaluation" and "implementation" of materials already produced or to be produced under a grant. A strong case can be made for evaluation and implementation when dealing with developmental projects such as those whose objective is widespread adoption of a new curriculum. However, these criteria do not seem appropriate for evaluation of research-type projects. Important though evaluation and implementation are, the Committee is of the opinion that, for the Foundation, research must take precedence over development in science education for a time. From this research can come the knowledge upon which major reforms can be based.

Accordingly, the Committee recommends the making of grants wherein one faculty member (or a small number of faculty) at a single institution, together with students who are candidates for doctoral degrees in science education (either through Schools of Education or science departments), are supported for their research in science education.

Doctoral theses produced under such grants and dealing in depth with matters of importance in science education under senior direction will be valuable in themselves and will serve to initiate continuing careers of study in such matters. For the "next generation" of Foundation grants for curriculum development and other types of educational programs, this would appear to be a mechanism for achieving the kind of basic disciplined research in science education which is being called for on all sides. It offers a most attractive alternative to the "team" approach so largely used, for example, in the first generation attempts at curriculum improvement, an approach that is perhaps less suited to basic studies.

Teacher Training

It does not require sophisticated systems or critical path analyses to come to the realization that, whatever else is done in improving science education, the ability, knowledge, and attitude of the individual teacher is what makes or breaks it. The questions are when, what, and how to teach the teachers and whose job is it? That they must be taught new skills and that learning must become a continuing process for teachers is beyond question. But with Schools of Education and the Office of Education and the whole marvelous panoply of school districts, boards, accreditation, professional societies, legislatures, and other inputs and controls, what is the legitimate role of the National Science Foundation?

The pre-service training in science of future elementary and secondary school teachers in teacher colleges and Schools of Education is clearly a special area of concern and responsibility for the Foundation. This is covered by a recommendation in the appropriate section below under *Undergraduate Education* calling for appropriate programs in support of innovations and increased and improved science content in the pre-service training of teachers. More can be, and has to be, accomplished here perhaps than anywhere, since it is this enormous corps of teachers which must be reached and educated before they can adequately educate the young.

Beyond just pre-service training, however, the Committee accepts the argument that the Foundation has a unique role to play in the science education of practicing teachers because it has the "right taste" and because educators professionally responsible for the training of teachers often have little interest in subject matter. This argument is further strengthened by the fact that the curriculum of the future elementary teacher is too crowded to permit extensive science education in college and also that changing science requires continuing postgraduate education for teachers. Consequently, the need is recognized for summer, academic year, and in-service institutes.

The Committee recommends continued support of institutes for teachers as long as a significant percentage of new participants can be attracted and as long as subject matter is genuinely upgrading.

Having made these recommendations, however, the Committee, recognizing the realities of budgets, cannot help but be alarmed at the inevitable restrictions on support by the Foundation for creative research in science education, if it projects for itself a major responsibility for the training of school teachers.

The Committee recommends therefore that in teacher training, as elsewhere, the Foundation limit its role to innovative efforts.

Educational Technology

No analysis of the present and future needs in education, and in particular science education, could fail to recognize the importance of technology. Whether this refers to the computer in all its possible roles, or systems in which man and machine function together according to their abilities and needs, it is clear to all that what we have seen is only the beginning and that much more lies ahead. The promises of individualization of instruction and information networks may now be merely promises, but even the severest critics of extravagant claims are pleading for support and encouragement of research.

Accordingly, the Committee recommends that adequate funding be committed to support experimentation and innovation in the application of technology in furthering the education of the individual and the group.

Science Education Outside of the Classroom

Here we are concerned not only with the outside activities of students but also

with adults who have concluded their formal education. Education outside of the classroom can take many forms such as museum activities, travelling exhibits, films, television, amateur science, articles in newspapers and magazines, and as has been suggested elsewhere,[10] some form of science extension service not unlike the agricultural extension service developed in the early 20th century in every State and county as a means of disseminating information.

We recommend that the rather limited support presently provided for these kinds of activities can be significantly expanded.

Science and Public Policy

This is a topic that extends far beyond the responsibilities of the National Science Foundation and, within the Foundation, permeates every administrative unit. We refer here both to "science for policy" and to "policy for science." The Foundation has already contributed significantly to the former by its support of basic scientific research and assigned areas of applied research (weather modification and sea grants), science education, dissemination of scientific information, and international science activities, and by its generalized institutional support programs. The Committee regards the establishment of the Research Divisions' new Office of Interdisciplinary Research on Problems of Our Society as a way to make even more meaningful contributions to "science for policy."

We recommend that a similar step be taken by the Education Divisions.

This need not be done by the establishment of a new administrative unit. Greater use can be made of existing programs, particularly the Special Projects programs in the Undergraduate and Graduate Divisions, to support activities designed to train young people, or to retrain mature scientists, to deal with such public issues as environmental pollution, the effects of drugs, crime, urban planning, transportation, and communications.

"Policy for science" is itself a public issue of ever-increasing importance. The Committee is aware that the Foundation is only one of several agencies (Federal, quasi-Federal, and private) concerned wih such problems as Federal support for science, the allocation of funds among various disciplines, the geographic distribution of science dollars, the organization of Federal science activities, the management of R&D, and the needs for scientific manpower. We believe that one of the chief contributions the Education Divisions can make in this area is in an increased public understanding of science and, to this end, we make recommendations below regarding precollege and undergraduate instruction for nonscientists. Courses and activities should cover not only substantive science but also the relationships among science, technology, and society. Nor should courses on science, technology, and society be limited to nonscientists. Prospective scientists, both at the undergraduate and graduate levels, should be exposed to the history and philosophy of science and to the cultural and

[10] "Science and Social Attitudes," Robert S. Morison, *Science* 165, 150-156.

sociological implications of science and technology. Moreover, at the graduate level, the Foundation ought to support educational programs designed to train experts in the newly emerging field of science and public policy.

Accordingly, we recommend that the Education Divisions expand their support of projects directed at increased public understanding of science so that the Foundation can make a meaningful contribution to national science policy.

SPECIFIC RECOMMENDATIONS BY LEVELS OF EDUCATION

Pre-College

At this level we are concerned with elementary, junior high, and secondary schools and with all students in these schools regardless of whether they are college bound. Moreover, we are concerned with curricula as well as individual courses and with the total environment in which learning takes place.

Course and Curriculum Improvement. The need for course content improvement has not disappeared. More needs to be done.

The Committee recommends first that course content improvement programs still in progress—what we may term "first generation" attempts—be supported to their conclusions.

The feeling among the leaders in course content improvement is that first generation attempts should be followed, not by second attempts at doing the same things, but by precedent-setting attempts to solve key curriculum problems. Courses need to be developed which are relevant to the interests of the students and society, but at the same time capable of preparing the college-bound, science-oriented student for undergraduate work. These must take into account the range of abilities, backgrounds, and varying vocational interests of children and young adults. If this requires more than one kind of approach, then different approaches should be supported, so that all students graduating from high school will be equipped to live in a technological world. Our citizens should be as literate with respect to science and technology as with the traditional three R's.

The articulation of mathematics with science, of science with technology, and of technology with the future of man and society, poses the greatest challenge we face in the area of curriculum. Without this articulation we will continue to suffer from a long list of educational ills which threaten both the future of science and of society. To cite just one effect, profiles of student interests in colleges show sharply dropping interests in science and engineering and yet students are more concerned than ever with societal problems such as environmental control. Many see no apparent connection between these as areas for study. This same schizophrenic division seems to exist in the minds of many legislators as well. Undoubtedly the fault lies not with our citizenry but with their education and its conventional breakdown of instruction into disciplines. Second

generation curriculum attempts must emphasize the interdisciplinary nature of science and technology.

The Committee therefore recommends (a) that second generation attempts in course development be focused on interdisciplinary, problem-oriented approaches that provide for differences in student abilities, backgrounds, and vocational objectives, and (b) that new curricula provide "vertical integration," that is, orderly and planned sequences of experiences and contact with science as a student moves through the pre-college grades.

The Committee has concluded and further recommends that in carrying out second generation efforts, less attention (and support) should be given, than has been in the past, to the development of polished end-products.

The Foundation emphasis should be on the creation of innovative materials which can then be taken to a final stage by others.

The Committee also recommends that teachers be key participants in the final stage of curriculum development and polishing.

Social and Behavioral Sciences. The Committee calls attention to Chapter VII of *Knowledge Into Action: Improving the Nation's Use of the Social Sciences.*[11] This report calls for a new direction of Foundation effort in recognition of the understandings and insights of the social sciences, their role and application to the problems of American society, and their particular needs as these disciplines assume their new roles in the Seventies.

In the pre-college area there is a dual reason for emphasis on support of the social and behavioral sciences. First, the understanding needed of the processes of education of the young, and second, the communication to the young of the content and spirit of these disciplines.

The Committee recommends greatly increased support for the social and behavioral sciences with particular emphasis on the area of pre-college education.

Experimental Schools. Beyond course content improvement, as significant as such improvement is—

The Committee recommends that the Foundation staff make a careful study of experiments now being carried out involving changes in the total school environment and explore ways in which the Foundation might appropriately support the activities of experimental schools.

Changing the total school environment calls for major efforts and suggests the need for cooperative efforts with other agencies.

[11] Report of the Special Commission on the Social Sciences of the National Science Board, 1969.

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Undergraduate

At the undergraduate level we are concerned with several types of students and several types of institutions: science majors in 4-year colleges and universities, non-science majors in the same institutions, elementary and secondary school science teachers in pre-service training, and technicians in training at 2-year community colleges and technical institutes.

Experiments in Undergraduate Education. The primary concern of the Foundation in undergraduate education must be science. But science education, by necessity, takes place in the rapidly changing environment of today's campus and is not and cannot be isolated from the questions and pressures to be felt on all sectors of the college and university community. Indeed, science and technology are often made the special subjects of criticism and reevaluation by faculty, students, and administration. Relevance in every sense of the word, cost and effectiveness are being examined with a toughness of mind new to the formerly sacred cow of science.

At key institutions we see changes in admissions, curriculum, requirements, grades, and campus living that amount to complete restructuring of undergraduate life and study. Under these conditions, college-level projects in science education may not be separated from experiments involving changes in the total undergraduate experience.

Accordingly, the Committee recommends that the Foundation, at selected institutions, broadly support curriculum modification and other components of educational change which occur as part of a restructuring of the total undergraduate experience.

Because of the complexity and cost of such experiments, it may be necessary to explore possibilities of joint funding with other agencies.

Science for the Nonscience Major. The previous section goes beyond science education *per se* to the total educational experience of the undergraduate. The present section is concerned with science education but goes beyond the prospective scientist and his education to the nonscientists who make up the bulk of the undergraduate population.

Much has already been said in this report about the need for a citizenry informed as to the relation of science to society. As in the case of pre-college education, it is necessary that the courses and materials generated for the undergraduate level serve to communicate the value and relevance of science to the individual and society as well as the concepts of science.

Accordingly, the Committee recommends that much more effort be put into the improvement of courses and teaching of science for the nonscience major.

Science for the Science Major. Narrowing down to the science major himself, we reiterate the need for scientists who will be at home in society. Let us add the hope that these scientists will find a welcome home in society. This requires education beyond a single science discipline and indeed beyond science.

There are two main points we call attention to in educating the future scientist. First, the need to have a science education which is (perhaps) less discipline-oriented and (certainly) more problem-oriented. This education will be inter- and multi-disciplinary, building upon a pre-college education with the same emphasis. Of particular significance, it is felt, would be extensions of the so-called "process" or "activity" approach of the AAAS pre-college program wherein students are called upon to participate actively in meaningful projects rather than to remain as passive spectators in lecture style classrooms.

Second, there is the need to educate the prospective scientist in the role of science and the scientist to serve the needs of society. This second requirement can be coupled closely and tangibly to the previous one through the selection of science problems and projects which serve to demonstrate the relation between society's needs and science's power to formulate and solve problems.

The Committee recommends the support of interdisciplinary problem-oriented science programs designed to improve and extend the undergraduate conception of science and demonstrate the relevance of science to society.

Pre-Service Training of Teachers. Without a well-trained corps of elementary and secondary school teachers we cannot hope to impart to pre-college students the kind of education and attitudes in science that this report calls for. Much can be done with institutes and other postgraduate education to assist in the preparation of teachers. Yet much of this is, admittedly, a "retread" job. The primary place to educate the teacher is in his pre-service training. The Committee believes the Foundation has a fundamental responsibility to upgrade the science education of teachers through any and all mechanisms.

Accordingly, we recommend that programs be developed and supported for dramatically increasing and improving the science component in the pre-service training of teachers.

This attempt will meet with enormous resistance both passive and active on the part of professional educators and Schools of Education. This resistance must be overcome and the cooperation of all sectors must be obtained through conferences, interagency cooperation, and all other means of communication. This most critical problem must not go unsolved because of traditional hostilities and rivalries in our institutions.

Training of Technicians. Much can be written about the need for a cadre of well-trained, second-echelon technical personnel to perform many science and engineering tasks in industry, government, schools, hospitals and so on. Often these positions are unfilled, filled with undertrained personnel, or filled by more highly trained scientists or engineers whose talents are thereby underutilized. Such positions offer meaningful careers in our increasingly technical society for many young people. There are, today, an increasing number of institutions concentrating on 2-year degree programs for the training of technicians for a very large variety of fields.

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In consideration of this question, the Committee recommends that the Foundation place increasingly greater emphasis on the support of 2-year programs for the training of technical personnel looking to the creation of a large and well-trained supporting echelon of technicians in science and engineering.

Graduate

The Division of Graduate Education in Science of the Foundation provides funds for fellowships and traineeships in science on the one hand and special projects (including course and curriculum development) and advanced training projects on the other. It is necessary to call attention in this report to the serious lack of funding and even diminishing funding in relation to needs in both of these areas. The entire scientific effort of this country depends on a continuing supply of Ph.D.'s in all areas of science, whose training is second to none. Yet we are assisting fewer of our best students percentage wise and even in absolute numbers each year, at a time when the cost of higher education continues to mount. Moreover, we are spending almost nothing on projects designed to improve the quality of graduate education. The absurdity of this becomes all the more striking when we consider the investment already made to upgrade primary and secondary education and to set new high standards for all undergraduate education in science through the college commissions.

The case for these programs within the Foundation must be made with utmost vigor.

Fellowships and Traineeships. Recent studies have once again shown that the overall supply of Ph.D.'s in science, despite alarmist statements to the contrary, will not be equal to the anticipated expanding needs of the future. We need more Ph.D.'s in science, and we need the fellowships and traineeships which extend graduate study opportunities to the best qualified students in the country.

The Committee most strongly recommends an expanding program of fellowships and traineeships for graduate study in science.

Special Projects. Innovations in course content, curriculum, teaching, cross-disciplinary projects, use of educational technology, etc., are needed in graduate education in science as badly as in lower levels of education. We know we need more Ph.D.'s for the future, but we are not at all sure that they should continue to be turned out along the patterns of the past.

The Committee recommends that special projects in graduate education be encouraged and supported at a meaningful and appropriate level.

Practitioner's Degrees. There is a need for new degrees in science at the doctoral level for the substantial number of highly trained experts who, rather than creating new knowledge through research, will be engaged in the practical application of existing knowledge. The Foundation should be providing support for the development of these degree programs and for students who are enrolled in them.

A specific proposal concerns the degree of Doctor of Arts for college teachers. Mass college education will arrive in the seventies and there is no reasonable prospect of placing a research-trained Ph.D. in the classroom before every college science student, or even of having one in every department in every college. The Ph.D. degree can be reserved for the relatively small number of graduate students who are qualified, and who seek to do original research. A degree such as the Doctor of Arts could be awarded to a considerably larger number of students, broadly trained in advanced studies, trained in college teaching, and dedicated to teaching as a career.

The Committee recommends support for "practitioner" degree programs such as the Doctor of Arts and for qualified students enrolled in these programs.

Master's and Specialists's Degrees. The need for large numbers of persons with different levels of training in science and engineering suggests the need for a revitalization of the traditional Master's degree. Positions in industry, government, and teaching—especially in 2-year colleges—will offer meaningful careers to a large number of properly trained people. Unfortunately, the Master's degree, in many cases, has either vanished or become a hardly identifiable stepping stone on the way to a Ph.D.

The Committee recommends that support be given to efforts to revitalize the Master's degree as preparation for intermediate careers in the teaching and practice of science.

A number of institutions, it should be noted, are offering so-called Specialist's degrees which go 1 year beyond the Master's in training. These programs address the same problem and deserve support as well.

POLICIES AND OPERATIONS

Policies and Operations

In making its study and seeking to make substantive recommendations, the Committee has encountered questions which refer to the Foundation's statutory authority; to staff, organization, and policies of the Foundation; and to the operation of the Foundation. The recent reorganization of the Foundation dates some of these questions and appears to answer others. However, some remain and the following recommendations are intended as suggestions which perhaps can assist the Foundation in carrying out the recommendations made in previous sections of this report.

Clarification of the Role of the Foundation in the Education of Nonscientists

On several occasions, interviews by the Study Group revealed what appeared to be unnecessarily restrictive interpretations of the legal position of the Foundation in the education of nonscientists. Thus, while it has been allowed to support, on a relatively large scale, projects for the education of pre-college students (who have not made any final decisions regarding career choices), of undergraduate science majors, and of graduate students in science, projects involving nonscience majors or the lay public who

have completed their formal education have been supported only on a small pilot-scale basis.

We recommend that the restrictions on the role of the Foundation in the education of nonscientists be reexamined and, if reexamination proves the restrictions to be legally binding, we recommend that the Foundation seek from appropriate legislative and executive agencies the authorization of programs for the education of nonscientists, which seem to us to be clearly in the national interest.

Development and Utilization of a Sociological Data Base

Much of the information received in this study has indicated the need for increased relevance of science instruction to the lives students live and to the pressing problems of urbanization, environmental pollution, dwindling natural resources, transportation, employment patterns and the economic system, and the alleviation of poverty. Another strongly indicated need is for the application of research skills to solve these problems. We conclude, in short, that we must press the scientific effort to serve human goals and human purposes wherever possible.

We therefore recommend that the Foundation explore means to provide for itself and those engaged in furthering science education a data base of sociological and demographic information to afford better insight into the human ends that can be served by science.

To this purpose it may be appropriate to develop further the programs of the Foundation's internal planning organization or to seek out such information from other agencies, Federal or non-Federal. In any event, it is essential to have maximum communication and utilization of these data in formulating and carrying out the educational programs of the Foundation.

A More Active Role for the Staff

We have examined the working styles of the staff of the Education Divisions and found them to be limited largely to a passive or reactive role to ideas generated from the field. In our judgment, the role and style of the working staff should of necessity become more active and less passive. The staff must seek out, and seek out *in the field*, promising directions of development, identify the competent men of science and education, open new frontiers, assess weaknesses and, with the aid of "judgment by peers," select and fund those efforts that will define, shape, and further the expanding roles of the Foundation.

We therefore recommend that the staff be encouraged to assume a more active role in the field and to seek out promising directions, promising men, and promising institutions both to define and to carry forward the work of the Foundation.

This recommendation has budgetary implications as it calls for a larger staff and more money for travel. These are dealt with in the next section.

Budget and Staffing

Budget allocations for the science education effort are not only inadequate for present responsibilities but need major increases to accomplish additional roles and reach new goals. In our judgment, this is a key limitation in the educational effort and may be true throughout the Foundation. The inadequacies become most apparent operationally in staffing and staff travel. It is the Committee's judgment that staff limitations and actual cutbacks have weakened staff morale and produced serious overloads. More importantly, staff and travel limitations have almost eliminated the needed outside contact and have seriously limited the outreach of the Foundation. If the Foundation is to assume an active leadership role and to break out of its isolation from the scenes of action, the matter of staff and staff travel will have to be met much more effectively than at present.

A program of sabbatical leaves and exchanges between staff members and members of university faculties, research laboratories, State departments of education or higher education, and the business-industrial community is needed. Certainly, the level of professional experience and continuing performance required of many Foundation staff members justifies these practices and for the same reasons that these are justified for corporation middle-management, college professionals, research staffs, and others. Failure to provide such opportunities for renewal and upgrading takes its toll in fatigue and isolation from professional contacts and the research laboratory, all of which contribute to rapid turnover.

We are aware of directives from the executive branch of the Government to hold down expenditure, the reduction in force by nonreplacement, and the limitation of new ventures and reduction in level of funding of many current commitments in the interest of cooling the economy. However, it is assumed that these restrictions are relatively temporary. The problem of budget for the Foundation is of much longer standing. Part of the problem results from a limitation clause placed on appropriations which commits a major portion of the funding of the Education Divisions to teacher education. We urge review of the whole Foundation budget in terms of priorities and programs.

Some of these arguments may be appropriate for inclusion in future fiscal year budget requests. For example, it is estimated that to change the image of the Foundation from passive to active agent, the budget for staff and travel would need an increase of approximately 50 percent. Travel allotment needs to be related to the function. Some programs involve many small grants widely scattered. Other programs need extensive developmental work in the field. And for all areas there is need for contact and visitation to identify and encourage new leadership in science.

We therefore recommend that the Foundation review its efforts to seek adequate funding of staff and staff travel sufficient for present programs as well as for the expanded role recommended in other parts of the report.

Education and Research Divisions—Coordination and Liaison

The activities of the Committee have made us aware of the need for effective communication between the Research Divisions of the Foundation and the Undergraduate and Graduate Divisions in Education. Whether communications are presently adequate we cannot judge. However, effective communication, coordination, and liaison between these Divisions with their special staffs, interests, knowledge, and outside contacts seems to us to be essential to the success of future educational efforts of the research-oriented, interdisciplinary, problem-approach kinds that we have recommended.

The Committee therefore recommends that the question of effective working relationships between Research and Education Divisions be reviewed.

One particular area of concern in the matter of interdivisional cooperation is connected with Foundation support of computer-related programs. In studying this support we were struck by what appeared to us to be a serious inconsistency. It seems that the Office of Computing Activities, which was established in response to a Presidental directive, was intended in part to serve as a mechanism for coordination and liaison between other divisions to provide more effective overall Foundation support to the development and use of computers. What in fact appears to be the case is that support for computer activities has become more and more limited to those projects which the OCA can itself directly fund.

Accordingly, we recommend that much more direct support for computer-related activities be forthcoming from the Education Divisions and that effective liaison for technical guidance and support be set up with the Office of Computing Activities.

Relationship Between the NSF and the U.S. Office of Education

The Foundation's activities in science education try to take into account programs and plans of the Office of Education insofar as they are known. There is, at present, coordination between the two agencies on a number of projects and in specific program fields, for instance, teacher training. Relationships and interaction between the staffs have been amicable and helpful; several members of the Foundation program staff serve on advisory councils and panels of the Office of Education. Recently, the two agencies have initiated discussions to arrange, on a limited basis, exchange of individual staff members.

There is, however, no general agreement on the related roles of the two agencies in the field of science. By congressional and executive decision, the Office of Education has the major responsibility for administering Federal support extended directly to schools and school systems at the pre-college level, particularly in regard to funds apportioned on various formula bases. The Foundation is authorized to further the quality and quantity of science education, which of necessity will involve some efforts for the lower schools. However, comparative funding of the two agencies reflects a

major role for the Office of Education in the lower schools and a minor role for the Foundation.

There are those who generalize to say that any Federal responsibility for science instruction in the lower schools should be assumed by the Office of Education and the Foundation should limit its educational efforts to the undergraduate and the graduate levels. Others feel that the Foundation should continue its instructional improvement efforts, its pilot programs, its development of instructional materials, and model implementation efforts, leaving to the Office of Education responsibility for mass dissemination of such ideas and materials as are appropriate. There is danger within the present confusion and potential misunderstanding of roles that the research and development effort in science instruction in elementary and secondary schools may be lost between the two agencies. It has certainly been true that, in recent years, the Office of Education has not had funds available to support the kinds of projects that the scientific community and the Foundation staff have deemed crucial to continued improvement of science eduation at the pre-college level. The sheer size of the Office of Education's responsibility is such that the Foundation should have continuing concern for the nature of science education in U.S. schools. There should be no thought of abandoning its present roles in elementary and secondary education unless and until it is assured that continuing concern with the upgrading of the science component is being handled in an appropriate manner through alternate programs.

In statements received by the Committee it was apparent that the style and prestige of the Foundation is an important factor in any assignment of roles in science education in the elementary and secondary schools. The ability of the Foundation to attract major scientists and scholars to work on problems and to develop materials has been a distinguishing feature of its work of the past decade. It is important that this interest and effort on the part of the scientific community be sustained.

We therefore recommend that the Foundation continue its support of research and development in pre-college science education, with appropriate strengthening of liaison between the Foundation and the U.S. Office of Education at all levels of operation to assure working understandings and appropriate interaction between the two agencies.

Use of the Talents and Resources of Nonacademic Organizations

In the development of the first generation of educational materials, the Foundation has relied primarily on institutions of higher learning and scientific societies. This was certainly not inappropriate and was in keeping with the traditional mode of operation of the Foundation as a whole. In the development of second generation materials, however, serious thought should be given to utilizing the talents and resources of nonacademic, nondiscipline-oriented organizations.

Many organizations with competent research staffs that have been concerned, for example, with defense and space problems will, if conditions permit, change directions and become involved with domestic, earthbound problems. It is possible, even likely, that with their interdisciplinary, problem-oriented approaches they could make a

unique contribution to course and curriculum development, educational technology, and other areas discussed in this report. Other organizations that could be expected to make contributions are those that are already engaged in the production of innovative educational materials or who are developing technological educational systems.

The Committee recommends that the Foundation recognize the resources for educational research and development lying outside the academic community and move to encourage and support the utilization of these resources in meeting its educational goals.

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REMARKS BY DR. JOSEPH B. PLATT

(Chairman, Advisory Committee for Science Education, 1969)
Before the National Science Board

March 20, 1970

Last year the National Science Board requested the Advisory Committee for Science Education to evaluate the support the National Science Foundation has given to course and curriculum development for science teaching in our schools and colleges from the inception of such support in 1954 to the present. We were also asked to make recommendations concerning the support of future programs for the improvement of science teaching. We now submit this report to you, which represents about 1 man-year of labor on the part of members of the Committee—particularly Drs. Herbert J. Greenberg, James F. Nickerson, and George H. Baird—the staff and consultants. I will summarize our year's findings, and Dr. Greenberg will deal more specifically with our recommendations.

To begin, about 400 projects for course and curriculum improvement were sponsored by the Foundation during these 15 years. The projects took place at 170 institutions and cost, in total, approximately $142 million. The majority of the projects, about 300 of the 400 total, were intended to improve the undergraduate teaching of science. Most of the money, about $94 million of the $142 million has gone into the support of larger projects intended to improve the teaching of science in the elementary and secondary schools. The net cost to the Federal Government of the pre-college projects is about $84 million, since nearly $10 million have now been returned in the form of royalties on the new teaching materials. The tangible output of these curriculum development activities include some 1,500 items: texts, teachers' manuals, laboratory materials, television courses, movies, film strips, etc.

There is no way in which we could "prove" through controlled experiments that the new teaching materials are better than the ones they replace. Any such evaluation is a major undertaking and must be built in at the beginning of the program. Only in one case—the School Mathematics Study Group (SMSG)—has evaluation of this sort been attempted. For the SMSG, approximately $2.5 million of a $10 million program to date has been invested in overall evaluation and the studies are still in progress. No other course content improvement program has an evaluation effort of like scope.

We do know that a significant fraction of all high school students take science courses which the NSF has assisted in developing. In the 1968-69 school year, about 3½ million high school students were taking one or another of these courses, about one-fourth of the 14.2 million students in high school that year. During their 4 years of high school, some students have several courses in science which the NSF has supported and others have none. Still, there is no question that the NSF support has had a major influence on the teaching of high school science. There has also been a consider-

able influence on the teaching of mathematics and natural science in the elementary schools.

These course and curriculum development activities have also influenced many of the teaching materials and much curriculum planning which never had NSF support. Textbooks now used in high school biology, chemistry, physics, and mathematics, frequently acknowledge the influence of the NSF programs, even though these texts were produced quite independently. Professional groups in the humanities and the social sciences have also developed teaching materials using approaches pioneered by the NSF programs, quite apart from any work the Foundation has supported in the social sciences. In short, the influence of the NSF programs goes well beyond the work the Foundation has directly supported.

The next question is whether this has done any good. Granted that many students are now exposed to the results of the NSF's programs, are they any better taught than they were previously? To find out, we questioned expert witnesses at some depth. We tried to find enthusiastic witnesses, skeptical witnesses and some who claimed to be impartial. We ran into the usual problems; we had little time, less money, and we would have needed formal approval to carry out a full-scale survey, which would have required more time than we had. We wrote some 30 people, of whom 22 responded. The replies were long and thoughtful. We invited several of the respondents to meet with us for 3 days last summer, and they did. We also interviewed a number of members of the NSF staff, themselves former teachers, who know the course content improvement work in great detail.

There is also a great deal of published testimony on the curriculum development activities. For example, the Biological Sciences Curriculum Study (BSCS) can claim more than 400 articles in the professional literatures. Other course content improvement programs have also given rise to books and articles of comment and criticism. Everyone who has worked with the NSF materials seems to have an opinion of them. A good many of these opinions are published, and we tried to familiarize ourselves with these opinions, too.

We found there was very general agreement that the NSF programs had accomplished one of their major purposes: to modernize the content of science courses, to teach the science that working scientists in the second half of the 20th century believe is now important. For a great many students it is no longer true that they learned their 19th century science in high school and their 20th century science in college. College teachers have repeatedly told us that entering freshmen in their institutions arrive considerably better prepared than they did before these curriculum development activities existed. The level of entering chemistry courses, entering mathematics courses, entering physics courses, has had to be raised in the universities and colleges because we cannot bore students who come from high schools with the NSF type of preparation. There is also a good deal of agreement that these entering college freshmen have learned, not only more subject matter, but more of the skills and methods of approach of present-day science.

We have heard that these materials are less successful for students who do not plan to go to college or who do not expect to make any use of science in their

professional careers. This again is a matter of opinion; and, for what it is worth, I give you our Committee's opinion. *We believe that each of the new courses has accomplished about what it was designed to do.* For example, the course designed by the Physical Science Study Committee (PSSC) was intended to replace, update and upgrade the existing high school physics course. Only about 20 percent of the high school students take physics, and nearly everyone who does expects to go to college. It is not too surprising that the PSSC physics course works best with this group. The Chemical Education Material Study (CHEMS) is also less effective with dull students than it is with bright students. That was true also of the traditional high school chemistry courses that CHEMS replaced. We believe the NSF programs have been most successful with the target audiences for which they were designed. Some of the more recent programs are intended for students who do not think they will need science in their careers, and we will be interested to find out how successful they are in attracting more students to the study of science.

Over the last 10 years, to the best of my recollection, the number of students in high school or college physics has held fairly constant, but these students are a smaller percentage of the growing enrollment. Chemistry has shown more increase, but not in proportion to the total number of students. The number of students taking mathematics, and in particular the number of students taking advanced mathematics in undergraduate colleges, has definitely increased.

We believe that course content improvement activities of the NSF have had a much larger impact on primary and secondary education in the United States than is generally appreciated, and the impact has been good. Primary and secondary education in the United States is a big business. It includes some 51.5 million students, over 2 million teachers, and decisions are made in some 20,000 school districts. The total expenditures for primary and secondary education in the United States during the decade from 1959 to 1969 came to about $250 billion. The amount of money the NSF put into the course content improvement activities for primary and secondary schools over a slightly longer period was less than $100 million, or about 4 cents on every $100. It is not easy to revise either the content or methods of teaching, and we believe no other single cause has had as much impact on the revision of the high school curriculum over the decade. A great deal has been accomplished with that investment of 4 cents on the $100.

There have been changes other than the revision of the curriculum which may be even more important in the long run. Working with the NSF programs has given a substantial minority of high school teachers a feeling of identification with the science they teach, a feeling that they are part of the profession of science, as are their colleagues in higher education. Developing these ties helps the teacher to know some of the excitement of science, to be able to share it with his students and to take greater responsibility for the development of his own teaching resources.

Another consequence of the course content improvement programs is that the NSF has demonstrated what can be accomplished in curriculum revision to others than the teachers and students of science. Professional groups in other disciplines are improving the ways of teaching their subjects. The Foundation staff has been consulted

by school boards and supervisory school personnel, and has worked with textbook publishers, film producers, and equipment manufacturers. The system of formal education is a complex one involving Federal, State, and local government, private corporations, and many different professions, as well as involving all our future citizens. The Foundation staff has learned a great deal about how things can be made to happen in this complicated system and has helped teachers' associations, school boards, governors' offices, and textbook publishers in their learning. This, too, may be of great importance in the long term.

One may argue that not enough has happened in the improvement of science teaching at either the college or pre-college level. One may also argue that much of our student population has not been touched by any of the NSF programs, including many whose lives will be greatly influenced by science. One can also argue that, in retrospect, some of the Foundation's course content improvement activities could have been done differently and perhaps better. We do not quarrel with any of these statements, and we will return to them. But *we reiterate our conclusion that a great deal has been accomplished, that the education of millions of young people has been bettered by the work of the Foundation, and that this has been accomplished at very modest cost in view of the results.*

The Advisory Committee spent a good deal of time on its second assignment: What recommendations should we make for the Foundation's ongoing activities in science education? It was our consensus that not only is science education in trouble at the present but, so is science, and so is education. The causes are deep, and the causes are continuing. We believe the Foundation has a particular role to play in mending some of the gaps between what is and what could be.

We all know that society has been transformed by science and technology. Forty years ago laborers (farm and nonfarm) made up 20 percent of the labor force. They now constitute 7 percent. Forty years ago the managerial, professional, and technical workers made up 14 percent of the labor force: we are now 24 percent. The shape of the labor force has changed dramatically. Formal education on a grand scale has been one of the essential conditions for this change. The change has paid off for us socially and economically. The average per capita personal income, in constant dollars, has increased 103 percent over the past 40 years. Increasing productivity is not the sole end of education—the end of education is to increase our understanding and, hence, to increase the choices open to us as individuals and as a people. But having more goods and services available to us helps to increase those choices.

We now have a great deal more information we can exploit than we had 40 years ago. The *Physical Review Letters*, for example, have trebled in the course of the last decade. Publications in the sciences have doubled every 10 years throughout this century. Library holdings double about every 18 years and have since the time of Thomas Jefferson. Since publications in the sciences grow more rapidly than total library holdings, something must grow more slowly, so I looked up Shakesperian scholarship. Indeed, the doubling time on Shakesperian scholarship is about 40 years.

We, of this Committee, concerned ourselves not so much with the availability of information, but with making that information useful. How is it taught? Teaching has

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also had its explosions which give straight lines on semilogarithmic plots. Three techniques we have used in education in the United States have served us well as far back as there are good statistics, which is about the 1870's. The first technique is that we teach increasingly more people. The second is that we teach any one person longer. The third is that we make any one person responsible for a smaller fraction of the total of knowledge, that is, we specialize. The fraction of the age group receiving any education beyond the sixth grade in the 1870's came to about 7 percent. Currently it is about 95 percent. At the turn of the century, 4 percent of the age group of college age actually got into college; in 1920 it was 8 percent; in 1940 it was 16 percent; in 1960, 34 percent. Currently about half of the people of college age in the United States have some form of post high school education. The number of doctorates produced in the United States has doubled every 10 years since the 1880's.

In the 1870's, a sixth grade education—the ability to read, write and cipher—was all the education required for most members of the labor force. The average person now entering the labor force has about 13 years of formal education. A new Ph.D. entering the labor force has 20 years of formal education and some specialties, such as brain surgery, may require as much as 26 years of formal instruction before the person is able to practice on his own. So the average person in the labor force now spends about one-sixth of his life span in formal education. Many specialists have spent about one-third of their life span in formal preparation.

It is more difficult to quantify the growth in specialization because there are few agreed definitions of what constitutes a specialty. However, I estimate the doubling time on specialties has been around 10 years. At the time of the First World War, for example, the medical man was a physician and surgeon. There are now at least 30 types of medical specialists, and it would take a year or two of internship or residency to shift from one specialty to another. As for engineering: from the time of Julius Caesar to that of Napoleon Bonaparte, the engineer was a military man. The civil engineers got their name by specializing in civilian engineering problems, and this first division in engineering came in the 1830's. The mechanical engineers appeared in the 1860's, the electrical engineers in the 1890's, and there must be at least 200 engineering specialties now which are more different, one from another, than the civil and military engineers were 140 years ago.

These three techniques of teaching more people, teaching any one person longer, and teaching him less of the total of knowledge, have been extremely important to us socially and economically. Through these techniques we have accomplished the changes in what we can now do as a Nation and the allocation of manpower within our labor force which makes this possible. We really have made an expanding body of knowledge socially useful.

We cannot continue to teach more people, teach any one person longer, and teach him less of the total. We cannot teach more than 100 percent of the population of the age group at the high school level. We now admit 96 percent of the age group to high school, and we graduate 79 percent. It now appears that by the middle 1970's half of our college-age young people will get some post high school education, and a quarter of them will earn the baccalaureate.

I do not think every teenager has the aptitude or the inclination for college; even if he did there are not many factors of two left here either. The length of formal education is also limited. For the specialist one can only double the period of formal education once more, and for all the rest of us only twice more. It is harder to prove that specialization is limited in its continuing growth. A consequence of specialization, however, is that it becomes increasingly difficult for differing specialties to understand each other, and we may be approaching some limit of that sort.

But let us look at the economic and social forces which are really limiting our ability to teach, to continue to exploit knowledge by further use of three methods which have served us so well for the last century.

As for teaching more people: now that we have nearly 80 percent of the age group graduating from high school, the remaining 20 percent is in much more trouble than high school dropouts were a generation ago. A high school education, or its equivalent, is very nearly a precondition for entrance into the labor force. The young people who are educationally disadvantaged, culturally deprived, or who just plain do not like school, are in much more trouble than they were a generation ago. It is harder to find work and it is harder to make a living, it is harder to find adequate ways to learn on the job. This is one source of our social unrest. It is also true that a college education, or its equivalent, is increasingly necessary for managerial or professional employment. Hence, more families expect their children to go to college whether or not the idea appeals to the child, and both parents and children consider it a right rather than a privilege to have a college education. These circumstances give us a larger fraction of our college population who are there with no great enthusiasm and who can be separated from college only with meticulous attention to due process.

As for teaching any one person longer: when I went to college I had already had some experience earning my own living and so had a good many of my college classmates. I knew I could support myself and be responsible for other people. Most of our children are denied this opportunity. The educational system is arranged so that they are in their middle twenties before they can be responsible for themselves and for others. It is pretty frustrating to be biologically old enough to be a grandfather before one can be economically self-supporting, or socially self-sufficient. Hence, we hear from the Students for a Democratic Society, and many of their sympathizers: "We are being tooled up for a world we never made. Our education is irrelevant to our hopes and the System is set against us."

As for specialization: any major job now takes many different specialties and, hence, requires not only specialists but people whose task it is to explain to the specialists how they are cooperating. These administrators, staff men, communicators, and systems engineers are frequently in greater demand than the specialists themselves. Someone has to understand what the whole job is about, and such people are in increasingly short supply.

In a larger sense, we also need to have common purposes and common understandings as a people. Technology really does shape our lives and shape our options. It is, therefore, an essential part of education for citizenship to have a general understanding of science and technology, and it is a national need that this understanding be

widely diffused throughout the population. We do not have an adequate consensus today. Each of us feels a little alienation because we do not understand what other people are doing. We do not understand, and we are suspicious.

In summary, our Committee has found itself agreeing that the techniques which have aided us in the exploitation of knowledge for over a century cannot, by extension, be expected to help us much more than another 20 or 30 years. We are already feeling the pangs of the economic and social dislocations which must bring teaching and learning into equilibrium with other activities of our people. Let us speculate on the nature of the equilibrium. Where are we going? What is the steady state, and how are we most likely to get there constructively?

Any steady state will, I hope, involve teaching more people; involve teaching any one person longer; and will accommodate some new specialties. We cannot suddenly terminate a century of expansion without frustrating millions of our young people and depriving the society of the contributions we had hoped those young people would make. But it behooves us to make this next portion of our expansion deliberately, thoughtfully, and with full consideration of the things which remain to be done.

One attribute of the steady state, for which we hope, is that our educational system really be responsive to the needs and hopes of all our young people. One consequence is that we must provide more different kinds of education and develop new methods of approach at the primary level, at the secondary level, etc., to the postdoctorate level. I am not arguing that everyone should have 20 years of education, I am suggesting there should be career paths available for everyone in the population to help him make the best use of his personal aspirations and talents. We already know enough to know that even at the primary level we need differing types of education for students of differing backgrounds and differing aspirations. People will continue for varying times in formal education, but it will be important to us in the steady state to have an educational system with enough flexibility and variety so that no segment of our young people is denied the education which will help its members to live and work with the rest of us, simply because they do not start where the rest of us did.

In the steady state I hope we will give a great deal more attention to ways of combining working with studying. It never has been true that one quits studying when he leaves school and goes to work. And we have a growing number of on-the-job training programs, executive refresher courses, and extension programs to provide help in formal study for people who are also working. I hope we will find better ways to begin this mixing of working and studying earlier in the life of the young person, and to continue it longer. The most selective of our institutions find that we have more and more students who wish to take a year off to see what the world is like. We need ways for our 14-year-olds as well as for our 40-year-olds to shift from studying to working and from working to study.

Another characteristic of the steady state is that we need *a larger common body of knowledge and experience which is shared by all our citizens.* For the reasons we have just suggested, they may very well obtain this information that is to be common knowledge in different ways and at different times in their careers. But if we are to work successfully, as a people, toward common purposes, we simply need more shared

understanding than we now have. Science education is, in our judgment, a most essential component of this common body of knowledge. We need more understanding of mathematics, of science, and of the methods of science for an increasing number of our future citizens, simply because they will need that knowledge in their jobs. They may not be scientists, and they may never contribute a new finding to the body of scientific knowledge, but they will need to understand computers, traffic flow, air traffic procedures, the uses of the ocean, and many other aspects of science and technology in order to be good mechanics, machinists, technicians, policemen, nurses, or vegetable growers. The success of our whole technological society depends on scientists, to be sure, but it also depends increasingly on the technical competence of many other vocations to make use of new technology. It may be more important to our national well-being that we teach understandable and useful physics to machinists and medical technicians, than it is that we really challenge our potential theoretical physicists. For one thing, there are going to be a great deal more people in the former categories.

We believe it is even more important that basic understanding and "feel" for science and technology be widely diffused through our population, including those who may not need this information to make a living. We need lawyers, journalists, ministers, stockbrokers, and truckdrivers who are sufficiently at home with science and technology to know that these social forces can be made to serve us all and how to go about it. These people may never design a computer, but they should know that computers are designed and operated by people, and that with their help people can make sense out of great masses of data. In a world in which we will need to make increasingly careful use of our air, our water, and our food, they will need to know how we can manage these resources with respect for the world our children will inherit. Common purposes do require common understandings. Science education can contribute greatly to the common understandings of the citizens who will manage our affairs at the turn of the next century. This seems to us an extremely important business.

The experience of the last 15 years has given the NSF more competence in approaching these broader problems of science education than is available to any other organization we know. Improving all of science education in the United States is a tremendous undertaking. How does one improve the teaching of teachers? What can be done to provide better science instruction in our junior colleges? How can one help a State department of education? The staff of the NSF now has experience with each of these problems and enjoys the confidence of scientists and teachers in developing new approaches to better science education. These are tremendous assets.

One may ask whether it is the proper business of the NSF to improve the education in science of people who do not expect themselves to become scientists. Is this not the business of the Office of Education? Is this not the business of the newly proposed National Institute of Education? Is this not the business of the newly proposed National Foundation for Higher Education? A partial answer to this question is, certainly, it is everyone's business. Furthermore, there will be enough for everyone to do. But the NSF does have unique experience now in making possible the catalytic changes in which others can join. The Foundation is accustomed to working with pilot programs which, when successful, are adopted by other organizations and supported with other

funding. The staff of the Foundation has learned to identify the bottlenecks in the creation of new programs and to help others to remove these bottlenecks. It seems to our Committee that the Foundation has a singular responsibility and opportunity in this area of science education for all our young people. It will, of course, become a shared responsibility. The improvement of the teaching of science for prospective scientists has also been a shared responsibility.

We do not argue that the NSF should double the science education budget immediately to undertake this new responsibility. Obviously, one does what he can with the resources at hand. We do argue—and argue with all the force at our command—that better science education for all our young people is a matter of substantial national priority for which the Foundation has singular qualifications. It should be very high on the list of tasks which can appropriately be addressed by the NSF as resources become available.

The converse of this task is to educate scientists more knowledgeable about the impact of science on the rest of the society, and better able to communicate to nonscientists the opportunities and the issues which the uses of science present. Here, too, there is much the NSF can do, and there are good beginnings on which to build.

I ask my colleague, Dr. Greenberg, the current Chairman of the Advisory Committee for Science Education, to present our specific recommendations.

April 1970

Note: Much of the material of the second portion of this paper has appeared in *Science Year*, 1969.

REMARKS BY DR. HERBERT J. GREENBERG

(Chairman, Advisory Committee for Science Education, 1970)

Before the National Science Board

March 20, 1970

Mr. Chairman and Members of the Board:

Let me talk directly to the report. First, I call your attention to the detailed recommendations of the Advisory Committee; there are some 30 in number divided into three groupings.

The first group of recommendations is general in the sense that they are not limited to any one level of education. The second group is specific by levels of education, namely, pre-college, undergraduate, and graduate. Finally, there is a group of recommendations relating to policy and operations; things that we stumbled on in our study which we thought we should include in the report. These are of less concern, particularly since in the course of this study many changes have already occurred in the Foundation under its new Director.

In my remarks today, I will group the recommendations somewhat differently in order to give emphasis to the main ideas and priorities as viewed by the Committee.

I begin with a few qualifying remarks. Dr. Fontaine, in his statement at the authorization hearings, arranged the Foundation's programs in education into three categories. First, those directed toward students; second, those directed toward instructional personnel; and third, those directed toward the instructional programs themselves. Our study, by your direction, was primarily concerned with the instructional programs. However, we have necessarily had to look at the other two categories. As a result some of our recommendations fall into the other categories. However, we would like it to be understood that recommendations in these other categories, and those dealing with the preparation of teachers in particular, are not meant to be comprehensive. The training of teachers is an involved question in itself. The Committee wishes to go on record on certain points about which it feels strongly, but we do not want these recommendations to be taken as a blueprint of a program for the future training of teachers.

Another preliminary remark is that we are not calling for the termination of essential continuing programs (directly or by omission in our recommendations)—there *are* essential continuing programs.

Now a final preliminary remark. Many of the changes that we are calling for in this report are already discernable within the Foundation. It is a year since we began this study, and the staff at all levels has been intimately involved in the discussions.

They have been more than responsive, and the Committee is very pleased to see that our discussions are bearing fruit.

With these explanations and qualifications, let me proceed to tell you some of the main ideas contained in our report.

First, I would like to call your attention to the phrase on the cover of the report which states the task ahead for the Foundation in science education:

> **To educate scientists who will be at home in society and to educate a society that will be at home with science.**

That phrase states, I would say, the primary message of this report. It seems to us that people are now willing to accept this task. A year ago it might not have been accepted. Action is already being taken toward these goals and much of the possible argument-discussion which might have arisen as a result of these recommendations may hopefully have disappeared. But we *are* seeking what we consider to be a new and a double commitment from the Foundation.

First, we want the Foundation to lead in improving and changing science education for nonscience students. We seek to advance the understanding by all Americans of science and technology, its content, and especially its human and social values.

Second, we want to improve and change science education for the science student. We want science students to appreciate the role of science and to have both the desire and the ability to use science in the solution of broader problems of society.

These innocent-appearing statements of purpose hold broad implications as you begin to examine programs at the various levels of education. Let us look first at the pre-college level. *We think this is going to call for a "second generation" of course and curriculum improvement programs. The new generation of materials is going to look a lot different from the first one.* It is going to be interdisciplinary and multidisciplinary. It is going to be genuinely *problem-oriented rather than discipline-oriented.* It is going to provide for a great deal of variation in individual backgrounds, abilities, and interests among students. It is going to begin with the very young and continue through secondary school with a planned and growing sequence of experiences with the subject matter of science.

In the second generation of course content and curriculum improvement, we would like to see much less attention paid by the Foundation to the production or "implementation" end of the business, i.e., widespread production and dissemination of published materials, and more concentration on research and innovation. We do not yet know *how* to achieve the kind of second generation materials for which we are looking. The support of the Foundation should be directed toward finding the way.

We are calling, too, at the pre-college level, for a new emphasis on the social and behavioral sciences. This is so obviously required that I need not comment further here; but let it be noted that the problems and attitudes of the social and behavioral sciences and the methods and tools of the physical sciences must not continue to be taught in isolation from each other.

At the level of undergraduate education, what are the implications for instructional program change in the new commitments we are asking of the Foundation?

First, there is a question of policy. The Foundation has, in the past, taken as its mission in education the training of future scientists, hence never felt uncomfortable about supporting programs designed to teach science to *all* students at the pre-college level. Justification? All children are potential scientists. However, support from the Foundation for the teaching of science to nonscience students at the college level implies a policy change inasmuch as the purpose clearly goes beyond supplying future scientific manpower. The mission here is public understanding of science. The Committee has taken the position most vigorously that it is indeed the business of the Foundation to support the development of new courses and materials for the nonscience student. These must communicate the value and relevance of science to the individual and society as well as the concepts of science.

For the undergraduate *science* student, courses have been designed primarily in the past for their content in a specific science—chemistry, biology, physics, or mathematics. Now, we look forward to changes in emphasis and direction. It is to be hoped that the new accents in the pre-college years will be continued and that there will be open to the college science student an interdisciplinary, multidisciplinary and problem-oriented kind of undergraduate experience which will broaden his conception of what science is and demonstrate to him the relevance of science to society.

Let it be noted that these changes may well also serve to increase the quantity and improve the quality of future scientific manpower. Many students in the colleges and universities are antagonistic toward science today and these include some of our most talented young people, certainly many who are concerned with the future of society. A broader kind of undergraduate opportunity to understand the relevance of science might attract people into scientific careers who are today turning aside from science and technology. These are people we need.

Let me turn from this thread of course content and curriculum programs to more sweeping changes which are in prospect in *the total instructional environment*. The very terms "course" and "curriculum" refer to an educational format that we have inherited. It is a familiar way of doing business but, as Dr. Platt has previously pointed out, we cannot expect to continue doing the business of education in the old ways forever. Hopefully, this report will have some relevance to the years ahead. We see on the horizon some revolutionary changes in education which go far beyond the mere content of courses. They aim at a total restructuring of the educational experience. The Committee believes that the Foundation must support experimental programs in education which may differ drastically from the past. Now again this has implications at the pre-college level and implications at the college level.

At the pre-college level, many of us are fascinated by *the Leicestershire type* of experimental schools in England. We recommend that the Foundation study these schools and then take appropriate action in support of experimental schools in the United States. The price tag may be very large; perhaps it will have to be done with help from other agencies. It is our belief that the environment in these schools, which encourage learning through activities and in which learning takes place according to the pace, abilities and interests of the child, should be particularly conducive to the learning of science.

Moving to the college level, we must face the fact that science education takes place in the rapidly changing environment of today's campus and cannot be isolated from the pressures and criticisms, justified and unjustified, to be found on all sides from state legislators as well as students; indeed, science is often made a special target. Science education must be viewed as a part of the whole undergraduate experience. With this undergraduate experience being turned on its head with regard to admission requirements, grades, course requirements and so on, we cannot in the Foundation just continue to support what amounts to packaging little things off in a corner. Therefore, it may very well be that the Foundation should support, at a few selected institutions where exciting things are happening, experiments at a very broad restructuring of undergraduate education. That implies support extending beyond science education. But the point is that it may not be possible to separate the *scientific* component of education from the *whole* educational experience.

Before leaving the group of recommendations which deal with the instructional environment, I wish to make a strong plea on behalf of the Committee for support of technology in education. Computers are, of course, the particular form of technology which currently dominates the stage in education. However, the next decade will surely see computers and communications combined in new technologies of great significance for our mass education needs. The recommendation of the Committee stresses that the promises of technology for individualization of instruction and information networks may now be merely promises but only through support and encouragement of research-oriented programs can progress be made. There is general agreement, even among critics, that now is the time for research in the use of technology in education.

I turn to a recommendation for change in the manner of support for instructional programs; what might be called the "style" of making grants in education. In the course of the study leading to this report, we had a number of people tell us that we must support "basic disciplined research in science education." Specifically, they recommended more education grants modeled on the research type grant with which the Foundation is very familiar. Typically, the grant would go to a faculty member, with one or two graduate students, to pursue an original plan of research relating to science education. This might involve a new manner of instruction, a new kind of course, a new way of presenting material, a new way of using computers, etc.

There are several implications of this type of grant. The first bears on the question which was mentioned before of end products. You are just not going to get polished materials of instruction out of this type of educational project. Moreover, you are not going to be able to measure the success of the project by the usual criteria advanced by the people in schools of education. It is more in the nature of research than development, and each project is inherently a high-risk venture. You cannot expect, for example, that any one of the projects is going to educate 20,000 students in a new seventh grade course in a year or two. It is a different kind of a game, the object of which is to discover promising new approaches to science education. Development would presumably follow upon research at a later time.

The second implication of research style grants is that, through the support of graduate students, a generation of people trained for careers in science education will

be produced. These students will achieve doctoral-level degrees under the direction of able people, scientists committed to science education, and they will do a thesis on a research topic in science education. We have not seen many of these kinds of grants and we feel that there should be a lot more of them in the future. Such grants, by providing support for faculty and graduate students, will also serve to encourage the spread of degree programs such as the Doctor of Arts, designed for future college teachers, reserving the Ph.D. for the science research specialist.

I turn now to a few peripheral recommendations. These are not at the heart of our study, but we feel compelled to call attention to these related matters.

In teacher training we see a continuing need for in-service training and institutes, but we are basically tired of the business of reeducating teachers whose original education was inadequate. This is particularly true of elementary school teachers. We are certainly not for sinking a large proportion of the future funds in education available to the Foundation in this way. *Our recommendations, therefore, stress pre-service education.* We think the Foundation has to do something to improve the education of teachers while they are in college. We find that the Foundation is moving in this direction, but there is a lot more that has to be done.

Next, I turn to graduate student production. The report contains a recommendation made many months ago concerning the need for more fellowships and traineeships to support graduate studies. Since that time there has been a lot of discussion about the number of Ph.D.'s in the country, an apparent oversupply created in certain fields, and a general atmosphere of anxiety. We now find ourselves faced with the situation where $9½ million has been lopped off funds for NSF traineeships in the next budget. Our recommendation said—and at that time there was as yet no cutback by the Foundation and other agencies—we are concerned that there is no *increase* in this kind of support. In the last two years support was held essentially constant and therefore decreasing in terms of percentage. Now, there has been a very drastic cut.

The Committee discussed the $9½ million Foundation cut earlier this week, and I want to report to you that we are enormously alarmed by it. We do not see any justification for it at all. We think that in making this cut, the Federal Government is tampering with a little understood *ecological* chain, although an institutional and social one rather than a biological one. We have no idea what the consequences are going to be of this action in the future. We urge that before any such drastic actions are taken, at least some attempt should be made to study the implications in terms of what it will do to developing institutions, what it will do to the *social* environment surrounding the institutions, how it will affect the funds which have already been invested by the Foundation, for example, the institutional programs, and so on. We earnestly plead for doing whatever you can to reverse this decision or at least to redistribute funds. Dr. Platt and I agree, and I believe the Committee would concur, that we would rather see the cut taken in fellowship funds than in traineeships since the fellows tend to gather in only a few institutions while traineeships are widely distributed around the country. We hope that it will not be necessary to cut fellowships or traineeships as this is a time to encourage new interdisciplinary graduate programs which, being new, may be the first hit by such cuts.

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Another recommendation relating to students has to do with training technicians. A technical society needs technicians. We know the story well, and I will not dwell on it. We recommend supporting 2-year college programs for technicians. In the graduate area, we recommend support for what are often called practitioner's degrees. These are advanced degrees for people who are not developing new science but who intend to apply what we already know. One type of practitioner degree would be for future college teachers, the Doctor of Arts already referred to.

In the final group of recommendations relating to policies and operations, there is one recommendation which I think needs to be brought to light at this time. This concerns the need in the Foundation for more staff. Consider for a moment the new programs which we are all talking about and calling for; for example, the interdisciplinary programs relevant to the needs of society. There is simply no way to judge major proposals in these areas without the staff going to these places and talking to faculty and administration to see how seriously the institution is committed to the programs. If a staff member is on a site visit he cannot be in his office. Therefore, you just simply have to have more people around.

By way of conclusion, may I read a paragraph or two to you from our report:

"This is a year of debate on priorities of many urgent social needs and of slowly growing resources. The Federal Government has many competing demands for the support of pure and applied research and of education. The National Science Foundation has limited additional funds with which to support any increase in its present programs, or to support additional programs the Foundation initiates or others ask it to undertake. Any proposal for new initiatives must be made in the context of other thoroughly justified claims on the same money and talent.

"We are quite convinced that the proposals advocated in the preceding chapters are part of the solution and not simply an addition to the problem. Effective action to meet our social needs will often require the application of science and technology, and will often require the understanding and direction of many people, not themselves scientists, who know the power and the limitations of science and technology. It is to the broadening of this understanding, to the competence of this direction, that our recommendations are addressed."

PART VI

Appendix

On May 1, 1969, the National Science Board formally requested the Advisory Committee for Science Education to take a retrospective look at the Foundation's support of course and curriculum improvement projects, to make a broad evaluation of these efforts, and to make recommendations regarding the future role of the National Science Foundation in science education.

The first step taken was the formation of a Study Group composed of Drs. Herbert J. Greenberg, Chairman; George H. Baird, and James F. Nickerson. At the outset the Study Group decided that it was beyond the capability of the Committee, in the time allotted, to make an exhaustive study of even the major projects supported. (Some idea of the magnitude of effort that would have been required is illustrated by the fact that a *partial* bibliography of articles published on the effects of the Biological Sciences Curriculum Study and its materials lists more than 400 references.)

Rather than focusing on the study of individual projects, therefore, the Study Group chose to approach the problem in a different way. On May 16, 1969, they sent a letter questionnaire to a group of 30 scientists, engineers, mathematicians, and other experts in education. The Committee chose to send the questionnaire to a small number of carefully selected people to sample the thinking of recognized leaders rather than surveying a larger, less carefully controlled group. Twenty-two replies were received, and copies were distributed to the full Committee. A list of those responding is is on p. 55. The questionnaire was designed not only to get some idea of the general impact of past efforts but to elicit suggestions as to future directions.

On June 11-12, the Study Group met in Washington to interview Foundation staff members who have been involved in programs supporting course and curriculum development (including programs of the Office of Computing Activities). Also interviewed was Dr. Norman Boyan, who at that time was Associate Commissioner for Research of the U.S. Office of Education. During the course of the staff interviews the Study Group decided it would be useful to have the staff members reply to the same questionnaire sent to the outside experts. This process saved time and allowed the Study Group to ask questions of a broad nature and thereby to elicit points for general discussion with the full Committee.

Prior to the next scheduled meeting of the full Committee in Claremont, Calif., two books of materials were sent to the Committee members, and a third book was distributed at the meeting. These books included the following materials: National Science Board presentation books; summaries of supported projects; lists of released textbooks, films, other educational materials and translations and adaptations for other countries; pertinent correspondence, staff papers, and papers by science educators; and the Foundation staff responses to the questionnaire.

The entire meeting of the full Committee on July 10-12, in Claremont, was

devoted to the matter of course and curriculum development support and the future role of the Foundation in science education. It began with an executive session during which Dr. Greenberg described the steps taken up to that point by the Study Group. These included the mailing of the questionnaire and the Foundation staff interviews. A list of 22 points, which evolved from the staff interviews, was circulated to the Committee, and each point was discussed, some at considerable length. It was agreed by the full Committee that the points were indeed relevant to the Foundation's future role in education and should be brought to the attention of the Board and the Director.

The main part of the meeting was taken up by consultation with eight invited educational leaders, four of whom were selected on the basis of their response to the questionnaire. The eight were Dr. Max Beberman, Committee on School Mathematics, University of Illinois; E. E. David, Executive Director, Research, Bell Telephone Laboratories; Uri Haber-Schaim, Education Development Center; Robert Karplus, Lawrence Hall of Science, University of California; Edward J. Kormondy, Executive Director, Commission on Undergraduate Education in the Biological Sciences; Patrick J. Suppes, Director, Institute for Mathematical Studies in the Social Sciences, Stanford University; Ralph Tyler, Science Research Associates, Inc.; and Mr. Donald W. Stotler, Science Supervisor, Portland Public Schools (Oreg.). Each person presented a brief statement, answered questions, and contributed to the ensuing discussion. The meeting concluded with the development of an outline for the report and writing assignments for the preparation of a draft document.

The draft document, prepared by Drs. Greenberg, Baird, and Nickerson, of the Study Group, together with Dr. Platt, Chairman of the Advisory Committee, was discussed at the November 6-7 meeting in Washington of the full Committee. A second draft was then prepared by Drs. Greenberg and Platt on the basis of comments and suggestions made at the meeting and circulated for approval to the full Committee. This report is the result of these exercises.

Special mention and appreciation is due Miss M. Joan Callanan, Associate Program Director, Advanced Science Education Program, who worked closely and diligently with the Study Group on all phases of the study and preparation of this report.

Finally, the Study Group and the entire Advisory Committee wishes to express its appreciation to Dr. Thomas Fontaine, Dr. Keith Kelson, and the other staff members of the Education Divisions of the Foundation for the tremendous encouragement, assistance, and cooperation which was extended to all of our efforts in conducting this study.

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3. Saul B. Cohen
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4. Don Davies
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5. Uri Haber-Schaim
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6. Julius Hlavaty
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7. E. Leonard Jossem
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10. Addison E. Lee
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