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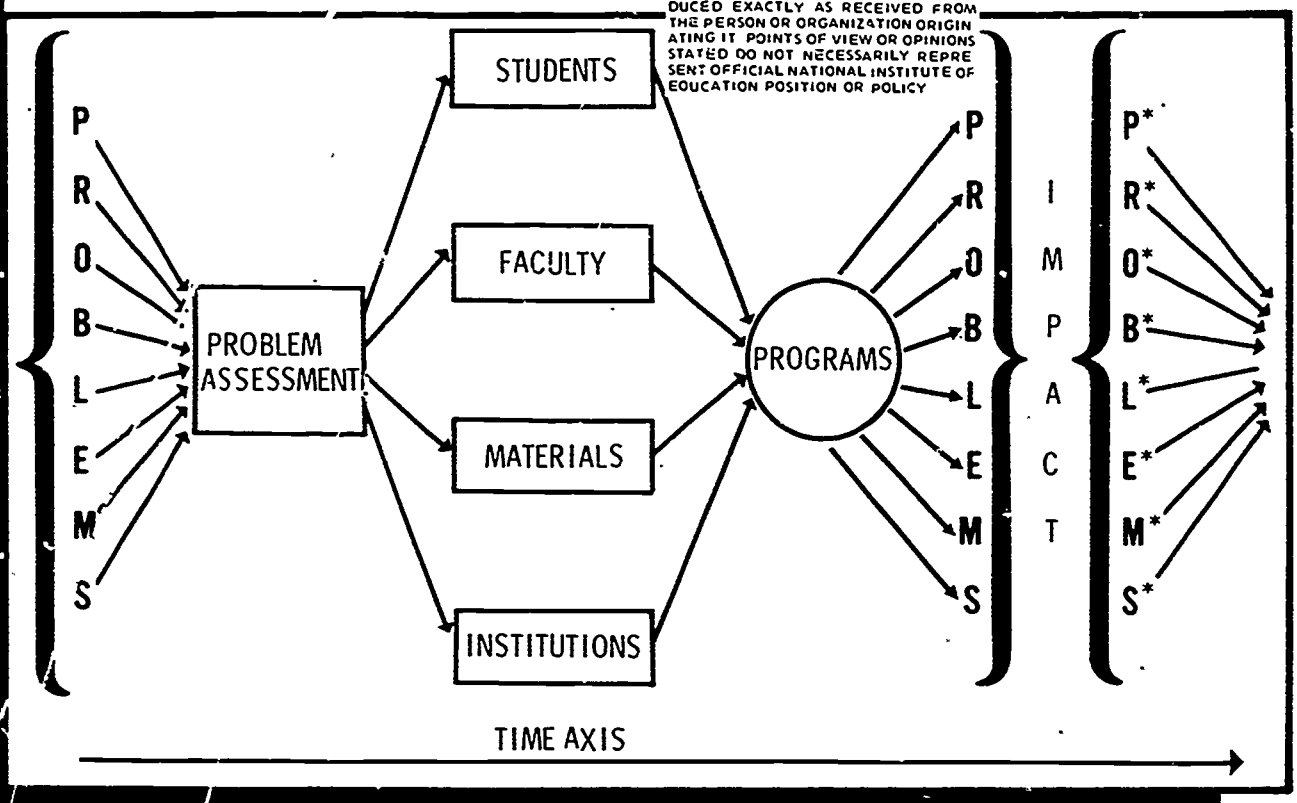
ABSTRACT

This publication encompasses the central core of the National Science Foundation's (NSF) explicit science education activities at the undergraduate level of the Nation's education enterprise. It is an outline of the character of the Foundation's educational constituency. A table is presented showing the Carnegie Commission's Classification Scheme for Institution of Higher Education and each group is described in relation to the service rendered by NSF. A schematic view of NSF's science education activities is presented in tables, graphs, and descriptive form. Impact points discussed include research done related to undergraduate students, faculty research participation programs and faculty fellowship programs, as well as materials and instruction and discussions related to examples of major societal problems converted into sets of operational science program type problems. Types of problems to be faced and their future implications for the Education Directorate are outlined and briefly discussed. (Author/EB)



UNDERGRADUATE EDUCATION IN SCIENCE:

A Rationale For Program Structure

NOVEMBER 1974

NATIONAL SCIENCE FOUNDATION
WASHINGTON, D.C.

NSF 75-11

UNDERGRADUATE EDUCATION IN SCIENCE:
A Rationale For Program Structure

NOVEMBER 1974

PRESENTED BY:

ASSISTANT DIRECTOR FOR EDUCATION:

- DIVISION OF HIGHER EDUCATION IN SCIENCE
  - MATERIALS AND INSTRUCTION DEVELOPMENT SECTION
  - INSTRUCTIONAL IMPROVEMENT IMPLEMENTATION SECTION
- OFFICE OF EXPERIMENTAL PROJECTS AND PROGRAMS
  - PROBLEM ASSESSMENT AND EXPERIMENTAL PROJECTS
  - EXPERIMENTAL PROGRAMS GROUP

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Introduction

Dr. Lowell J. Paige

PROBLEMS TO PROGRAMS

The House of Representatives Committee on Science and Astronautics[1/], in its report accompanying the Authorization Act of 1975, requested the National Science Foundation to prepare a report on the future of the Foundation's science education activities. The Committee asked the Foundation to consider, in particular, the future relationship between research in science education and sustaining programs. It is in the spirit of the request that this analysis of undergraduate science education of NSF is being presented.

This paper encompasses the central core of the Foundation's explicit science education activities since approximately half of the funding for Science Education Improvement is directed at the undergraduate segment of the Nation's education enterprise. It is for this reason that I have chosen to outline briefly the character of the Foundation's educational constituency.

1/ The Science and Technology Committee as of the convening of the 94th Congress in January 1975

The Carnegie Commission in 1973 prepared "A Classification of Institutions of Higher Education" which used the following taxonomy for schools (Figure 1):

CARNEGIE COMMISSION CLASSIFICATION OF INSTITUTIONS OF HIGHER EDUCATION

1970

TYPE OF INSTITUTION	ENROLLMENT (IN THOUSANDS)	NUMBER OF INSTITUTIONS
TOTAL	8,500.0	2,827
DOCTORAL-GRANTING INSTITUTIONS	2,677.9	173
RESEARCH UNIVERSITIES, I, II	1,711.2	92
DOCTORAL-GRANTING UNIVERSITIES, I, II	966.7	81
COMPREHENSIVE UNIVERSITIES/COLLEGES, I, II	2,501.4	453
LIBERAL ARTS COLLEGES, I, II	685.9	719
TWO-YEAR INSTITUTIONS	2,347.8	1,061
SPECIALIZED INSTITUTIONS	286.8	421

Fig. 1

The designations appearing in the table are largely self-explanatory. The research universities are divided by Federal research funding and doctoral degrees granted; the comprehensive universities and colleges may have some doctoral programs but the division here is largely one of enrollments; liberal arts I are those 146 institutions ranking high as sources of graduate students.

The specialized schools include theological seminaries; medical schools or centers not campus-associated; other health-related schools; schools of engineering and technology; schools of business and management; schools of art, music and design; schools of law; teachers' colleges; and other specialized institutions lacking a liberal arts program.

It would appear that the Carnegie classification differs somewhat from the well known Cartter and Roose-Andersen reports on the quality of graduate education; but remember the latter considered only doctoral-granting institutions and the disparity in numbers occurs because there are doctoral-granting institutions in the Carnegie comprehensive university/college category. NSF's Science Resources Studies group surveys some 280 institutions which they define as doctoral-granting.

Still another classification of schools is the ranking of schools relative to Federal research support received and this includes 458 schools in FY 1973 with 179 receiving more than $1,000,000 in Federal support.

Finally, one last statistic -- there are approximately 225,000 science and engineering faculty members.

You will note that we serve institutions that vary in size from the small, heritage-clad liberal arts college, such as Sweet Briar, to the large multi-university such as the University of Minnesota; the former having an enrollment of under 1,000 and the latter an enrollment of over 60,000.

We serve institutions whose research support exceeds $100 million a year and those who receive no research support at all.

We serve community colleges who operate under locally elected shool boards and privately funded institutions whose Trustees are hardly known to their own alumni and students.

We serve institutions with open enrollment and those whose admissions are severely limited to only the most intellectually gifted.

We serve institutions whose enrollment consists almost entirely of disadvantaged minorities and those with rarely a minority student.

We serve institutions which provide only the first two years of post-secondary education and those who concentrate almost exclusively on graduate education and research.

We serve institutions located in the inner cities, like CUNY in New York or USC in Los Angeles, and those serenely isolated from urban woes, like Sheldon Jackson College in Sitka, Alaska.

We serve institutions that are wildy experimental and those whose educational policies derive from centuries of tradition.

We serve institutions thot savour liberal orts as the epitome of education and those which respond to the vocational needs of their community.

It is illusionary to assume that science has such a uniquely unifying character that only a few selected programs can satisfy all the needs deserving attention in this conglomerate of educational institutions. Let us look at some of the problems facing our institutions of higher education.

Although the next few years may see slightly increasing college enrollments, the drastic decline in births in 1973 will send a shockwave through our education system well beyond the decrease in enrollments already predictable for the middle 1980's. Let me emphasize this point. Wisconsin had 63,000 births in 1973 at a time when their first grade enrollment was 79,000. The changing age distribution and society's changing attitude toward college ond university degrees as a credential for employment will add to enrollment woes. These concomitant forces will imply fewer new faculty positions at all educotionol levels in the years ahead ond the teaching and reseorch vitality of institutions, as well as the viability of tenure, will be challenged.

The spiraling costs of education occurred long before inflation was a household word. The funding provided by the Foundation's science education activities is very small in comparison with the $100 billion notional educational budget. Hence, we cannot solve problems of institutional fiscal stability but we may have an impact and we do have a responsibility to encourage innovation and improvement in science education both through applications of technology and the organization of science education. It is conceivable that the lotter has more to offer in potential savings than the former.

The heavy-handed application of offirmative oction guidelines could be detrimental to the future of science in the absence of a significant number of minorities and women pursuing graduate degrees in science and engineering. The moral responsibility and the need to utilize heretofore untopped human resources compels us to devise programs that will encouroge more women ond minorities toword scientific ond engineering careers.

Where, formerly, the Foundation's undergraduate programs might concentrate almost exclusively on attracting students toward traditional discipline-oriented graduate careers, today's employment opportunities bespeak the need for a broader educational experience. The science and engineering research and technology critically needed to maintain an increasingly productive economy requires a wide spectrum of scientific manpower. Opportunities for the continuing education and professional growth of technicians, engineers, nonacademic scientists, and faculty members themselves, in the face of changing national priorities and technological advances, present a whole host of problems for science education.

The growing acceptance of open enrollment in many institutions places a changing emphasis on course content and curricula for science students in order to accommodate a broader spectrum of student abilities.

These are but a few of the problems we see influencing science education in the future. And, through all this maze, we must keep in mind that maintaining a steady flow of the most gifted students toward research careers in science must not be overlooked. Our oil resources may diminish, our fertile lands may yield to housing development and highways, but the nation's capability in scientific research is a renewable resource if we continue to encourage the most gifted students to careers in science and provide research opportunities later.

The long-range goals we have set for science education do not change materially year by year and, hence, we see the problems we face encompassed by the objectives summarized in Figure 2:

To help assure the Nation of an appropriate variety, flexibility, quality and number of scientific and technological manpower, with greater participation of minorities and women.

To improve science education for a broad range of students, in order that a substantially increased number can: (a) make effective use of the processes and results of science in their work and personal lives, whether or not they are engaged in scientific or technical occupations; and (b) can understand public issues involving science and technology.

GOALS
OF
SCIENCE EDUCATION IMPROVEMENT PROGRAM

- SCIENTIFIC AND TECHNICAL MANPOWER DEVELOPMENT
- IMPROVED SCIENCE EDUCATION FOR BROAD RANGE OF OF STUDENTS
- INCREASED EFFECTIVENESS AND EFFICIENCY OF SCIENCE EDUCATION

Fig. 2

To increase the effectiveness and efficiency of science education by means of: (a) programs involving the modern instructional technology; and (b) new instructional organizations, strategies, and methodologies.

A coherence of the Foundation's educational activities is more easily understood if we review briefly the manner by which programs originate. The diagram in Figure 3 is meant to illuminate that process.

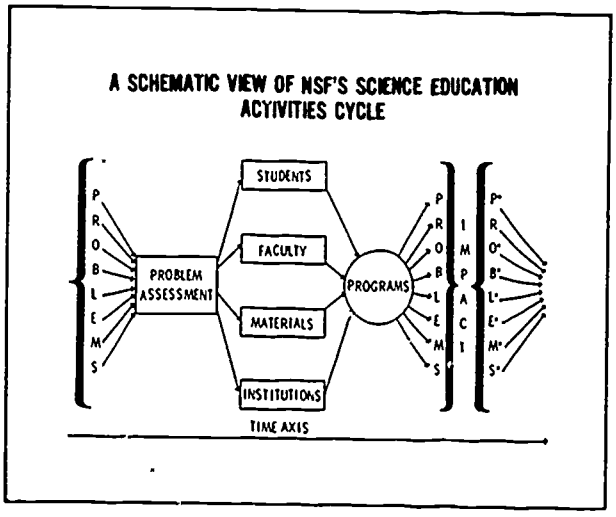

Fig. 3

The National Science Foundation begins with a collection of problems for science education as perceived by the academic community (including students), Congress, society, advisory committees, the National Science Board, the Administration, and the professional staff of all Directorates of the Foundation.

The assessment of the problems for science education and the determination of priority in effort includes consultation with the Advisory Committee for Education, the administration, the National Science Board, and others. There may be problems for which no response is appropriate for the Foundation or problems with low priority that are not addressable within the limits of funding for science education. In any event, the assessment effort establishes priorities for action and the Foundation recommends a response to Congress through the budget process. It should be noted that the only possible responses to problems are through four distinct access-leverage points: students, faculty, materials, and institutions.

From the emphasis decided upon for students, faculty, materials and institutions emerges a program focused on a given problem. It is noted in the diagram that even though a program may focus on a particular problem, there is a scattering influence on other problems.

It is possible that some problems are not addressed by any program or, even if addressed, they may be persistently unresolvable. On the other hand, there may be problems that are addressed by more than one program. In any case, after a period of time, the programs will have an impact upon the original problems and they will be replaced with a new set of problems. The process begins over again and a new set of responses is recommended.

Let us illustrate with an example. The problem of attracting more minority students toward scientific or engineering careers is almost independent of discipline and has high priority. The following chart (Figure 4) shows the latest enrollments we have in several fields at the graduate level. Note that minorities represent only 5.5% of the total fall 1973 graduate enrollment in science and engineering at 154 Ph.D. institutions surveyed.

FY 1973 REPRESENTATION OF MINORITY GRADUATE STUDENTS IN SCIENCE FIELDS 1/

	NUMBER ENROLLED	PERCENT OF TOTAL GRADUATE STUDENT ENROLLMENT
ENGINEERING	1,658	5.4%
LIFE SCIENCES	1,247	4.5
MATHEMATICAL SCIENCES	668	5.4
PHYSICAL SCIENCES	1,053	4.9
SOCIAL SCIENCES	2,387	6.71
TOTAL SCIENCE AND ENGINEERING	7,043	5.5%

1 BASED ON DATA FROM 154 PH.D. GRANTING INSTITUTIONS

Fig. 4

There is little agreement on how the attraction of minority students to scientific or engineering careers might be accomplished. Hence, through problem assessment, we fund several studies primarily involving students and institutions but not a formal program. The first year there will be little impact on this problem and the original problem will persist. However, if we find a successful method among our studies, we would then recommend the creation of a full-scale program focusing on this program.

It seems reosonable that the desirability of attracting minorities to careers in science and engineering would persist for many years, and a program so directed would appear to be a sustaining effort while, in reality, it would merely be a reflection on the continuing nature of the problem.

It seems to me that perhaps we can provide some clarity to our programs if we concentrate our attention on how they develop. First, let us again look at some of the problems of undergraduate education which I mentioned earlier and which we are responding to through the access-leverage points of students, faculty, materials, and institutions (Figures 5a and 5b).

Next, the access-leverage points and programs (Figure 5c).

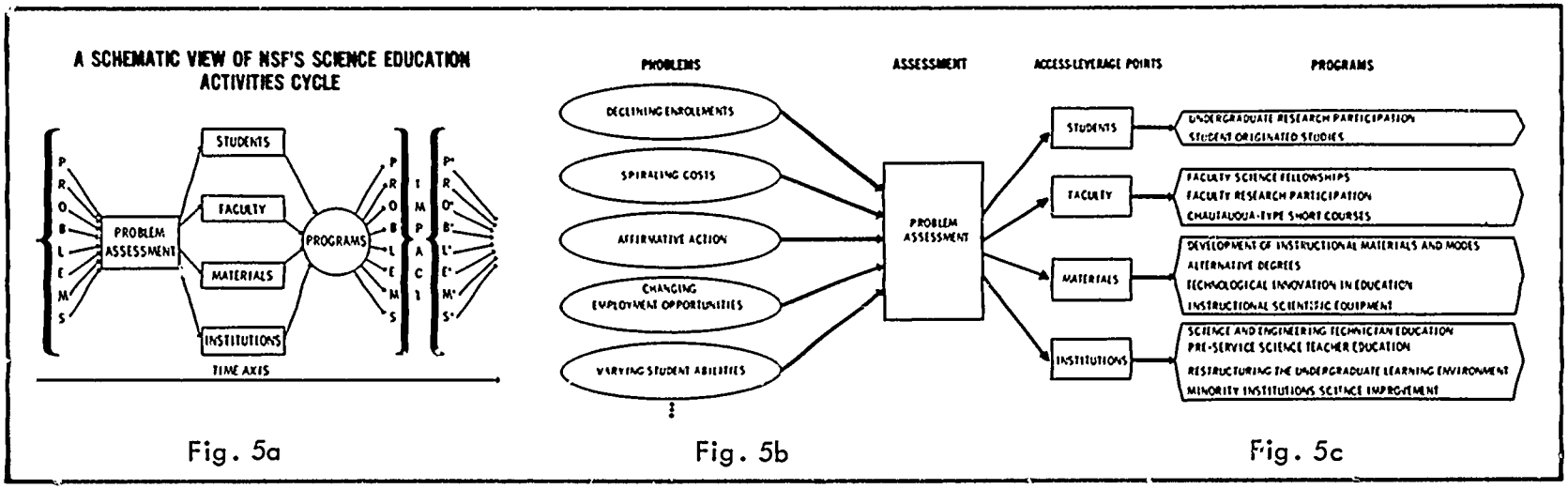

Fig. 5a Fig. 5b Fig. 5c

I admit that any program probably involves all access-leverage points but most of our programs have a primary component and this is reflected in the way the programs are aligned in Figure 5c.

All of these programs are found under the budget category Careers in Science, except for the Pre-Service Science Teacher Education, Restructuring the Undergraduate Learning Environment, and Technological Innovation in Education. These latter three occur in the category Increasing Effectiveness of Educational Processes. Problem Assessment -- the process we continually employ in conjunction with our programs -- and Experimental Projects forms a separate budget category. However, there are no programs at the undergraduate level in the fourth subactivity -- Science Literacy.

Dr. Lafe Edmunds will discuss those programs having mainly a student emphasis; Dr. Robert Watson will discuss those programs having largely faculty emphasis; Dr. John Snyder will concentrate on problems dealing primarily with materials and instruction; and Dr. James Mayo will present those programs dealing primarily with institutions.

***

Impact Points

UNDERGRADUATE STUDENTS

Dr. Lafe R. Edmunds

Dr. Paige identified students as one of the four access-leverage points for action by the Education Directorate. Dr. Paige also identified several problems to which we might add: The need to assure an appropriate number, variety, flexibility and quality of professional scientific and technological manpower. We can meet this need only by taking specific steps to: (a) identify and conserve science and engineering talent; (b) enhance the preparation for further study of those identified as having such talent; and (c) promote those educational practices and techniques that will lead to a wider range of career options and a greater individual capacity for self-directed learning.

As its approach to this problem -- which depends upon a limited and achievable effort producing a broader systemic effect -- the Foundation has identified two discrete but mutually complementary student program elements, Undergraduate Research Participation (URP) and Student-Originated Studies (SOS).

Undergraduate Research Participation (URP)

This program is designed especially for the upper division student who, in most cases, has already decided on working toward a degree in one of the science disciplines, and is thinking, ultimately, of a career in research and/or science teaching. The projects are aimed at providing experience, through participation in ongoing research at the grantee institution, that will enable undergraduate students to learn what the "research" process is like and to grow in independence of thought and action. At the same time the project can demonstrate to college faculties the potential of this kind of activity in serving as an adjunct to, or as a replacement for, at least a part of traditional, formal, classroom instruction.

Proposals are prepared and submitted, participants are selected, and projects are managed, by science faculty members of the four-year college or university and participation may either be full-time during the summer period, or may combine part-time activities during the academic year with full-time activities during a 10- to 12- week period. The objectives and methods of the program and data summarizing its entire period of operation are given in Figures 6, 7, and 8.

UNDERGRADUATE RESEARCH PARTICIPATION PROGRAM OBJECTIVES

- TO MEET THE NEED FOR AN ADEQUATE VARIETY, NUMBER, AND FLEXIBILITY OF SCIENTIFIC AND TECHNOLOGICAL MANPOWER
  - TO IDENTIFY THOSE WITH SCIENTIFIC TALENT AND INTEREST
  - TO REINFORCE SCIENCE CAREER DECISIONS
  - TO ENHANCE PREPARATION FOR GRADUATE STUDIES IN SCIENCE
  - TO INDUCE COLLEGE FACULTIES TO INCORPORATE URP-LIKE ACTIVITY INTO THE REGULAR CURRICULUM FOR SCIENCE MAJORS

Fig. 6

PROGRAM METHODS

- EXPERIENCE IN ACTUAL RESEARCH PROJECT
- APPRENTICESHIP TO PRODUCTIVE SCIENTISTS
- GROWING INDEPENDENCE COMMENSURATE WITH GROWING ABILITY

Fig. 7

16-YEAR CUMULATIVE DATA

• TOTAL INVESTMENT	$66.61 MILLION
• TOTAL NUMBER OF GRANTS	7,176
• TOTAL NUMBER OF PARTICIPANTS	67,143
• AVERAGE COST PER PARTICIPANT	$992

Fig. 8

Another important statistic -- on which, unfortunately, we have no objective data -- would be the number of departments or institutions which, because of their experience with URP, have made URP-like experience a part of the normal undergraduate curriculum for science majors. There is, however, a wealth of anecdotal evidence, much of it included in URP proposals from grantees with previous URP experience, that research participation has become a normal component of academic year science major curricula in many institutions.

Since its initiation 16 years ago the program has been open to all disciplines -- physical sciences, biological sciences, and social sciences -- its major "customers" coming from the physical sciences (engineering showing a special interest), with the social sciences not being well represented. However, two years ago, a change in guidelines placed certain restrictions on eligibility: in part as a move to bring the program more in consonance with Federal objectives, but admittedly influenced also by severely limited funding for the program itself, the program was restricted to research areas that could be justified as being either energy-related or directed toward problems of renewable natural resources.

The guidelines were again modified for the current year's program. In the FY 1975 program, all disciplines are eligible, but within those fields where energy-related activity is feasible, priority will be given to those projects that are energy-related.

I shall return to the question of the justification for such targeting. First, let me refer you to Figure 9 which lists a few specific examples of URP projects taken from FY 1974 operations:

Harvey Mudd College: Ten undergraduates at Harvey Mudd College, Claremont, California, worked on the design of solar hot water heaters. They simulated such factors as size, shape, and orientation of the collector, as well as effects due to geographic location, climate, air quality, construction materials, and heat transfer.

UNDERGRADUATE RESEARCH PARTICIPATION
PROJECTS (FY 1974)

- HARVEY MUDD COLLEGE CLAREMONT, CALIFORNIA
  - SOLAR ENERGY AND ITS UTILIZATION
  - 10 PARTICIPANTS
- VANDERBILT UNIVERSITY, NASHVILLE, TENNESSEE
  - ELECTRICAL ENERGY ALLOCATION
  - 8 PARTICIPANTS
- CLINCH VALLEY COLLEGE WISE VIRGINIA
  - CHARACTERISTICS OF COAL STRIP-MINED LANDS
  - 3 PARTICIPANTS

Fig. 9

Vanderbilt University: At the Engineering School, Vanderbilt University, Nashville, Tennessee, eight students worked with their faculty mentors on electrical energy allocation problems of the region. The project involved students in an intense technology assessment of various options for confronting an important local energy problem, requiring the integration and impact-assessment of technical, economic, and social strategies.

Clinch Valley College: Three undergraduates studied soil, water and biotic characteristics of coal strip-mined lands on the campus of Clinch Valley College. Study sites were areas mined in the early 1950's with no reclamation, and areas mined in 1970-71 and reclaimed by grading and seeding.

Before describing some of the problems relating to URP, I turn now to the companion program, Student-Originated Studies.

Student-Originated Studies (SOS)

The general aim of the Student-Originated Studies Program is to provide students experience in independent, self-directed study, and to demonstrate the effectiveness of such study as an adjunct to or replacement for portions of their traditional formal course work (Figure 10).

Following in Figure 11 are some salient characteristics of SOS. Each project proposed is problem-oriented -- to deal with a local problem that has immediate relevance to the community, that is concerned with the biological, physical, or social environment, and that poses as yet unanswered questions of a scientific or technological nature on which the student group can collect meaningful data.

STUDENT-ORIGINATED STUDIES PROGRAM OBJECTIVES

- TO PROVIDE STUDENT EXPERIENCE IN INDEPENDENT, SELF-DIRECTED STUDY
- TO DEMONSTRATE THE EFFECTIVENESS OF SUCH STUDY AS AN ADJUNCT TO OR REPLACEMENT FOR TRADITIONAL FORMAL COURSE WORK

Fig. 10

PROGRAM METHODS

- EACH PROJECT IS PROBLEM-ORIENTED--TO DEAL WITH A LOCAL PROBLEM THAT HAS IMMEDIATE RELEVANCE TO SOCIETY
- THE APPROACH TO UNDERSTANDING THE PROBLEM(S) AND THE SEARCH FOR SOLUTION ARE TO BE INTERDISCIPLINARY IN NATURE
- EACH STUDY OR SET OF STUDIES IS CONDUCTED BY A GROUP OF STUDENTS COMPRISING UNDERGRADUATES OR GRADUATES, OR A COMBINATION OF THE TWO
- PROJECTS ARE STUDENT-ORIGINATED STUDENT-PLANNED AND STUDENT-DIRECTED

Fig. 11

The approach to understanding the problems and the search for solutions are interdisciplinary or multidisciplinary in nature.

Projects proposed are student-originated, student-planned, and student-directed, and are carried out under the leadership of one of the students in the group.

Each study or set of studies is conducted by a group of students comprised of undergraduates or graduates, or an appropriate combination of the two.

Support for projects is provided by grants to 4-year colleges and universities that agree to serve as host and fiscal agent for the project.

The 4-year college or university endorses the proposed project; agrees to make available space, facilities and equipment as required; agrees to accept the grant and assume responsibility for expenditures of funds; and appoints a (student solicited) member of its faculty as project advisor.

The 4-year cumulative data for SOS are shown in Figure 12.

FOUR-YEAR HISTORY (1971-74)

• TOTAL NUMBER OF PARTICIPANTS	4,336
• TOTAL COST OF GRANTS	$6.10 MILLION
• COST PER PARTICIPANT	$1,407
• TOTAL NUMBER OF GRANTS	451

Fig. 12

SOS projects deal with problems of immediate social relevance, and it is mutually advantageous for the student groups to coordinate their activities with potential users of their data. As a result, a number of SOS projects have immediate impact upon the surrounding community, and vice versa. A recent third-party study of the impact of SOS, included consideration of the program's "side effects" outside of academia. Of 639 community "decision-makers" who, it was thought, might be familiar with the work of one or more of the first 316 SOS projects supported, 340 replied in depth.

Of the respondents (Figure 13), 63% were government users at the Federal, state or local level and 39% were non-government personnel including citizen action groups, professional societies, profit-making companies, etc.

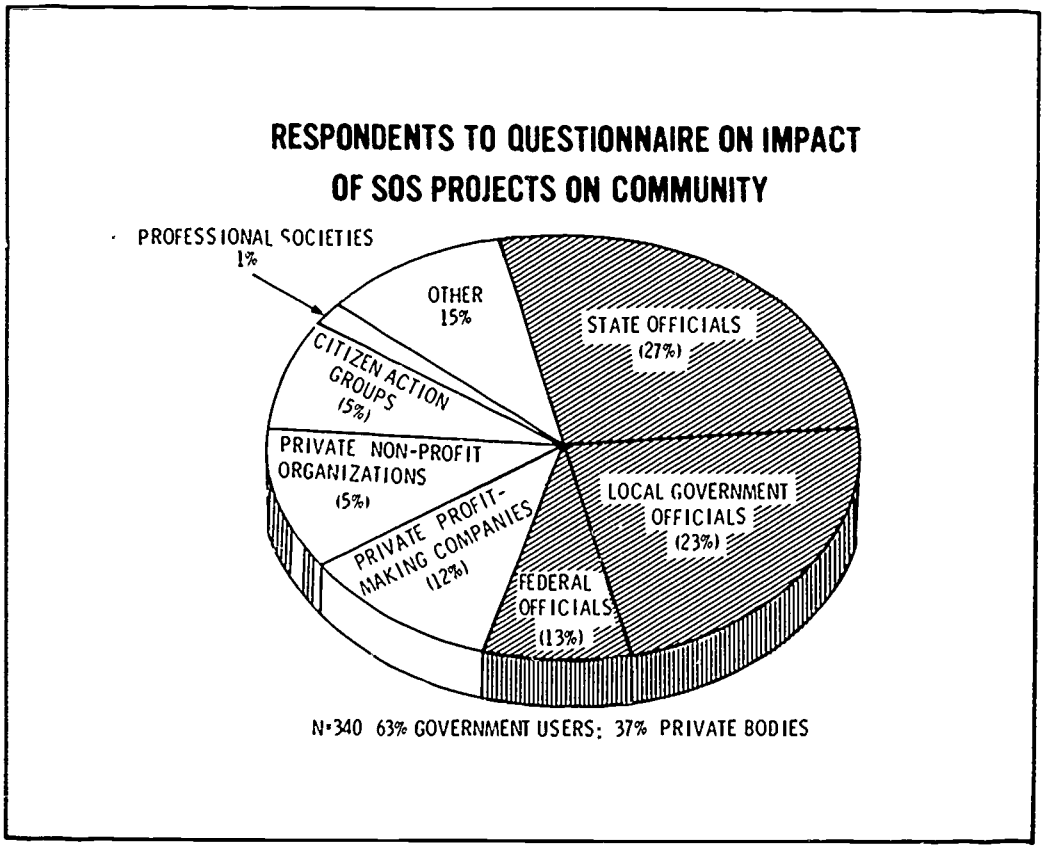

Fig. 13

The respondents' perceptions of the impact of SOS projects on the community are shown in Figure 14. The range of specific community outcomes is very broad and the following examples were selected from among many that could have been used:

Santa Rosa, California has adopted zoning measures and a special ordnance to protect Mark West Creek.

Bucyrus, Ohio has appropriated $18,000 to continue the river pollution study begun by Heidelberg College students.

Plans to pump municipal water supplies from the Jersey Pine Barrens have been extensively revised in the light of hazards identified by Princeton University undergraduates.

An SOS project at Benedict College, South Carolina has increased the level of awareness in the black community of sickle-cell anemia.

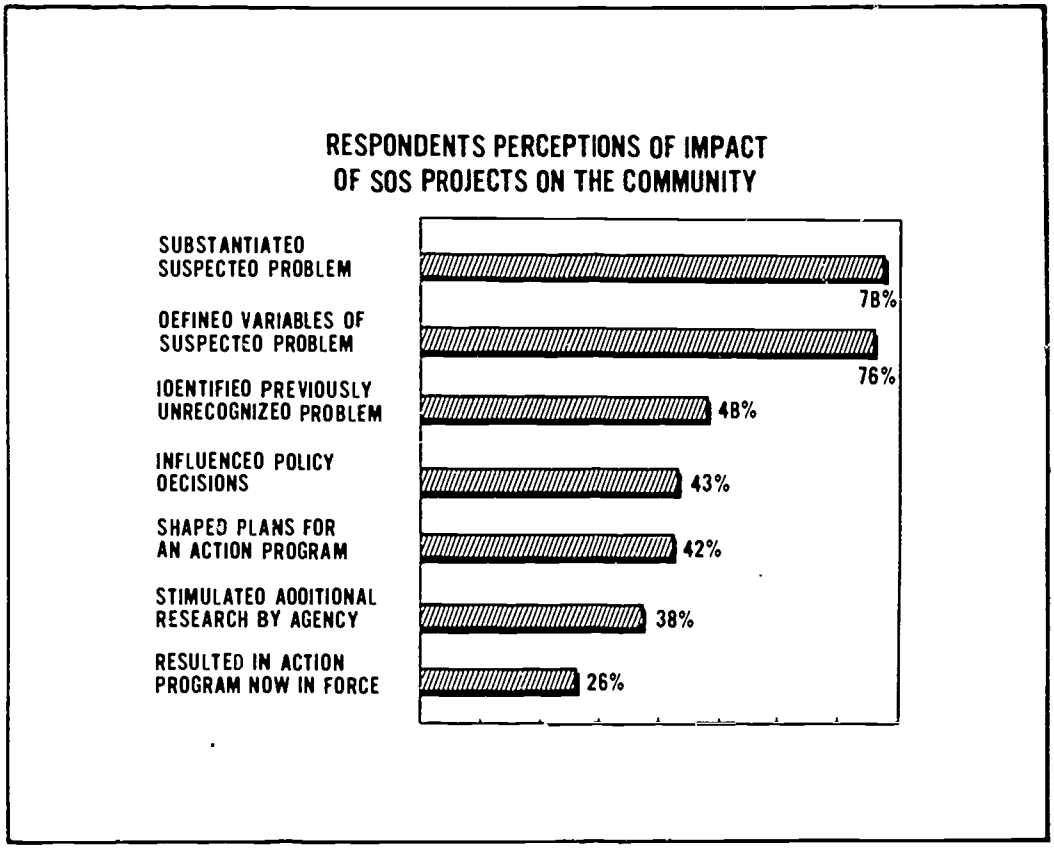

Fig. 14

I think it is clear from these examples that many of the SOS projects did deal with a local problem which had immediate relevance to society.

In closing, I would like to summarize a few points for you. Both URP and SOS involve research type activities. In a sense, URP parallels basic research and is relatively long-term in its effect of turning out research scientists. SOS, on the other hand, favors problem-solving aimed at a much more immediate impact in the community. Another major difference is that URP involves faculty participation directly, and often has important side effects upon the faculty. This is particularly true in the small institution or with the young research-oriented teacher trying to get started in research.

Now that we have looked at URP and SOS, let me leave you with some of the program management issues, summarized in Figure 15.

URP has been influential in leading to the introduction of research activity into the academic year -- often as part of the regular curriculum. But it is difficult to believe institutions can ever make summer activity a regular institutional-supported thing, and most students cannot afford a summer without income. There are clear benefits to faculty and in providing URP experience to prospective scientists. Should not URP, like research, receive Foundation support on a continuing basis?

PROGRAM ISSUES

- CONTINUING SUPPORT OF URP
- JUSTIFICATION FOR TARGETING URP
- FACULTY ROLE IN SOS
- STUDENT INTEREST IN SOS
- PROPER MIX BETWEEN URP & SOS

Fig. 15

Both URP and SOS have elements of targeting. In the case of URP, one justification was the need to limit the number of proposals. Another justification was to direct student attention to important areas. Are these two reasons sufficient justification for targeting?

In SOS faculty members are called upon to function basically as advisors to students. What is the impact of this role on the faculty and should steps be taken to change or strengthen this relationship?

In SOS there is one additional point to be considered. This program was started, in part, to enable those students who were finding fault with society to actually respond to societal needs. In view of the recent diminished student activism will such a program remain viable?

To achieve optimum benefits, what should the mix be between URP and SOS? How does it depend on institutional type, nature of student body and faculty responsibility?

In speaking of faculty responsibilities, Dr. Robert Watson will now describe some of the Education Directorate's faculty-oriented programs.

FACULTY

Dr. Robert F. Watson

As Dr. Paige has pointed out, 225,000 persons make up the science and engineering faculty of United States colleges and universities. This figure represents one third of the total of over 600,000 faculty in all of U.S. higher education today. It does not distinguish between "graduate" and "undergraduate" faculty, consisting both of Nobelists who teach an occasional undergraduate class, and the two-year college instructor, who does little else. All have a crucial impact on the quality and nature of undergraduate science instruction, which is our basic interest here.

The constitution of this group has undergone significant change over the past three decades of the Foundation's existence. These persons are older and more of them are tenured. Even excluding junior college faculty, their teaching loads are increasing, and their movement among institutions is thought to be on the decline. Like those in other scientific-related occupations, they are faced with an increasingly rapid rate of potential obsolescence.

Although the students and thence society are the ultimate beneficiaries of the Foundation's Education Directorate activities, these scientist-teachers are the operatives through whom we work. Virtually all proposals are the products of faculty effort, and most awards are in direct support of faculty effort.

This partnership role of the faculty in Education Directorate efforts, not unlike the situation in the Foundation as a whole, should be kept in mind as the other three access-leverage points are discussed, because solution of the problems to which these other areas address themselves must always be dependent on the faculty.

Despite, or possibly because of, this dependency which the Foundation has on the faculty, there are relatively few Foundation programs today which are primarily intended for a direct impact on the problems of the faculty themselves.

With this dichotomy as a preface, Figure 16 may be considered as a device for delineating individual faculty characteristics, and as an introduction to viewing their attendant problems.

FACULTY CHARACTERISTICS

- QUALITY
  - INTELLECTUAL CAPABILITIES
  - INFORMATION BASE
  - ATTITUDE
- QUANTITY
  - DISCIPLINES
  - INSTITUTIONS
  - MINORITIES & WOMEN

Fig. 16

The manner in which the Foundation's programs have a beneficial effect on these characteristics is the focus of this discussion. These are our problems with regard to faculty.

At present, the only Directorate activities aimed at increasing the numbers of persons entering the faculty professions are those related to the more specific problem of increasing the participation of minorities and women in the scientific professions. This is, of course, illustrative of Dr. Paige's changing programs to meet changing problems statements. Whereas at one time increasing scientific manpower was indeed essential, today even the term "manpower" seems less than acceptable.

Clearly, the principal Foundation effort toward alleviating faculty problems is aimed at that aspect of quality we have termed "information base." This is the continuous challenge of keeping abreast of the changes and advances in science, technology, and education to maintain and enhance the vitality of the science programs received by the students. This is a problem complicated still further today and in the immediate years ahead by the adverse societal factors already alluded to.

It seems useful to classify the effects of Foundation efforts on faculty as being of two general types: deliberate and coincidental. In the first category are those programs whose awards have the stated primary objective of enhancing certain qualities of individuals associated with their roles in teaching. In contrast, coincidental types may fulfill this objective, but were created for other primary purposes.

In the deliberate category there are currently three areas of effort whose titles are:

Chautauqua-Type Short Courses for College Teachers;
Faculty Research Participation Program; and
Faculty Science Fellowships Program.

Chautauqua

The Chautauqua project is named for its similarity in operation to the famous travelling cultural program.

The country is divided into three regions or Choutauqua circuits, as shown in Figure 17, each with its own set of courses, students, and instructors.

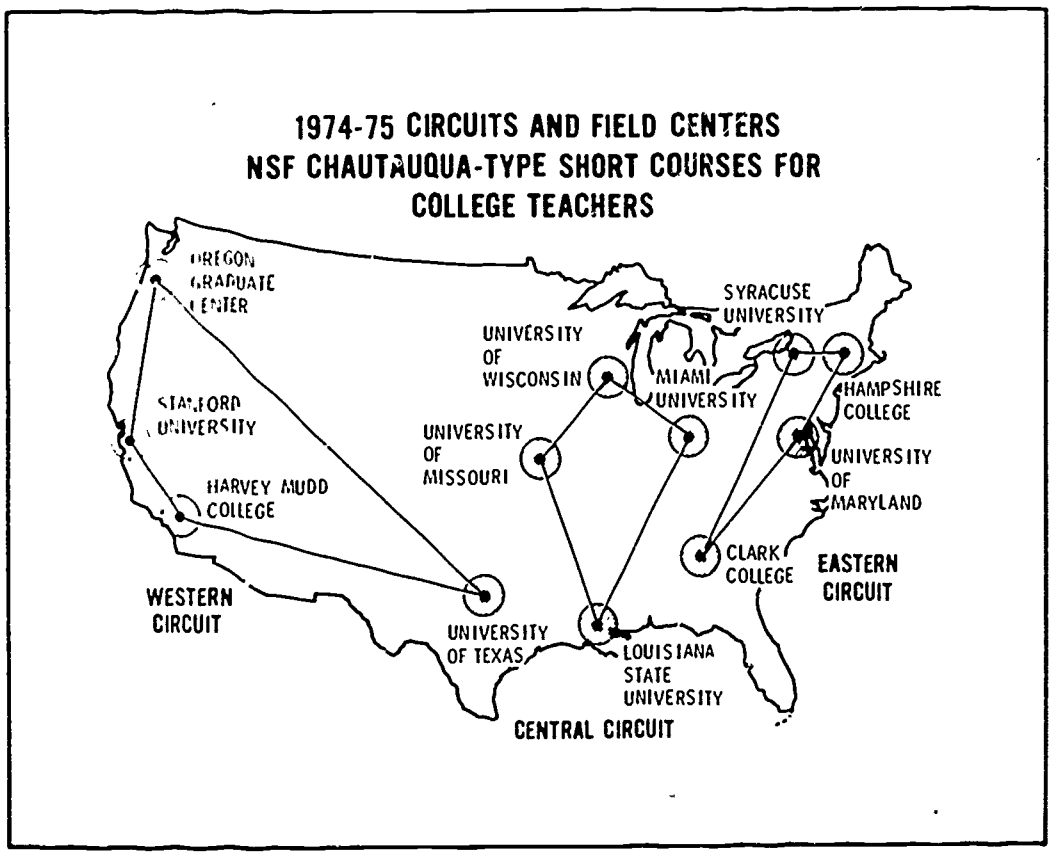

Fig. 17

Very briefly, the Chautauqua mechanism consists of a series of short duration (usually two days in October or November) intensive presentations by experts, so-called "circuit riders," who meet with college faculty at a host university (the "center"). Following this first session, the involved faculty return to their home institutions, carry out mutually-agreed-upon independent activities, and then return to the "center" for a second two-day session in the spring to examine their work with the "circuit rider" and the other participants.

In Figure 18 courses listed for this year's eastern circuit, which consists of centers at Syracuse University, Hampshire College, University of Maryland, and Clark College, are presented. This list is also illustrative of the types of individuals serving as "circuit riders."

CHAUTAUQUA EASTERN CIRCUIT

PARTIAL LIST OF COURSES

- **HUMAN HEREDITY AND SOCIETAL PROBLEMS**
  E. PETER VOLPE, DEPARTMENT OF BIOLOGY, TULANE UNIVERSITY
- **HOLOGRAPHY**
  TUNG H. JEONG, DEPARTMENT OF PHYSICS, LAKE FOREST COLLEGE
- **IMPROVING COLLEGE INSTRUCTION THROUGH EVALUATION**
  JASON MILLMAN, DEPARTMENT OF EDUCATION, COLLEGE OF AGRICULTURE, CORNELL UNIVERSITY
- **POLITICAL SOCIALIZATION: APPLICATIONS TO COLLEGE TEACHING**
  JACK DENNIS, DEPARTMENT OF POLITICAL SCIENCE, THE UNIVERSITY OF WISCONSIN
- **BEHAVIOR-GENETIC ANALYSIS**
  JERRY HIRSCH, DEPARTMENT OF PSYCHOLOGY, THE UNIVERSITY OF ILLINOIS, CHAMPAIGN-URBANA
- **HUMAN SEXUALITY: PSYCHOLOGICAL, BIOLOGICAL AND SOCIAL ASPECTS**
  MILTON DIAMOND, DEPARTMENT OF ANATOMY AND REPRODUCTIVE BIOLOGY, SCHOOL OF MEDICINE UNIVERSITY OF HAWAII

Fig. 18

Some additional data on Chautauqua are presented in Figure 19. From the top, note the large number of faculty and institutions affected. Note, particularly, the cost per participant of $250. which is extraordinary compared to other types of individual improvement programs.

CHAUTAUQUA DATA

	FY 73-74	FY 75 (ANTICIPATED)
PARTICIPANTS PH D'S M S	6,867 60% 30%	2500
INSTITUTIONS REPRESENTED 4 YR 2 YR	1,000 (EST AV) 75% 25%	1000
COST PARTICIPANT	$250.	$250
TOTAL PROGRAM COST	1 709K	$650K

Fig. 19

Chautauqua was originally considered to be a potential cheap alternative to traditional methods of summer institute-like courses for college teachers, which, indeed, it is. Now, however, it appears to have possibilities in addition to its low cost, which are summarized in Figure 20. These include its serving as:

(1) A rapid dissemination device for new educational developments. For example, one course offered both this year and last, is the Physics of Technology project, a new curriculum developed with NSF support.

(2) A forum for directly enhancing public scientific literacy. Whereas some courses presently deal with subjects for nonscience majors, other potential audiences include high school teachers, and possibly the general public in connection with NSF bicentennial activities.

FUTURE CHAUTAUQUA USES

- NEW KNOWLEDGE DISSEMINATION
- SCIENTIFIC LITERACY
- OTHER NSF INTERESTS

Fig. 20

Faculty Research Participation Program

The second example of our deliberate efforts aimed at faculty problems, the Faculty Research Participation Program, possibly typifies Dr. Paige's remarks on the changing of programs to meet changing problems.

Research participation was originally an effort to promote scientific and scholarly opportunities, and thus teaching effectiveness generally, of college and university faculty involved in undergraduate instruction. Typically, small college faculty spent summers in larger university laboratories initiating modest academic research activities which hopefully could be continued to some degree on their home campuses.

The program in frequent cases induced faculty to fulfill doctoral degree requirements, and in fact, served as a university doctoral feeder program.

Today, research participation is completely different -- with regard to the nature of its activities, the individuals it benefits, and the problems it attacks. The program now strives specifically to provide faculty with experience in the uses of scientific information in the solution of real world problems. Grants are typically made to industrial laboratories, which involve the participating faculty in their ongoing research and technological efforts over a summer period. The academic scientist-teachers are, in effect, colleagues of the industrial facility's research staff.

Figure 21 lists two examples of projects active in the summer of 1974. At Bell Labs the work focussed on ion induced x-ray analysis of materials, and surface studies using low-energy ion scattering. At Olinkraft the problems associated with papermill waste water recycling, scaling and corrosion, and effluent sulphur recovery were studied.

FACULTY RESEARCH PARTICIPATION PROJECTS

- **BELL TELEPHONE LABORATORIES.** 600 MOUNTAIN AVENUE MURRAY HILL, NEW JERSEY 07974.
  - ELEMENTAL AND CHEMICAL ANALYSIS USING ENERGETIC ION BEAMS
- **OLINKRAFT RESEARCH AND DEVELOPMENT CENTER,** P. O. BOX 488, WEST MONROE, LOUISIANA 71291
  - PULP AND PAPERMILL RECYCLED WASTE CHARACTERIZATION AND TREATMENT

Fig. 21

This applied research emphasis is in line with other Foundation -- in fact, Federal-wide -- prerogatives toward greater pragmatism in program aims. The program now assists even senior faculty in directing their research interests into more applied areas.

Figure 22 reveals the national distribution of project sites. Note the dearth of projects in those areas of lower industrial research activity. This figure also shows the distribution of projects among industry, government, and academe.

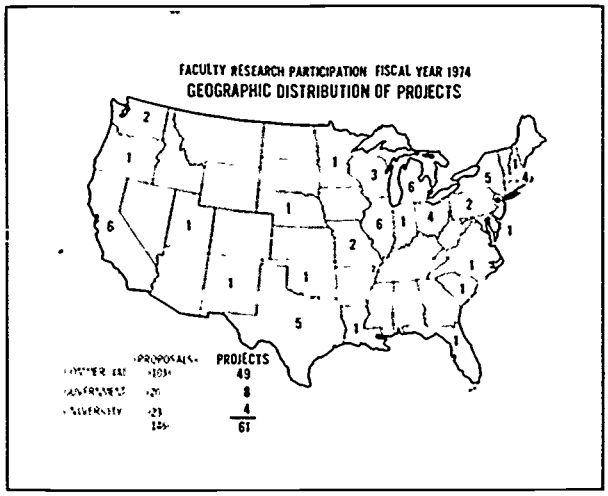

Fig. 22

Figure 23 gives a sense of the magnitude of the effort and permits a comparison of the old with the new. Note the increased percentage of Ph.D.-type faculty from baccalaureate degree granting institutions with the changed program emphasis. Note also that this costs more per participant, as we now pay on the standard 2/9 academic year salary. This was deliberate and for the purpose of attracting senior researchers.

FACULTY RESEARCH PARTICIPATION PROJECTS

	FY 71	FY 74
• TOTAL FUNDS AWARDED	$1,027,720	$919,440
• AVERAGE GRANT	$ 14,593	$ 15,073
• COST PER PARTICIPANT	$ 2,593	$ 6,663
• NUMBER OF PROJECTS	72	61
• NUMBER OF PARTICIPANTS	428	138
• POSTDOCTORAL	289	130
• PREDOCTORAL	139	8
• FOUR-YEAR COLLEGES & UNIVERSITIES	366	135
• TWO- YEAR COLLEGES	62	3

Fig. 23

Faculty Fellowships Programs

The third of the Foundation programs for faculty is the fellowship program, now termed Faculty Fellowships in Science Applied to Societal Problems. As was the case with the Faculty Research Participation Program, the Fellowship Program has been directed recently toward a greater emphasis on familiarity with societal problems and related scientific knowledge for more effective training and motivation of students in these areas. As also was the case with the other faculty programs, it aims at the problem of maintaining the information base of faculty in the face of rapidly changing science and technology fields.

Because of the highly individualistic nature of the activities pursued, an example of a typical fellowship program is not easy to describe. Most Fellows spend a single academic year at a major university in this country or abroad, but some might spend part of their time at their home instituions and over consecutive summers.

Thus, an instructor at a community college, trained originally as a chemist, has regularly taught chemistry, physics, and physical science courses. She plans to emphasize upgrading her capabilities in physics coincident with the college's intention to expand its offerings in physics. During another summer, she expects to concentrate on problems associated with off-shore oil drilling, and its effect on society, the ecology, and economic development in the State of Florida.

A brief look at the map in Figure 24 shows the national distribution of the current Fellows' home institutions. Figure 25 gives some further indication of the program's scope and impact. Note the total number of participants and the cost/participant.

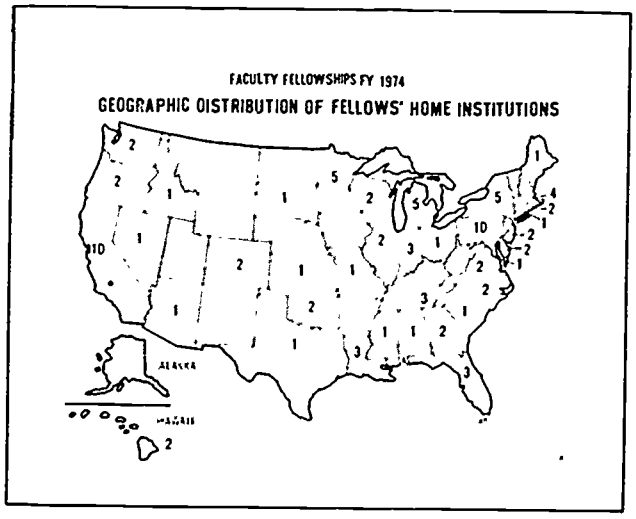

Fig. 24

FACULTY SCIENCE FELLOWSHIPS
FY-74

• BUDGET	$1,436,000
• AVERAGE COST/PARTICIPANT	$15,800
• COST RANGE/PARTICIPANT	$4,780 - 23,510
• NO. OF APPLICANTS	683
• NO. OF AWARDS	91

Fig. 25

The significance of this type of faculty program is three-fold: First, it permits an in-depth and sustained pragram of study for maximum impact per individual; second, it is expensive in terms of cost per individual; and third, because of its highly competitive and selective nature, with relatively few awards, considerable status is attached to being a Fellow. The program may, therefore, have signigicant influence on faculty motivation and attitude, as well as on their information base.

To reiterate, each of these three programs: Chautauqua, Faculty Research Participation, and Faculty Science Fellowships, is intended to have a direct effect on the general problem of maintaining the information base of undergraduate faculty. Each also, has some impact on the attitudes and motivations of the faculty. Again, the ultimate abjective is the quality and effectiveness of their instructional programs for the benefit of students.

Each of the programs has its own strengths and weaknesses in attacking the problem. Chautauqua, for example, is clearly the least expensive in actual cost per participant, and has the most obvious wide-ranging impact. On the other hand, the Fellowship Program, at the other extreme, while being far more costly per participant, has a payoff in permitting complete individuality and a much greater intensity of effort.

The point here, as Dr. Paige discussed earlier, is that a single program cannot hope to surround completely the faculty problem, actually a societal problem, of this complexity. It is the sum of all the related efforts, including the ones yet to be discussed, which must be considered.

To return to our classification of programs, the second, or "coincidental" category contains those which have serious implications for faculty development, but were created to serve some other purpose, primarily. Some randomly selected good examples are:

RIG	Minority Research Initiation Grants
URP	Undergraduate Research Participation
SSTP	Student Science Training Program
ISEP	Instructional Scientific Equipment Program

RIG, as you know, is intended primarily to strengthen the research capability of a set of institutions which serve predominately minority student populations. Yet these institutions are by and large predominately undergraduate, with a faculty who, despite research support, continue to be involved in undergraduate teaching. The professionalism, including their capacities as teachers, is enhanced significantly by the experience and stature fostered by the Research Initiation Grants Program.

Undergraduate Research Participation presents a more complicated though analogous picture. The majority of URP project support is vested in graduate-oriented institutions. The faculty recipients view these grants as a relatively minor component of their research interests, and they probably make a negligible contribution to the individual faculty member's capabilities or attitudes. At the small college, however, this program is thought to be extremely important for enhancing faculty motivation and contributing directly to good teacher qualities.

Both of these previous categories of grants, deliberate and coincidental, affect faculty competencies and/or attitudes in a direct way, whether by our design or not.

This type of analysis can be extended to include, at least to some extent, the Foundation's basic research and most other types of support. Though not easily measured or verified, we believe this to be a valid extension.

For the future, through problem assessment efforts, several study areas pertaining to faculty problems are receiving attention. We are expecially concerned about, and are seeking ways of maintaining, the intellectual vitality of faculty and their instruction under the adverse conditions predicted for the near future. Without a vital science faculty, other Foundation efforts, whatever their intrinsic merit, will be of no consequence.

MATERIALS AND INSTRUCTION

Dr. John L. Snyder

Of the four access-leverage points identified in Dr. Paige's introductory statement, the one I will discuss is unique in that it is not comprised, even in part, of people. Students, faculty members, institutions, these are not only leverage points, they are beneficiaries. But a film on topology, or a course on lacustrine pollutants, is a tool. The beneficiaries are the students who will see the film or take the course, and ultimately the society to which they will contribute through their increased knowledge.

There are, however, problems whose solution may be advanced by programs that focus on materials and curricula. Let us take a look at some of these:

Lack of Flexibility - Traditional materials tend to lack flexibility. Consider textbooks. Many are large, most are expensive, and a student is constrained to purchase the entire volume, even though only a small part may be used.

Rapid Change in Content and Method - As the content of courses changes with increasing scientific knowledge, the materials used for teaching must change with it. Where the rate is rapid, existing materials become obsolete very quickly.

Need for More Diversified Training - There is an ever-increasing demand for scientists with training that differs from the traditional. Very often these people -- environmentalists or energy experts for example -- need some combination of physical, biological, and social science backgrounds.

Utilization of New Technology - Advances in education technology offer new potentials that need to be tested and exploited. This may require a major coordinated effort because the multiplicity of materials often discourages widespread use of any one.

Escalating Costs - As has been mentioned, education costs are skyrocketing. These include not only the expenses of changing to newer, technologically more sophisticated approaches, but also the basic cost of traditional materials such as journals, textbooks, and laboratory apparatus.

The programs identified in Figure 26 are all designed, directly or indirectly, to help the undergraduate science community overcome these and other problems. I would like to describe each very briefly, and then examine some particular projects that they have supported.

PROGRAMS – MATERIALS AND CURRICULA

- ALTERNATIVES IN HIGHER EDUCATION (AHE)
  - A. INSTRUCTIONAL MATERIALS AND MODES
  - B. NEW DEGREE PROGRAMS
- TECHNOLOGICAL INNOVATION IN EDUCATION (TIE)
- INSTRUCTIONAL SCIENTIFIC EQUIPMENT PROGRAM (ISEP)

Fig. 26

Instructional Materials and Modes provides funds for the development and evaluation of different, experimental kinds of science teaching materials or programs. New Degree Programs does much the same thing but for an entire curriculum. Technological Innovation in Education is aimed specifically at problems involving computers and other kinds of educational technology. All three of these programs are designed to have a national focus. Instructional Scientific Equipment, on the other hand, provides limited funding to many departments for the purchase of needed instructional equipment. Science and Engineering Technician Education will be discussed by Dr. Mayo under institutional programs, and I call your attention to it here simply, because it does have a secondary impact in the area of curricula and materials development.

Now, let us look at a few projects that these programs have assisted from the standpoint of the problems to be remedied.

We'll start out with the problem, and I will describe one or two relevant projects, and refer to the program providing the funding:

(1) Flexibility - Over the last few years much interest has been shown in the use of small, individualized teaching modules, and the Foundation has supported several projects for their development, evaluation, and dissemination. In the area of technician training, such modules are particularly suitable because of the diverse skills that technicians, taken as a whole, must have. Someone working for the National Institutes of Health may have a quite different set of job requirements from one employed by the Colorado State Agricultural Experiment Station, even though both would qualify as biological technicians. With support from Instructional Materials and Modes, Project BIO-TECH was established to develop a large number of short modules, each of which covers a specific skill that some biological technician might need. A module consists of a student booklet, a set of slides, and a cassette tape, all groupd in areas such as allied health skills, or food technology skills. Figures 27 and 28 are taken from the module on "Handling, Restraint and Gavage of the Rat" from the Animal Handling Skills series. In showing them, I hope to convey a sense of how these and similar materials can be used to learn a specific, clearly defined technique.

Just under 150 of these modules will be developed with NSF funds, a number sufficient to test the concept and provide some options for the student. The commercial distributor anticipates a good market.

(2) Rapid Change in Content - The incorporation of new knowledge and the updating of equipment in undergraduate science classes often present difficulties. To assist departments in staying current, both scientifically and pedagogically, the Instructional Scientific Equipment Program provides matching grants for the purchase of equipment needed to improve undergraduate teaching. For example, large amounts of quantitative information are currently provided the geological sciences through many new sources -- the Deep Sea Drilling Program, rapid chemical

Fig. 27

Fig. 28

analysis techniques, extensive geophysical surveys and Earth Resources Technology Satellite (ERTS) photographs, to name but some. It is important for undergraduates to deal directly with these data, so the University of New Mexico received funds from the Instructional Scientific Equipment Program to help purchase a programmable calculator for its geology department. This calculator will allow students to work with this basic information in more than a dozen undergraduate courses.

A second project, supported not by ISEP but by Instructional Materials and Modes, deals with the problem of changing scientific content in an area of national concern; namely the field of shipbuilding and ship design where the U.S. has had a long and distinguished history. Donald McKay, Henry Kaiser . . . these names recall days when we were a leading maritime nation. No longer! By 1972 the United States had dropped to 12th in terms of gross tonnage constructed, behind, among others, Poland, Italy, Spain, Yugoslavia and Denmark. At present, there are only three undergraduate programs in the area of ocean engineering and ship design in the U.S.; at the University of Michigan, MIT, and the Webb Institute. The first two recently received grants to develop new teaching materials -- largely computer-based -- and to restructure their respective curricula. Because Webb Institute will serve as an evaluation center for the materials developed at the other two institutions, this project should reach essentially 100 percent of the undergraduate students in this field.

(3) New Kinds of Training - With the proliferation of environmental and energy problems, the close tie between social, political and technological factors becomes increasingly significant. In the past, scientists qualified to work in more than one limited field were rare, but many institutions are recognizing the need for generalists who are able to deal with large interdisciplinary problems despite their complexity. Grants to Cornell University, Indiana University, and Dartmouth College, among others, fall within the category of "Science and Society," and are generally designed to make science students aware of the political, economic and social implications of their work, as well as to interest them in problems where all of these are major factors.

A slightly different approach is being supported at the Illinois Institute of Technology through a grant from New Degree Programs. The Education and Experience in Engineering (E^3) project is producing a completely restructured alternative to the traditional undergraduate

engineering curriculum. All four years are devoted to real-world problem solving, using teams of students -- freshman through senior, with the humanities and social sciences being aspects of the problems attacked. The technological base is provided by several hundred small, self-paced learning modules consisting of sets of readings, problems, and exercises. When Foundation support ceases in another year, this activity will be an integral part of the curriculum at IIT. We hope and expect that, given time, it will influence the curricula at other engineering schools as well.

(4) The Impact of Technology on Teaching Materials - As you know, a great number of new sophisticated "devices" are now available for the benefit of undergraduate science students -- video cassette players, plasma display terminals, and pocket calculators to name but three. Some of these have been developed with NSF support. But our real problem is how to make use of these widely and efficiently; how to encourage them where they are an obvious improvement, and to discourage them where they are merely candles on the academic cake (candles easily snuffed out I might add). Computer programs represent a particularly difficult dissemination problem, and Project CONDUIT, supported by Technological Innovation in Education grants, attacks this problem head on. CONDUIT is a consortium of five regional networks (Dartmouth College, the University of Iowa, North Carolina Education in Computing Service, Oregon State, and the University of Texas) involving 100 colleges and universities with an enrollment of over 300,000 students. It is a large scale experiment on transportability, with a concern to determine the factors that inhibit the transfer of computer-based teaching materials from one institution to another and then to try to do something about them. Many such factors have been identified, and it is clear the problem will not be solved over night. But there have been some tangible successes. Dartmouth College reports that an educational program following standards established by CONDUIT can be made operational on their computer in fifteen minutes, as opposed to 42 hours for the non-standardized version of the same program. So far, Northwestern, Indiana University, and the University of Colorado have voluntarily agreed to adopt the CONDUIT standards and guidelines.

(5) Escalating Costs – The problem of increasing costs is so obvious these days that elaboration is unnecessary. It seems a contradiction to talk about a grant for reducing costs, yet many of our projects have this as a secondary objective. Let me illustrate with two examples. Several projects are now preparing single-use materials on newsprint, either in newspaper or tabloid format. As an example of the savings that can be realized this way, the Physics of Technology Project has prepared some of its soft-cover booklets on both newsprint and more conventional paper. The conventional booklet must be sold to students for $2.50 to break even. Its newsprint counterpart sells for 75¢. Publishers, conservative by nature, are reluctant to do these kinds of things without some clear, effective examples to provide the necessary stimulus.

A different approach to economy is taken in a project at Syracuse University also funded by Instructional Materials and Modes. The project director has induced each speaker at a national research symposium to prepare, as part of his presentation, a three-page summary including a bibliography, and three overhead transparencies. These summaries will be bound into a booklet and sold for a nominal amount at the meeting. In addition, paper copies of the overheads will be available from which new projections can be made. As a result, the attendee can return to his own institution with a teaching package, including visuals, on the latest research, at very little cost to himself or his department. A significant added benefit is that the time lag between the presentation of research and its incorporation into teaching materials will have been drastically reduced.

In conclusion, two points should be kept in mind with respect to these programs and the projects they support.

First, all of these grants, excepting those from the Instructional Equipment Program, contain an element of experimentation, which is to say, uncertainty. Thus, not all of the projects will be equally successful. If they were we would have to ask ourselves if we were being too conservative in our evaluation of proposals.

Second, departments and institutions receiving these grants represent only a small fraction of those whose students should ultimately benefit from them. The departments affected range widely in size and subject area, strengths and weaknesses. Thus if grants in the area of materials and curricular innovation seem diverse it is because they are. And they are diverse because of the many different kinds of problems that

can be attacked through this leverage point in a variety of ways. Although directed at materials and curricula, these grants all have coincidental but ultimate impact on institutions, faculty, and most of all, students. We believe that programs aimed at materials and instruction will be needed for some time to come, although the emphasis may change (Figure 29) in response to new problems. It is now apparent that lack of information and dissemination mechanisms is a major barrier to the effective and widespread use of materials, and we have an obligation to try to improve this situation. Also, we may wish to respond to the increasingly frequent requests for support of projects in science for non-scientists, an area where now we award no grants. Dr. Paige will remark on this point.

NEW DIRECTIONS

- EXPLORE MECHANISMS FOR ACHIEVING GREATER USE OF MATERIALS AND PROGRAMS
- SCIENCE FOR NON-SCIENTISTS

Fig. 29

ACADEMIC INSTITUTIONS

Dr. James W. Mayo

In this segment, examples of major societal problems are converted into sets of operational of science program type problems. This conversion is a part of the program design process and it will be described from the point of view of institutional emphasis.

In order to assume the institutional perspective, let us look again at the national institutional setting. There are some 2,700 institutions of higher education in the United States; about 1,000 of these are two-year institutions and 1,700 are four-year institutions. These institutions employ some 30% of the nation's working scientists and enroll some 4.7 million of the 7.8 million students enrolled in degree courses. These institutions spend some $29.5 billion of which $4.5 billion are Federal funds.

Even though the institutions range from a small school offering an associate degree to a major university offering graduate training and basic research, the operational program categories are the same.

Let us concentrate on the educational category which includes the academic and related supporting services. Seventy-five percent of institution expenditures are in this educational category. More specifically the academic sub-category includes: instruction and instructional services; research (internal and sponsored); and public service as described in Figures 30 and 31. Thirty-three percent of the institution's expenditures are instruction and research. This is the order of $10 billion.

ACADEMIC AND RELATED

- DEPARTMENTAL INSTRUCTION INCLUDING INSTRUCTIONAL SERVICES
- RESEARCH
  - DEPARTMENTAL
  - SPONSORED
- PUBLIC SERVICE (INCLUDING CONTINUING EDUCATION)
- LIBRARY SERVICES

Fig. 30

- **INSTRUCTION**
  - DEVELOPMENT OF UNDERSTANDING, SKILLS AND ATTITUDES
  - PREPARATION FOR PARTICULAR TASKS AND FUNCTIONS IN SOCIETY
  - TRANSMISSION OF KNOWLEDGE AND CULTURE
- **RESEARCH AND CREATIVE ACTIVITY**
  - DISCOVERY, PRESERVATION AND DISSEMINATION OF KNOWLEDGE
  - ARTISTIC CREATION AND PERFORMANCE
- **PUBLIC SERVICE**
  - CONTRIBUTIONS TO GENERAL CULTURE AND ENTERTAINMENT
  - CONSULTATIVE SERVICE

Fig. 31

The specific target of the Foundation's program is instruction. The courses of instruction, the facilities for instruction, the faculty who deliver instruction, and the students who receive instruction. Every one of the aforementioned leverage points is involved. The basis for the NSF institutional perspective is change of the balance and modification of relationships between these elements.

The Foundation input to higher education is about $30 million, some 0.3% of the institutions' expenditures for instruction alone. In an effort to induce a strong effect in spite of this input magnitude we focus on changing relationships via the project approach aiming at tipping the balance of operations.

Let's take a look at how we go about doing what we do.

First, we have continued to use the project approach because it permits "competitive evaluation of alternative approaches and choices of what seem most economic or most likely to succeed." This approach also allows the flexibility of having different promising approaches at the same time.

We have used the Science Improvement project approach for relatively different problems and goals, and different objectives, as listed below:

To increase the number of graduate centers of excellence;

To accelerate development of predominantly undergraduate schools;

To improve two-year/four-year science program articulation; and

To accelerate development of minority institutions' science education capability.

Current Activities

These mechanisms have survived natural selection and they have evolved as have the problem-types.

Currently the Science and Engineering Technician Education Program (SETEP) and the Minority Institutions Science Improvement Program (MISIP) make contributions to careers in science. Restructuring the Undergraduate Learning Environment (RULE) and Pre-service Science Teacher Education (PSTE) make contributions to improving effectiveness.

SETEP

The Directorate objective for SETEP is the appropriate number, variety and quality of technological and scientific manpower. This is addressed by increasing an institution's capacity to provide trained technical personnel for research and technology efforts.

Stated in problem solving terms:

> How can an educational foundation be generated that is capable of supporting further professional growth?
>
> How can an education program be established that responds to immediate job demands and changing problems of education?
>
> How can technical manpower be assisted in developing an ability to adapt to evolving and emerging technology?

For which our response is:

> Development of a limited number of technician education programs at collegiate level institutions;
>
> Testing of a limited number of programs which are responsive to recognized technical manpower needs;
>
> Development and testing of technician education programs which are designed to provide a firm base for continuing education.

A primary emphasis in all of the actions is basic scientific, engineering, and mathematical knowledge. The program stimulates development and evaluation of collegiate level technician programs.

The examples or project support given here are not given in any detail. But rather, they are meant to illustrate that the program permits the design or identification of relationships between existing or new instructional elements. The relationships may be adopted or modified by others.

SETEP projects are responsible for identifying the basic objectives of a chemical technology program featuring a two-year component that is independent and transferable. This has a fairly non-local impact.

MISIP

The Directorate objective of insuring the appropriate number, variety, and quality of technological manpower is addressed here through improving the science education capabilities of institutions mainly serving ethnic minorities.

The problems considered are:

How can institutions be assisted in overcoming the effects of institutional isolation and lack of facilities and equipment?

How can institutions attract and hold promising scientist-scholars?

How can institutions develop programs that establish effective instructional procedures for preparing their students in science?

The actions stimulated are:

Development of plans for improving preparation of minority students for careers in science;

Testing new education procedures, designing curricula, developing instructional strategies;

Developing faculty competencies and improving instructional facilities.

Figure 32 lists types of MISIP projects, two of which emphasize relationships between institutions in this target population and other external national resources.

First, a conference on computers for instruction in 100 minority institutions to make informed decisions regarding computer equipment, courseware, instructional techniques, and the use of computer based instructional systems that may be employed in improving their science education programs. A combined resource handbook and proceedings will be published for use by future planners.

Second, an educational technology workshop for 60 institutions is responsible for providing national expertise for training in the design and production of mediated

MISIP PROJECT EXAMPLES

- COMPUTER CONFERENCE
- EDUCATIONAL TECHNOLOGY SYMPOSIUM & WORKSHOP
- SCIENCE IMPROVEMENT PROJECT

Fig. 32

materials and the use of media hardware in the teaching of science and mathematics. The project is also responsible for a case study handbook to provide a guide for materials and hardware purchase and planning.

An example of a science improvement project at an individual institution is Sheldon Jackson College. This project is responsible for a bootstrap operation opening science careers to Indian and Eskimo students in curricula relevant to Alaska. This is a part of an institution developing in the face of geographical, cultural and academic isolation.

RULE

Educational Restructuring assists in the design, development, and evaluation of new approaches to the organization, management, delivery and content of science education. This meets the Directorate objective of improving effectiveness and efficiency of science education.

The problems addressed are:

How can institutions meet the need for changing science education programs in response to changing clientele and societal needs?

How can institutions meet the needs for change in response to cost of operations?

How can institutions meet the need for change to give real options to themselves and new types of students?

Some actions to be stimulated are:

Development of simple experimental models;

Demonstrations of mechanisms to effect comprehensive changes;

Discovery of the effective range of diversity in undergraduate instructional models.

RULE Project examples are given in Figure 33.

RULE EXAMPLES

- EARLY BACCALAUREATE DEGREE
- PROBLEM SOLVING, NEW APPROACH

Fig. 33

One project is directed at the establishment of an early entrance baccalaureate degree college. Within four years, high school juniors complete programs and enter graduate or professional schools with no credential disadvantage.

Others either use a problem solving approach for a single track in a traditional program such as the E^3 plan mentioned earlier or develop and implement an educational scheme permitting a completely flexible program tailored to the goals and needs of the individual student, such as the WPI plan (Figure 34). An important aspect of the plan includes student responsibility for developing, with faculty guidance, an individualized program leading to a degree. The requirement is that a student demonstrate competence in the chosen field in lieu of accumulating

RULE PROJECT WORCESTER POLYTECHNIC INSTITUTE

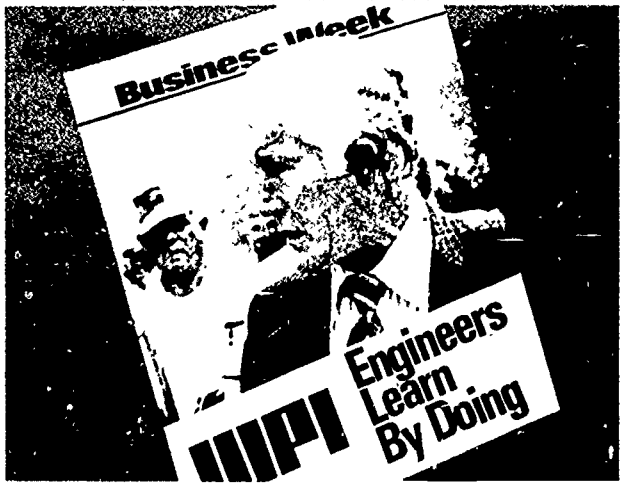

Fig. 34

credits in disciplines. The final objective of the project is a totally new approach to the education of scientists and engineers in an effort to produce graduates who are masters of the selected field and aware of the impact of their scientific and engineering decisions on society.

PSTE

Pre-service Teacher Education is a special type of institutional program aimed at a restricted but extremely important group of undergraduate students. It is designed for the young people who will teach science at the pre-college level, mostly in secondary schools. It promises to have leverage in improving science education by increasing the effectiveness and capacity for self-renewal of the few who influence the many. And these new teachers will have students in all academic tracks: those vocation-bound, those with broad-interests, and those who have made decisions to pursue a given career in a professional field, science based or not. (Figure 35). From the projects supported thus far in a variety of institutions that train teachers we have learned that:

> Students benefit from early contact with the pre-college teaching situation, i.e., the classroom, the students, and the in-service teacher; as sophomores or even as freshmen they sort out many things that affect their academic plans.
>
> Teachers in training respond very positively to collegiate instruction by means of active scientific inquiry; and this is the context in which most of them will do their teaching.
>
> Science teaching resource centers that provide access to equipment and materials and modern instruction in science bring together in a meaningful way the substance of science, the things of science, the experienced teacher and the learner.

PSTE PROJECT MECHANISMS

- EARLY TEACHING EXPERIENCE STARTING IN THE FRESHMAN OR SOPHOMORE YEAR
- UNDERGRADUATE INSTRUCTION IN THE INQUIRY MODE
- SCIENCE TEACHING RESOURCE CENTERS
- ADMINISTRATIVE AND OPERATIONAL LINKING OF SCIENCE AND EDUCATION

Fig. 35

Pre-service Teacher Education establishes an effective interface among professional scientists, professional educators, and school administrators, all of whom are essential to improving instruction in science.

These concepts, we now know, are feasible in a limited number of institutions where they were developed. Our next step is to find out whether the basic ideas can and will be utilized successfully by others.

Most of all we see great benefits in areas where minority populations are concentrated. Students from the reservations, the ghettos and the barrios usually drop out before they see a connection between their studies and their lives. The opportunity to teach their peers or younger students, along with access to modern materials, and the growth of a colleagueship with teachers can set many of them on the road to productive careers.

In summary, we have looked at the environment on which we act, we have looked at mechanisms used to act and we have shown how the problem to program to project process unfolds.

***

Prologue for the Future

Dr. Lowell J. Paige

We have attempted to present briefly several aspects of science education; these were:

(1) NSF institutional constituency;

(2) Several problems for science education which the Foundation's present programs were designed to alleviate;

(3) The manner in which programs operate through the only leverage points available; students, faculty, materials and institutions.

Let us turn to types of problems we face and their future implications for the Education Directorate. I would classify the problems into three distinct categories:

(1) Problems unaddressable by NSF;

(2) Problems requiring changing emphasis of existing programs;

(3) Problems requiring new programs.

Let me propose several examples of the first type (Figure 36):

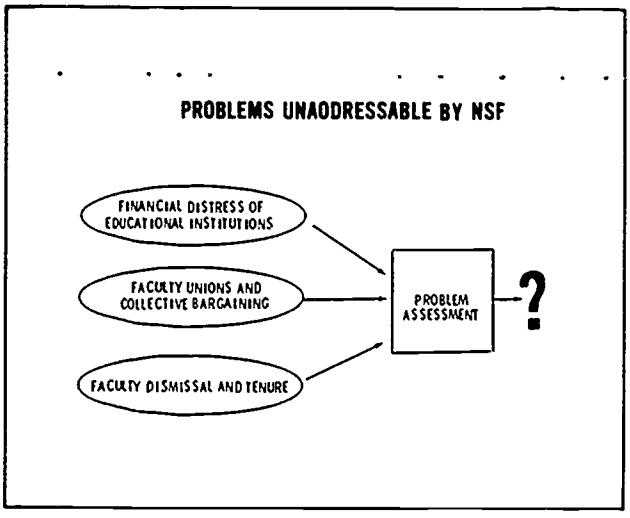

Fig. 36

(1) Financial Distress of Education Institutions

The financial strains faced by most of our educational institutions suggest the need for a massive institutional program. However, I believe such a program is impossible until there is some national consensus on financing post-secondary education. In the meantime,

Science educational equipment is deteriorating and sometimes obsolete;

Colleges and universities are unable to provide the needed special educational assistance for students accepted under more open enrollment policies;

Faculties are unable to initiate new programs suggested by changing national needs -- energy, materials.

Hence, we believe it critical to continue programs supporting science educational equipment and models of institutional change as well as new institutional programs, however modest, designed to assist and encourage those schools responding to changing patterns of student enrollment, student interests and national needs.

(2) Problems Accompanying Faculty Unions and Collective Bargaining

I believe it is impossible for anyone to predict the impact of faculty unions on materials development if course content and curriculum becomes a collective bargaining issue. And, as a matter of future concern, what impact will unions have on university research!

(3) Problems of Science Faculty Dismissal. Even Tenure Itself.

The courts, unions and economic conditions may well emphasize difficulties here.

Next let us turn to problems which may require changing the emphasis of present programs (Figure 37):

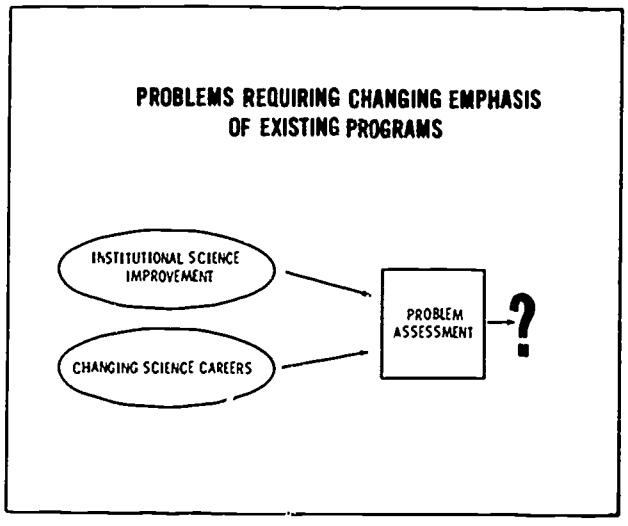

Fig. 37

(1) Institutional Science Improvement - Why and How:

It should be remarked here that we are reemphasizing a point made earlier. We do not envisage a program designed to provide fiscal stability; but either one to provide special purpose grants or one designed to provide some flexibility to institutions who have already evidenced a desire to respond to changing societal priorities.

(2) Science Education More Reflective of Changing Science Careers.

I envisage here additional university-industry interaction in providing both faculty and students alternatives. I would say we welcome proposals from institutions under our New Degree program -- and we will continue to seek innovations under our Faculty Research Participation program.

It is at this point that I should say that programs with changing emphasis are often misinterpreted as sustaining subsidies when, in reality, we are often using the mechanism of an on-going program to respond to new problems; the Chautauqua program described by Dr. Watson is an excellent example.

I will now turn to problems for which new programs are needed (Figure 38):

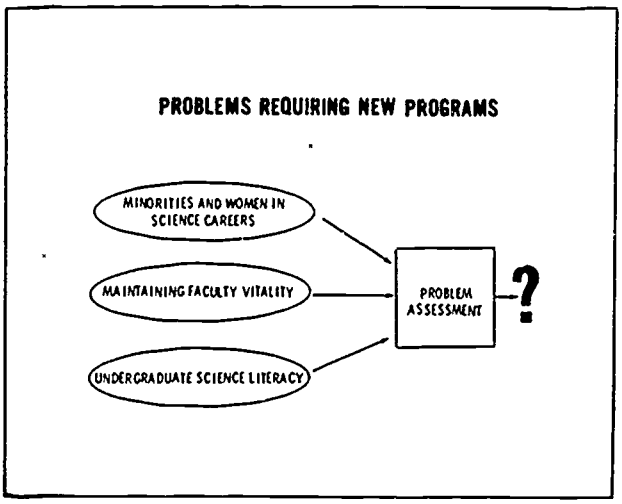

Fig. 38

(1) Attracting Minorities and Women to Careers in Science

Perhaps I need not, but I will, emphasize again the problem of increasing the access to careers in science and engineering by under-represented groups. This needs additional effort. So far, the major emphasis has been on improving institutions primarily serving minority groups with some opportunity for faculty members at those institutions in research initiation. Special attention should now be addressed to students and this may require changes in our statutory authority. Studies we now have under way may suggest additions to our student programs, perhaps at the secondary level.

(2) Maintaining Science Faculty Vitality

Dr. Watson has discussed the spectrum of faculty responsibility in our programs. However, as for programs specifically designed for maintaining faculty vitality, he has noted the gap between Faculty Science Fellowships and the Chautauqua program. We believe that a need exists for a new program that emphasizes course improvement by individual faculty, an effort to integrate important scientific as well as educational advances into the undergraduate program; a knowledge transfer problem, if you will. Prior emphasis on national impact at the college level seems unrealistic. The Foundation should shoulder the responsibility for disseminating faculty achievement in course innovation.

(3) Undergraduate Science Literacy

It may not be apparent, since science literacy was mentioned only briefly by Dr. Snyder, but we have a glaring gap in materials development at the college level for students who are not science-oriented. This problem is so closely related to the Public Understanding of Science that perhaps we should seek further need assessment before launching a new program.

Finally, a few closing remarks. Our activities are not a randomized collage of projects and criticism of the Foundation's educational program, more often than not, is directed at the priorities chosen for alleviating the problems we face.

Our concern for the impact of our programs has led to the creation of a group within the Directorate with responsibility for evaluating on-going programs and assessing the impact of our efforts. Independent third-party evaluations have already suggested modifying our programs.

There is no recipe for an instant scientist or engineer nor a handbook for science literacy. Educational policies naturally focus on long-range goals. However, within an overall concern for students, a diligence for the quality of science education, a careful consideration of alternatives, and a responsiveness to national policies and societal priorities, we must never lose sight of the fact that it is our responsibility to provide our most intellectually gifted students in science opportunities to investigate and pursue research in science as a chosen career.

It is difficult for the Foundation to predict which of its programs will have greater impact or which programs may prove to be more cost-effective in their consequences. However, by means of a continuing program of impact assessment and evaluation, we will recommend to the National Science Board through the budget process those programs we believe meet the needs and challenges of science education most effectively. Since our recommendations may very well reflect priorities with which the Board or Congress might not agree, the Education Directorate understands that programs may be continued which we had planned to discontinue and conversely. In this case, the Education Directorate stands ready to conduct those programs to the best of its ability.

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