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ABSTRACT

This report describes the findings of the 1990 National Science Foundation (NSF) Workshop on the Dissemination and Transfer of Innovation in Science, Mathematics, and Engineering Education, and the resulting recommendations for action to the NSF, to university administration and faculty, to professional societies and journals, and to industry. The workshop was comprised 20 members, representing all levels of responsibility in higher education, and a broad range of disciplines, including chemistry, communication, computer science, earth science, engineering, life science, mathematics, and physics. Six broad needs that must be addressed if the United States is to meet the challenges facing higher education are: (1) the need for visibility; (2) the need for collaboration; (3) the need for taxonomy; (4) the need for evaluation; (5) the need for infrastructure; and (6) the need for educational insight. (PR)

# Report of the National Science Foundation Workshop on the Dissemination and Transfer of Innovation in Science, Mathematics, and Engineering Education

DIVISION OF UNDERGRADUATE SCIENCE, ENGINEERING, AND MATHEMATICS EDUCATION

DIRECTORATE FOR EDUCATION AND HUMAN RESOURCES
NATIONAL SCIENCE FOUNDATION
MAY 1990

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# Report of the National Science Foundation Workshop on the Dissemination and Transfer of Innovation in Science, Mathematics, and Engineering Education

DR. RICHARD D. BRESLIN, CHAIR
MAY 1–3, 1990

DIVISION OF UNDERGRADUATE SCIENCE, ENGINEERING, AND MATHEMATICS EDUCATION

DIRECTORATE FOR EDUCATION AND HUMAN RESOURCES
NATIONAL SCIENCE FOUNDATION
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# FOREWORD

In March 1986, the National Science Board (NSB) released its report "Undergraduate Science, Mathematics and Engineering Education" (NSB 86-100) that described the outcomes of a year-long study conducted by the NSB Task Committee on Undergraduate Science and Engineering Education. The NSB report identifies serious problem areas in U.S. undergraduate education and suggests remedial actions that should be taken by academic institutions, the private sector, states, the National Science Foundation, and other Federal agencies.

As a follow up to the NSB 1986 Report, the NSF, through the Division of Undergraduate Science, Engineering and Mathematics Education of the Directorate for Education and Human Resources, has sponsored several workshops dealing with undergraduate education: "Undergraduate Engineering Education," May, 1986; "Disciplinary Workshops on Undergraduate Education," April, 1988; "Science, Engineering, and Mathematics Education in Two-Year Colleges," June, 1989; "Engineering, Engineers, and Engineering Education in the Twenty-First Century," December, 1989; "Dissemination and Transfer of Innovation in Science, Mathematics and Engineering Education," May, 1990; and "Undergraduate Laboratory Development," June 1990.

The workshop held in May of 1990 was comprised of twenty members, representing all levels of responsibility in higher education and a broad range of disciplines including chemistry, communication, computer science, earth science, engineering, life science, mathematics, and physics. This report describes the findings of the NSF Workshop on the Dissemination and Transfer of Innovation in Science, Mathematics and Engineering Education, and the resulting recommendations for action to the National Science Foundation, to university administration and faculty, to professional societies and journals, and to industry. The opinions expressed in this report are those of the expert panel and do not represent NSF policy. Recommendations of the panel are currently under review by NSF.

The National Science Foundation expresses its gratitude to Dr. Breslin and to all workshop participants for their hard work and valuable contributions.

# NATIONAL SCIENCE FOUNDATION
# DIRECTORATE FOR EDUCATION AND HUMAN RESOURCES

March 30, 1991

Walter Massey
Director
National Science Foundation
Washington, D.C. 20550

Dear Walter:

I am pleased to submit to you the report of the experts who participated in the National Science Foundation Workshop on the Dissemination and Transfer of Innovation in Science, Mathematics, and Engineering Education.

The report is the result of the dedicated efforts of Dr. Richard Breslin, President of Drexel University, and a panel of twenty distinguished leaders within the higher education community. It succeeds several studies that have emphasized the importance of undergraduate science, mathematics, and engineering education, and reflects the critical role of the National Science Foundation in furthering the dissemination and transfer of quality innovation in this area.

Luther S. Williams

Luther Williams
Assistant Director
Education and Human Resources

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# EXECUTIVE SUMMARY

Innovation in science, mathematics and engineering education is a powerful and necessary tool for addressing the nation's manpower shortages, revitalizing undergraduate education and meeting the educational needs of non-traditional students in the quantitative disciplines. While innovation activities are taking place at some colleges and universities, the results of these efforts are, for the most part, not being disseminated throughout the nation's higher education community. We need to multiply the benefits of educational innovation activity at one location by providing for the dissemination, transfer and adaptation of quality innovation to other institutions and additional learning environments.

The transfer of educational innovation is frustrated by a multitude of barriers. Some difficulties arise from the independent nature of institutions of higher education. Many difficulties arise from the second-class citizenship of teaching, relative to disciplinary research, in the practice of higher education at many colleges and universities. And, for those educators who do pursue activity in educational innovation, there is frustration with an almost complete lack of national infrastructure to aid and foster such activity.

Dissemination, transfer and adaptation of quality innovative educational methods must increase substantially if innovation is to be an effective agent in helping to address the nation's pedagogical needs. For this to occur, activities in educational innovation must become visible to others, and an infrastructure as effective as the infrastructure that supports disciplinary research must be created to support educational innovation. Of very great importance is the need to restore balance between teaching and disciplinary research in the nation's colleges and universities.

Virtually all parties in higher education have an important role to play in addressing the nation's manpower needs through innovation in educational methodology, and the transfer of such innovations, in science, mathematics and engineering education. Colleges and universities must restore a significant measure of value to quality teaching and faculty activity in educational innovation. Professional societies and journals must act to recognize achievement in innovation and become agents for the dissemination of information about quality innovation. The industrial complex must become a partner with higher education in supporting and setting direction for innovation activity. The national government, through the Office of the President and through appropriate agencies, must speak to and actively support both quality innovation and the entire higher education enterprise. The National Science Foundation, long a supporter of innovative activity in undergraduate education, now has a crucial role to play in furthering the dissemination and transfer of quality innovation so as to lead the nation forward in seeking solutions to current difficulties in science, mathematics and engineering education. In particular, the Foundation can foster the transfer of innovation by building appropriate transfer-potential evaluations into all education development projects and by supporting the transfer and adaptation of completed, successful innovations to other institutions and to additional learning environments.

# INTRODUCTION

The vitality of education in science, mathematics, and engineering [1,2,3,4,5] in colleges and universities is essential to the health of the nation. [6] Numerous studies have predicted a severe shortage of manpower in science and technology unless we can attract an unprecedented number of new students, including women and minorities, to the serious study of science, mathematics and engineering. [7] Even if we are able to attract enough students, it is an enormous task to retain and motivate them while providing a topflight education which will enable them to cope with the pace of scientific and technological development throughout their careers. Many students are overwhelmed by curricular offerings that are overcrowded with too many courses and bored by outdated topics and equipment. A strong case can be made that these students are denied a quality education by an over reliance on a passive lecture/recitation format. Employers worry about whether recent graduates and those engaging in continuing education have the skills needed to make effective contributions to the nation's economy.

In short, there is a national need for innovation in undergraduate science, mathematics, and engineering education.

President George Bush has said that our "nation will not accept anything less than excellence in education." [8] Such a national effort will require major funding from many sources and personal energy on the part of many individuals. Responsibility for innovation and continuous program review and development must be the shared commitment of federal agencies, private foundations, administrators, college faculty, pre-college teachers, and industry.

For those who teach, this is an exciting time. Much educational innovation is occurring. There is a heightened interest in the importance of teaching and learning at the college level. [9] There are new understandings of the learning process based on outcomes of research in science education and cognitive psychology. There are such new technologies as computers, electronic mail and video equipment that can help both faculty and students engage in active, collaborative learning in many disciplines. In addition, new developments in many fields of science require us to rethink both the content of our curricular offerings and the manner in which we train scientific professionals.

Today's educators in science, mathematics, and engineering are developing and testing new approaches in undergraduate learning that range from changes in a single college course to major revisions in an institution's entire curriculum. However, to meet the challenge to the nation of reshaping outdated programs and attracting new students, educators must not only develop bold innovative curricula and educational materials themselves, but also assist their colleagues in adopting their innovations and find ways of adopting the educational innovations of others. In an effort to share innovations with others successfully, educators face a variety of challenges, many springing from the highly varied and independent nature of American higher education.

While there has been some investment over the past few years in the use of new methods and technologies in the classroom, many inspiring and worthwhile educational innovations never move beyond the walls of local institutions. It is important to the vitality of teaching in mathematics, science and engineering, therefore, that the best of new programs become known and seriously considered for adaptation, where appropriate, for use at other institutions. Faculty in other departments and at other institutions must learn about the best of the innovations and must have access to the financial and human resources needed to evaluate and adapt worthy ideas to other settings.

The workshop participants came together to engage in an in-depth exploration of the issues of transfer of educational innovation and to develop strategies and recommendations to disseminate such innovation. In this report, the workshop participants

define the issues by making some observations about the nature of educational innovation and its transfer, examining the barriers to adoption of new curricular ideas;

state goals for a national effort to improve the transfer of educational innovation;

present strategies to be followed in this effort; and finally,

offer recommendations for action by the wide variety of persons and institutions which have a role to play in the higher education enterprise.

# ISSUES AND NEEDS

An examination of the state of innovation in undergraduate science, mathematics and engineering education exposes a large number of difficulties for, and barriers to, the transfer of innovation both within and between institutions of higher education. These difficulties and barriers can be grouped so as to identify six broad needs that must be addressed if the nation is to meet the challenges facing higher education.

### *1. The Need for Visibility*

Many valuable innovations in science, mathematics and engineering education now occur, yet few of these are visible, and therefore few are widely used by a broader base of educators. Partly as a result of the "invisibility" of such educational innovations, and partly as a result of skewed incentive systems, such educational activities are too often held in far less esteem in universities than are innovations in scientific and engineering research. In the main, the typical university incentive system actively discourages any significant focus on teaching-related innovation. External funding for research innovation is far larger than that for educational innovation, causing the latter to appear relatively valueless among nati nal priorities.

National leadership today expresses concern regarding manpower shortages and the lagging technological status of the United States of America. Within academia, however, innovations in science education are not afforded the same collegial respect as are those in disciplinary research. Faculty peer review and the impact of promotion and tenure interfere with our ability to stimulate research activity and progress in the area of educational innovation. Untenured faculty (and tenured as well) are rarely rewarded for working on innovative teaching methods.

The historical traditions of disciplinary activity in universities are a major barrier to formation of an interdisciplinary community of science, mathematics and engineering educators. Normally, there is little interchange between and among fields about teaching methods that could cut naturally across discipline lines.

Within the academic community there is an obvious need to improve the visibility of innovation in science, mathematics and engineering education. There is an equally obvious need to make such innovations visible to the larger public audience so as to empower supporters of innovation to sanction, stimulate and reward productive activities for the development of undergraduate education.

### *2. The Need for Collaboration*

In their roles as teachers, university faculty members usually work in relative isolation, seldom sharing their methods and innovations with others. Thus, one might hear of a "new, computerized instructional system" for some field and then find it very difficult to acquire and to use. Teaching thereby contrasts with research, which is usually conducted by a community of peers with considerable sharing of results through a rich variety of mechanisms. Collaborative ventures have long been important and, in some cases, essential in scientific and engineering research; they must also become the norm in educational and instructional innovation.

### *3. The Need for a Taxonomy*

In contrast with the characteristics of research activity, in which there is usually a shared understanding of the problems of interest in the field, there is no common taxonomy of problems and results in instructional innovations. There is no accepted method for comparing the effectiveness of one curriculum versus another. Thus, when innovations do occur in science, mathematics or engineering education, it is difficult to characterize their nature and to estimate their potential common use and their impact. Scientists, specifically, often feel that they have no clear defined language and/or methodology for dealing with teaching and related innovations.

### *4. The Need for Evaluation*

For curricular or pedagogical innovations to acquire credibility in the academic, industrial, or wider communities there must be a mechanism for, and evidence of, rigorous evaluation. The evaluation scheme must assess the purposes, process, and product of the innovation. Evaluation instruments must provide defensible evidence of the level to which the innovation has met its stated goals.

Over-committed time and lack of money to pay for that time pose the most significant barriers to providing program evaluation. Potential users are likely to be the best evaluators, but these persons are usually unable to invest the time necessary to determine the relative usefulness of new approaches. A lack of expertise on the part of innovators in the areas of educational research and testing protocols and a lack of knowledge about the extent of curricular innovation in progress hamper the evaluation process. It is also important to distinguish between evaluation and accreditation. While we recognize the need for accreditation processes in some disciplines, accreditation criteria, and their application, can sometimes be perceived as counting in ways that stifle innovation.

Inter- and intra-disciplinary competition, turf battles, institutional biases, and other academic foibles all too often form barriers to objectivity in the evaluation process. Most institutions lack incentives for adopting innovation. To counter this tendency, educators have to be convinced that the innovation is sound educationally, the innovation has to be perceived as being effective and the expertise needs to be available to implement changes. In the final analysis, educational innovation which improves the teaching-learning environment needs to be seen as a value unto itself.

### *5. The Need for Infrastructure*

There does exist some infrastructure for support and transfer of educational innovation. The media for curricular innovations include written materials, video tapes and disks, software, journal articles, and new apparatus. Methods for distribution of information regarding innovation include both formal and informal techniques. Informal methods include workshops at conferences, electronic bulletin boards and mail, personal contact, presentations at conferences, articles in journals and distribution of materials at cost via mail. Formal methods include in-house grant-supported distribution and distribution by educational organizations, software companies, publishers, equipment manufacturers and supply houses. One publisher is even offering on-demand publication of textbooks [10] from master computer files of instructional materials and texts, an approach which permits faculty members to tailor a textbook to their specific courses.

However, in contrast with the superb infrastructure that has developed to support the national research effort, the infrastructure supporting educational innovation has obvious weaknesses. There is a lack of peer-reviewed journals devoted to educational innovation which would hold the interest of engineering, mathematics and science educators. There are very few ongoing interdisciplinary conferences at which educational innovations are featured. The larger publishers are sometimes wary of software and other new media, leaving their distribution to smaller, more financially precarious firms.

Faculty in many disciplines are not yet equipped with adequate computing facilities and network access [11] that can be used to communicate with other educational innovators. For those faculty that have network access, the sharing of innovative teaching methods, educational materials, and particularly computer software has been significantly facilitated by national and international electronic networks such as NSFNET and BITNET. Electronic networks capabilities such as electronic mail, bulletin boards, and file transfer have been important in both the development and dissemination of innovation in some fields. Other fields, even though well equipped, have not yet adopted the modern computing culture of networking.

Developing an infrastructure takes resources. The cost of adoption or adaptation of curricular materials and new equipment, and especially the cost of extra staff time to support this enterprise, may seem prohibitive. The cost of maintaining the new program may be more expensive than that of maintaining the old system. The present and projected manpower problems in science, engineering, and mathematics may slow the pace of educational innovation and its transfer. Finally, behind any discussion of resources looms the difficult and complex issue of intellectual property, the conflict between free dissemination of information and the use of patents and copyrights to protect commercial interests. [12]

### *6. The Need for Educational Insight*

Because most faculty do not know enough about educational methodology and how students learn, some faculty have a tendency to use teaching strategies which may not be appropriate to the culture of their students; this does not create an environment conducive to adopting more effective teaching techniques. Moreover, philosophies of education suitable at the graduate level are frequently not suitable to the instruction of undergraduates, especially in their early college years. Another current reality is that existing curricula in many disciplines are often jammed with required courses, leaving virtually no room for innovation.

In higher education, scholarship should be defined to include traditional research, original curriculum development and educational innovation. Original educational innovation and adoption of innovation take time and energy and unless such activity is rewarded, it is difficult to stimulate faculty interest in such activities.

# GOALS

As a result of identifying the national needs and issues previously set forth, the workshop participants established a focused set of goals which should help the higher education community improve engineering, science and mathematics education.

1. Raise the visibility of both good educational innovations and their innovators, enhancing public esteem of innovators in science, mathematics and engineering education while at the same time redirecting academic incentives to encourage peer recognition of educational innovators.

2. Restore a balance between research and teaching in university and college level science, mathematics, and engineering that is more in tune with the nation's needs for competent, technical professionals.

3. Evolve a meaningful taxonomy of educational innovations, providing case studies with significant examples, to help the community characterize and communicate the nature of such innovations.

4. Develop networking, both in the social sense through encouraging contacts between and among instructors in similar courses and in the technological sense through supporting the modern computer culture of electronic networking as well as the non-electronic media and publishing to enhance the intellectual marketplace in educational innovations.

5. Develop a national community of science, mathematics and engineering educators who have a common interest in, and who will speak forcefully to, the need for quality educational innovation and its transfer.

6. Evaluate educational innovation at all stages, during development, upon completion, and after transfer to users—and in all its components: pedagogical improvements, curricular content changes, software-based items, and uses of still emerging electronic and optical technologies. Evaluate learning and not merely teaching or technique and ensure that evaluation supports and stimulates rather than stifles innovation. Encourage externally-based assessment to foster objectivity and dissemination.

7. Build an understanding that the objective of innovation is to increase the quality of education, and not merely to increase productivity or to change for the sake of change.

8. Achieve widespread dissemination of successful innovations to other campuses so that the nation experiences the greatest good from the expenditure of resources used for innovation in undergraduate science, mathematics and engineering education.

# STRATEGIES

A variety of strategies will be needed to achieve the goals articulated above and many of these strategies will cut across boundaries to be important for the achievement of more than one goal. The strategies are listed in three major groupings.

### 1. *Enhance the Visibility of Educational Innovation*

Encourage top-level leadership to focus attention on the issue of science, mathematics, and engineering education, and the need for innovation in this area. For example, a "university presidents' message" to the faculties of a group of leading universities stating that teaching and educational innovations will now be as necessary as research in tenure and promotion decisions might (1) help shift the incentive systems, (2) provide a highly newsworthy item that itself would enhance the visibility of teaching and educational innovation and (3) change faculty attitudes towards the value teaching and educational innovation.

Develop a taxonomy of educational innovation with a sponsored workshop, followed by a conference, on the nature and structure of educational innovations. The resulting improvements in our ability to describe, discuss and communicate about such innovations will greatly enhance their visibility and credibility. Exploit the increasingly available video resources at universities to project powerful, positive images of great teachers and innovative educational activities to the university community and to the public at large.

Encourage science, mathematics and engineering faculty to make presentations to talk about their educational activities and innovations to campus visitors—the tradition now is to talk about one's research.

Identify the key professional publications that mold opinion in science, mathematics, and engineering communities, and encourage respected thought leaders in these fields to write and comment in these publications on the issues of innovation in science, mathematics, and engineering education.

Enhance all efforts for increasing visibility by deliberately orchestrating a planned "simultaneity effect." The "presidents' message" could be followed by the timely appearance of articles by opinion leaders across many fields that reach a wide science, mathematics, and engineering audience, followed by the national workshop. The joint result of this group of activities could be made far larger than the sum of individual, uncoordinated efforts, and ultimately reach and impact a wide audience, both within and without the college and university community.

### 2. *Evaluate Educational Innovation*

Emphasize peer review as the primary mode of evaluating innovation. Involve in the evaluation both the developers of a project and individuals from outside their group or institution. Include among these peers educational research specialists who may reside at the institutions that developed the innovation, at other academic institutions across the country, or at industrial centers for curricular development. [13] Recognize that choosing external reviewers from among prospective users will increase the probability of transfer of the innovation to additional users. Ensure that the evaluation team include perspectives from all three partners in the educational enterprise: academia, industry and government. Evaluation should also include significant student input. Use this system of networked peer review for evaluating proposals for funding, for journal articles, for professional workshop proposals and for conference plans. Tap the expertise of curricular advisory groups where they exist, and/or create them if they do not exist.

Demand clear articulation of the goals for an educational innovation project and of the criteria developed to assess its effectiveness. Insist that evaluation start at the beginning of the project, continue through development, and be maintained through the implementation phase of the project.

Ensure that accrediting agencies, in their evaluation of programs, encourage rather than stifle innovation.

Within each discipline, and across disciplines if possible, conduct a review of the literature summarizing successful innovation project case histories. Such literature, plus banks of standardized tests and evaluation instruments, should be housed in appropriate resource centers, in both print and electronic forms, and made available by them to interested users.

Make available appropriate levels of funding for evaluation of innovation on a stable and predictable basis. Funding should be made available for the development of new instruments and techniques as well as for applying known evaluative techniques. Funding should be made available for longitudinal studies.

### 3. *Combat Isolation of Educational Innovators*

Support the widespread use of information technology to promote networking among educators. [14] Make the sharing of information via electronic networks easier so that those implementing new innovations will have help and support from others who have worked in the same area of cutting-edge innovation endeavor. Encourage interdisciplinary research in educational innovation.

Develop closer ties among science, mathematics, and engineering educators and those groups in society which rely on universities and colleges. Such groups should include American industry as well as federal, state, and local research and development organizations.

# RECOMMENDATIONS

Virtually all constituencies in the community of higher education have an important role to play in addressing the nation's manpower needs through innovation, and the transfer of innovation, in science, mathematics and engineering education. Consequently, all parties must accept a responsibility for helping to change the culture of higher education in our nation. Specific recommendations, therefore, need to be addressed to the National Science Foundation, to university and college personnel, to professional organizations and to industry.

### *1. To the National Science Foundation*

Continue and expand funding for projects that address innovation in mathematics, science and engineering education. Strive to develop consistent and predictable levels of funding to support all aspects of original innovation and the evaluation of its potential for transfer to other institutions and new learning environments. Directly support transfer of innovation by making available to institutions matching funds for the adoption and adaptation of innovations developed by others.

Require that innovation projects have clearly defined methods for both internal and external evaluation to assess originality, effectiveness, quality and transferability. Insist that funded projects have built in mechanisms to ensure that the higher education community is aware of the innovation under development for purposes of possible transfer, and require dissemination plans in educational innovation proposals.

Support the development of standardized testing procedures which properly link evaluation criteria to the pedagogical and curricular goals of a given innovation. Encourage innovation activities that include the participation of specialists in educational psychology and cognate disciplines. Maintain easily accessible banks of proven standardized testing procedures and act to assure that standardized testing supports, rather than stifles, educational innovation. Encourage accrediting bodies to foster innovation.

Support the testing of innovation through subsidized student participation and support, through thesis work, the direct involvement of undergraduate students in the development of educational innovation.

Encourage more faculty to participate in originating and adopting educational innovation by supporting innovation activities through release time and teaching associate grants. Support the selection of educational innovators to give colloquia on their work at other institutions. Provide resources for women and minority programs which stress innovation in science, mathematics and engineering education. Encourage innovators to apply on a competitive basis for funding which is specifically dedicated to dissemination and transfer activity.

Fund university centers for science mathematics and engineering education so as to leverage university and industry matching funds.

Review and as necessary revise budget and supporting information guidelines used for projects in curriculum development given that research oriented budget and information documents are not always appropriate for education innovation programs.

### *2. To University and College Administration and Faculty*

A select group of college presidents identified by the National Science Foundation, should provide a leadership role in molding the nation's understanding of the need to improve science, mathematics and engineering education.

Make educational innovation and teaching as important on campus as research by considering excellence in educational innovation in the reward, promotion, and tenure process. Give prominence to teaching and educational innovation, for example, through awards at commencement.

Develop and put in place means to assess teaching performance, which will be accepted by faculty and used in performance reviews. Initiate sabbatical leaves to focus on educational innovation and faculty exchange programs to facilitate the exchange of teaching ideas.

Dedicate a fixed percentage of undergraduate tuition dollars to educational innovation. Encourage and facilitate faculty activity in educational innovation including linkages to pre-college (K–12) and graduate education. Establish and maintain a national clearinghouse or resource center, such as a center for innovative teaching or a center for science education. Develop a newsletter, or utilize an existing newsletter, to keep the campus community informed about educational innovations.

Arrange for educational innovators to make presentations at conferences for administrators and encourage sessions on educational innovation at disciplinary conferences.

Encourage faculty and staff to become familiar with educational research findings that relate to the evaluation of innovation in science, mathematics and engineering education and encourage faculty to expand their activities in the utilization of standardized test instruments. Develop a cadre of faculty and staff who are prepared and inclined to conduct both internal and external peer review of innovative projects, including on-site testing. Develop regularized testing methods and procedures with the cooperation of individuals trained in educational techniques and testing protocols.

Encourage innovation that improves learning through small classes with close faculty-student interaction.

Take new modes of instruction into consideration in the design of new undergraduate classroom and laboratory facilities.

### 3. *To Professional Societies and Professional Journals*

Clarify the relationship between the accreditation process and the encouragement of educational innovation to assure that improper application of accreditation criteria does not stifle experimentation and innovation.

Provide seed money grants to support the development of new courses and educational innovations. Give awards for excellence in education and educational innovation.

Establish journals for the publication of educational innovations within disciplines and among disciplines. Invite keynote speakers for disciplinary research meetings who will focus on issues of educational innovation.

### 4. *To Industry*

Speak loudly to the national need for a strong infrastructure to support innovation in science, mathematics and engineering education. Share industry's knowledge of evaluation of innovation in education and training with the academic community.

Participate in cost sharing for the enhancement of science,mathematics and engineering education.

Exchange faculty members and industry research lab staff so as to facilitate the flow of new ideas into the classroom and into the nation's laboratories. Encourage the use of industry personnel as instructors in project courses, and encourage industrial participation in the development of projects for undergraduate laboratory courses. Encourage appropriately qualified and motivated industry employees to take early retirement to accept teaching positions in universities where their fresh point of view can aid in educational innovation.

### 5. *General Recommendations*

Government, industry and academia should form strong partnerships to facilitate the development of the infrastructure needed to handle all aspects of increased innovation.

Non-profit philanthropic organizations should be identified to provide grants to develop and evaluate new programs and provide funding for sending faculty members and administrators to visit new programs they intend to adopt. A number of government agencies need to be more heavily involved in funding education innovation. The Department of Education should continue to expand its Fund for the Development of Post-secondary Education; and other Federal agencies such as the Department of Energy, the Environmental Protection Agency, the National Aeronautic and Space Administration, and the National Institute of Standards and Technology should develop action plans to recognize the important role they have to play in the restoration of the vital importance of science, engineering and mathematics.

Given the critical importance of education to the vitality of our country, we recommend that President George Bush continue to affirm the importance of cultivating innovation in science, mathematics and engineering education.

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**Dr. Allan Smith**
Department of Chemistry
Drexel University

**Dr. James Voytuk**
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National Research Council

**Dr. Kenneth Waldron**
Department of Mechanical Engineering
The Ohio State University

**Dr. James Wyche**
Department of Biology
Brown University

June 1990

Dr. Robert Watson, Director
Division of Undergraduate Science,
Engineering and Mathematics Education
The National Science Foundation
Washington, DC 20550

Dear Dr. Watson:

I am most pleased to forward to you this report prepared by twenty members of the higher education community who participated in a workshop, held May 1–3, 1990, in which we focused on the transfer of innovation in undergraduate science, mathematics and engineering education. We truly hope that our observations and recommendations will be of value to you and your colleagues as you move forward to address the pressing issues in higher education in our nation.

There are two important points to be made about the workshop and this report.

First, it is important to note that the twenty participants represented not only all levels of responsibility in higher education, but also a very broad range of disciplines including chemistry, communication, computer science, earth science, engineering, life science, mathematics and physics. This broad range of disciplinary skills added immensely to the excitement, breadth of perspective and the productivity of the workshop.

Second, as you read this report, you will see very early on that we believe that all partners in the higher education enterprise including administrators, faculty, industry, government and professional societies have an important role to play in supporting the transfer of innovation. To this end, we encourage you to give the views set forth in our report the widest possible circulation. We encourage the National Science Foundation to take the leadership role in orchestrating the broad response that is needed to help the nation address the critical challenges that we face.

On behalf of all of the participants, I extend to you and to your staff our deepest appreciation for your support of our endeavor. Your encouragement of our study is a clear and certain signal of the well placed concern that you and your colleagues have for the quality of higher education. Thank you for making our workshop a reality.

Sincerely yours,

Richard D. Breslin, Ph.D.
Workshop Chair

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WASHINGTON, D.C. 20550

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