DOCUMENT RESUME

ED 383 274 HE 028 387

TITLE	Project Impact: Disseminating Innovation in Undergraduate Education. Conference Proceedings (Arlington, Virginia, May 31-June 3, 1994).
INSTITUTION	National Science Foundation, Arlington, VA. Directorate for Education and Human Resources.
REPORT NO	NSF-95-69
PUB DATE	94
NOTE	123p.
AVAILABLE FROM	National Science Foundation, Division of Undergraduate Education, Directorate for Education and Human Resources, 4201 Wilson Blvd., Arlington, VA 22230.
PUB TYPE	Collected Works - Conference Proceedings (021)
EDRS PRICE	MF01/PC05 Plus Postage.
DESCRIPTORS	Biology; Chemistry; *College Curriculum; *College Instruction; Computer Science Education; Engineering Education; Higher Education; *Information Dissemination; *Instructional Innovation; Mathematics Education; Physics; Research Utilization; *Science Education; Social Sciences; *Undergraduate Study

ABSTRACT

These proceedings report the efforts of National Science Foundation researchers to disseminate innovations in undergraduate education. Section 1 contains forewords and keynote addresses by Robert F. Watson, Neal F. Lane, and Luther S. Williams. Section 2 contains overviews on dissemination and publishing including "Full-Scale Implementation: The Interactive 'Whole Story'" by Susan B. Millar; "Awareness, Access, Assistance: Dissemination Reconsidered" by Donald P. Ely; and "Getting the Word Out: Disseminating Innovation by Means of Traditional and Electronic Publishing" by Jay Sivin-Kachala and Maryellen Kohn. Section 3 contains essays on innovations in specific disciplines, including the following titles: (1) "The Nature of Efforts To Effect Interdisciplinary Reforms: Drivers, Barriers, and Strategies for Dissemination" (Steve Landry); (2) "Current Trends in Undergraduate Biology" (Jeffrey L. Fox); (3) "Chemistry Education: Innovations and Dissemination" (T. L. Nally); (4) "Education Projects in Computer Science" (A. Joe Turner); (5) "Engineering Curricula: Beginning a New Era" (Lyle D. Feisel); (6) "Keep on Moving: Energizers in Mathematics Education Reform" (Brian Winkel); (7) "Bridging the Gap: Disseminating Physics Innovations" (Robert H. Romer); and (8) "From Idea to Impact: Realizing Educational Innovation in the Social Sciences" (Kenneth E. Foote). Section 4 contains a list of conference participants and participating publishers. (MDM)

ED 383 274

Project Impact: Disseminating Innovation in Undergraduate Education

Conference Proceedings

National Science Foundation

Division of Undergraduate Education
Directorate for Education and Human Resourc
4201 Wilson Boulevard
Arlington, VA 22230

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Catalog for Federal Domestic Assistance: CFDA 47.076

Abstracts and further information about the projects referenced in this document are found in Project Impact: Disseminating Innovation in Undergraduate Education, Abstracts of Projects: Things That Work, *NSF 95-70.*

Project Impact: Disseminating Innovation in Undergraduate Education

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Conference Proceedings

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PROJECT IMPACT: DISSEMINATING INNOVATION IN UNDERGRADUATE EDUCATION

May 31–June 3, 1994
Crystal Gateway Marriott
1700 Jefferson Davis Highway
Arlington, Virginia 22202

Division of Undergraduate Education
Directorate for Education and Human Resources
National Science Foundation

PARTICIPATING AGENCIES:

United States Department of Agriculture
United States Department of Education
National Aeronautics and Space Administration
National Institutes of Health
Division of Research, Evaluation and Dissemination, NSF
Division of Elementary, Secondary and Informal Education, NSF
Division of Engineering Education and Centers, NSF
Division of Materials Research, NSF

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Special thanks to McGraw-Hill Publishers for their sponsorship of the opening reception.

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Any viewpoints, opinions, and conclusions or recommendations expressed in the Conference Proceedings are those of the writers and or participants of the Project Impact conference and do not necessarily reflect the views of the National Science Foundation

SECTION I

Introductory Material

Introduction

Ann P. McNeа.
Division of Undergraduate Education
Directorate for Education and Human Resources
Conference Coordinator

The idea for a conference on dissemination arose from discussions among Program Directors in the National Science Foundation's (NSF) Division of Undergraduate Education (DUE). The calculus reform efforts, which are gathering momentum across the country, sparked by NSF funding, were aided by yearly conferences of principal investigators (PIs). As we searched for ways to speed transformation in other areas of science, mathematics, engineering, and technology (SMET) education, the idea of bringing selected PIs together with interested publishers became more attractive.

We see a clear need for amplifying federally supported projects so that each curriculum project has the greatest impact outside the walls of its originating institution. NSF obviously does not have enough funds to reach each SMET classroom individually. Therefore, we rely on PIs to publish, speak, meet, and spread the word so that their innovations are adapted and adopted at other institutions. This conference was conceived to foster that process. But what format would serve that purpose?

The committee that shaped the conference decided early in the process that we wanted a participatory conference, not one in which people sat and listened to expert speakers. After all, we were gathering a group of 250 extremely active thinkers, teachers, and developers. So each PI should show his or her project to all others. Likewise in the discussions, we wanted to get ideas from all participants, rather than talk *at* people. In short, we designed the conference to model the kinds of active hands-on participatory learning that we are fostering in so many of our projects.

The result was a conference in which everyone had a poster or booth to display their project, many with hands-on activities. More than 10 hours during the 3 days were given to participants to roam the exhibit hall (and still, many said that they wished for more time for this activity). Periods for PIs to staff the displays were staggered so that everyone could see most of the exhibits.

Another 12 hours were spent in group discussions of no more than 12 people, some gathered by discipline and some across disciplines. These groups were tasked with generating suggestions for better and more vigorous dissemination of curriculum reform. Valuable suggestions from these discussions have been encapsulated in the essays that are the backbone of this volume. We hope they will serve as an aid

to present and future PIs so they may spread their ideas more widely.

It is difficult to convey on paper the excitement that characterized this conference. Clusters of PIs gathered around exhibits, told one another of other exhibits, and talked excitedly. Many times in passing, I heard comments such as "Did you see that exhibit on engineering design? They have an idea that I really want to copy for my biology course . . . Let me show you this math display. It really is similar to what we're doing in geology, and I think we can use it . . . What's your e-mail address? . . . Do you have a handout or disk on that?" The cross-disciplinary fertilization, in particular, was extraordinary. Comparing the various essays on trends in educational reform in the different disciplines, appearing later in this volume, one can see a good deal of convergence on the following themes:

- Changes in course content (both inclusion of new, often interdisciplinary, topics, and paring down of coverage in order to allow better learning),
- Improved pedagogy with more active student participation, cooperative learning, project-based learning, and use of writing,
- Use of technology emphasizing visualization, tools for students to explore material actively, and access for all students.

Although PIs are actively developing these ideas, the major issue is how to spread and implement them further, faster, and more effectively. One major stride taken at the conference was bringing together text and software publishers with the PIs to talk and find a common ground. For many innovations, publishing a text or courseware is an important means of disseminating the innovation. Hence it is important to have publishers working with PIs in order for publishers to appreciate the opportunities and challenges of working with innovators and for PIs to see how to interact effectively with publishers (see essay by Jay Sivin-Kachala and Maryellen Kohn in this volume). At the same time, it is important to recognize that innovation spreads in a community of scholars (see Susan Millar's essay). Just as research results are disseminated by multiple active paths—word of mouth, conferences, articles, and reviews—so educational news and changes need more than simple publication. Some techniques, both in research and in education, spread more by word of mouth and face-to-face contact than through text. An example is collaborative learning, which seems to spread largely through faculty contact with students or faculty who demonstrate the technique. Among the suggestions in the following essays are many ideas for active face-to-face dissemination.

This volume is organized as follows:

(1) **Introductory material**—keynote addresses and forewords from Robert Watson, Neal Lane, and Luther Williams.

(2) **Overviews on dissemination and publishing**—all-encompassing essays on the process of dissemination, which serve as a guide for current and future PIs on both the practical and philosophical aspects of dissemination,

(3) **The disciplines**—disciplinary essays outlining trends in education reforms as well as dissemination in each area, and

(4) **A resource guide**—with PIs' and participating publishers' names and addresses, which can serve as a way for the SMET education community to learn of innovations.

Our hope is to publish an electronic version of this resource guide, with more information on each project and the capability for searching by topic. If this guide proves useful, DUE will consider expanding it to include all projects.

Foreword

Luther S. Williams
Assistant Director of the National Science Foundation
Directorate for Education and Human Resources

Disseminate: *to spread or send out freely or widely as though sowing or strewing seed; to foster general knowledge of; broadcast, publicize; to strew or scatter over a large area or into many places.*

The Directorate for Education and Human Resources (EHR) has two strategies underlying its diverse educational initiatives. The first strategy is to fund projects that serve as models for educational efforts throughout the nation. The second is to accomplish systemic reform by supporting projects that bring about substantive change in educational practices.

Integral to both of these strategies is the proper dissemination of information, which can be compared to the old question: If a tree fell in the forest but no one was present to hear, would it make a sound? Likewise, a principal investigator, working under an EHR grant, might develop an innovative method of teaching science to undergraduates. However, if news of the project does not travel beyond the edge of the campus, other educators will never have the opportunity to adopt it for their own use. Thus, the impact of our work would be severely limited.

This is why the Project Impact: Disseminating Innovation in Undergraduate Education conference is so important. The conference brought together more than 250 principal investigators and approximately 50 representatives of text, software, and multimedia publishing companies, to consider the opportunities and challenges in disseminating and implementing innovative instructional materials.

Participants were quite pleased with the format of the gathering, which limited the number of formal presentations. Aside from opening and closing panels, the conference consisted entirely of small workshops, exhibits, and informal networking among participants. These exercises helped bring about a true meeting of the minds on how best to disseminate information about the important work being done on campuses throughout the nation.

One exciting aspect of the conference was the focus on new ways of disseminating information. The Information Superhighway is fast becoming a reality, and formerly arcane expressions such as Mosaic and World Wide Web are quickly entering the vocabulary of educators throughout the nation. The exchanges between the PIs and the electronic publishers at the conference will further the electronic dissemination of educational initiatives.

The conference succeeded because of the hard work of its organizer, the Division of Undergraduate Education (DUE). Other key participants from NSF included the Division of Research, Evaluation and Dissemination (RED); the Division of Elementary, Secondary and Informal Education (ESIE), all of which are part of the EHR Directorate; and the Division of Engineering Education and Centers (EEC), which is part of the Engineering Directorate. I also want to thank the Fund for Improvement of Post Secondary Education (FIPSE) of the Department of Education as well as other government organizations for their participation. Special thanks go to McGraw-Hill for their support of the opening reception. And most of all, I would like to thank the more than 250 PIs who came to share the results of their innovative work and the publishing representatives who attended to provide advice.

I look forward with great anticipation to the next dissemination conference.

Foreword

Robert F. Watson
Director
Division of Undergraduate Education

Several years ago, we at the Division of Undergraduate Education discussed a proposed conference on information dissemination. Our original concept was to hold a modest conference where principal investigators could gather to discuss ways of disseminating information about their projects. At the time, I do not think any of us foresaw how this simple idea could develop into such a successful effort. The Project Impact: Disseminating Innovation in Undergraduate Education conference ranks among the most successful gatherings DUE has ever sponsored.

There were two keys to the conference's success—the people and the format—both the result of thorough planning by DUE's dedicated Program Directors and staff members. More than 250 PIs attended the 4-day gathering, along with approximately 50 representatives of text, software, and multimedia publishing companies. As I interacted with participants during the conference, I was very impressed with the caliber of the investigators and the quality of their work.

The format of the conference emphasized small group discussions. PIs and publishing representatives were able to move quickly beyond formal presentations and enter detailed discussions about how best to disseminate information. The networking performed at the conference will likely lead to many valuable collaborations through which the important work of the PIs will be widely disseminated.

An interesting aspect of the conference was the opportunity to explore the burgeoning channels for information dissemination. Although electronic information exchange has been in existence for 25 years, it is only within the last 3 or 4 years that Internet has become a commonplace term. Advances in computer hardware and software are rapidly increasing the volume, quality, and quantity of information dissemination.

This conference gave DUE staff the opportunity to receive feedback from participants about how to facilitate information dissemination better. DUE staff have already implemented many recommendations that resulted from the conference, and they are researching ways to implement additional recommendations. This process will lead to closer interaction between the Division, PIs, and publishers.

DUE was pleased to sponsor this conference. We hope to have an even more successful program at the next dissemination conference.

Keynote Address

Neal F. Lane
Director
National Science Foundation

A special thanks goes out to Robert Watson and the staff of the Division of Undergraduate Education for making this conference a reality. It's a pleasure for me to join you this evening.

I want to extend a special welcome to all of you on behalf of the entire Foundation. You may not have realized yet how unique a gathering this is. As a group, you represent the full spectrum of institutions of higher learning—2-year colleges, predominately undergraduate institutions, liberal arts colleges, and research universities. Just as significant is that we are joined by the leading innovators from the other side of the dissemination equation—publishers of text and software. We have to do this together.

You represent the best of the best of innovation and dissemination in undergraduate education. No one here was selected randomly. We asked ourselves, and our fellow and sister agencies in the government, "Who is working and thinking at the cutting edge" of education and dissemination? That's who we wanted to be part of this potentially historic gathering.

For me, this is the kind of event I like best. I get to stand back and watch you do the hard work. Then I can take the credit when it's all over.

Rest assured, however, tonight I'm not just going to stand back and watch. I want to use my time to give you a sense of why we brought you here.

I have heard more than one person remark that this is just a way for NSF to avoid having to make some 300 separate site visits. There might be some truth to that statement, especially given the state of our travel budget.

However, we do have a few other, but perhaps equally pragmatic, reasons for bringing you to our nation's capital for the better part of a week. We have great expectations for you and for this conference. We want to be able to look back many years from now and say, "This was the week that shook undergraduate education in this country." Never before have we brought together educators and publishers on this scale for that purpose.

Just so you don't think we have any hidden motivations, I want to tell you what Luther, Bob, and the rest of us at NSF see as our role in this conference.

First, we would describe ourselves as a "societal venture capitalist." Most of you are PIs. We have made an investment in you—a sizable one in every case. Your proposals were selected from among thousands of competing ideas.

This meeting of principal investigators is one way to ensure that society gets the highest possible return on that investment and that you as individuals receive the maximum benefit from that effort.

Second, we are what my colleague Labor Secretary Robert Reich calls a "strategic broker," meaning we bring together people and organizations with complementary skills. Another way of saying this is that we're a matchmaker. Many of you are experts at inventing new approaches to teaching; others are experts at helping those inventions reach the widest possible audience. Therefore it goes without saying that this conference promises to be the beginning of many beautiful and productive friendships.

Third, there is more than a little bit of the "proud patron and sponsor" in us. We have supported your work, and now we want to put it on display for all to behold. This conference is in many ways a festival to show off your artistry as innovators in science and engineering education.

Fourth, and finally, we see ourselves the same way we see you—as agents of change. NSF is committed to bringing about a fundamental change in what we teach and how we teach at our nation's colleges and universities.

That is our business. NSF is a foundation for discovery and learning. But it is also a foundation for change.

Our programs in undergraduate education are built around a five-part strategy:

(1) Support the development of new and creative ideas,

(2) Support the development of new courses and sequences of courses,

(3) Support the involvement of entire faculties across disciplinary lines in improving instruction,

(4) Support the evaluation of products, of supported projects, and of the effectiveness of various teaching approaches, and

(5) Support efforts to ensure that the best approaches and products are widely used to improve undergraduate education nationwide.

These five points are based on the obvious fact that we will never have anywhere near enough money to support the needed changes, indeed improvements, in every course at every institution in the country. Even if our wildest dreams were fulfilled and that level of support were available, such an approach would still not be our strategy.

Our strategy begins with you. We rely on the most talented and creative scientists and educators to develop the best approaches and the best materials for teaching. Then we work with you to see that these approaches and materials are adopted at institutions throughout the nation.

As you know from your background materials and the printed program, the goal of this conference flows directly from these overall strategies. Our goal reads as follows: "to increase the impact nationwide of federally sponsored curriculum projects in order to revitalize and transform undergraduate education."

I want to take a few moments to dissect this wordy but worthy goal so that we can more fully appreciate what we will be doing for the next 3 days. Each word is important.

The first phrase reminds us that we are here to increase the impact of our work. We know that our past efforts have already made a difference in how math and science are taught. But we also know that we need to make an even bigger difference in the future.

This is true first for budgetary reasons. Every dollar we get is scrutinized more closely than ever before. But it is also true because undergraduate education plays such a key role in shaping the future of our society and strengthening our economy.

This is why the next part of the goal's statement contains the word "nationwide." No challenge is felt in every city, town, and neighborhood quite like education. In a recent survey conducted for NSF, 81 percent of the respondents said that education should be the government's highest priority—higher than health care (a close second), pollution control, and scientific research. That's a point you might be able to use to quiet your less supportive colleagues at your next department meeting.

To have a nationwide impact, we have to put every mechanism available to work for us. We have learned it takes more than just word of mouth, or en word of Internet, to get the job done. Of course, quality publication of text and software is of vital importance.

I know that having a nationwide impact sounds like an overwhelming task. But we have already learned that it can be done. For example, the calculus renewal project centered at Harvard University began on eight campuses, including one community college and one high school. Now the new materials, developed with NSF support, are in use at 315 colleges and universities and 35 high schools. Over one-fifth of the undergraduates currently studying calculus are enrolled in courses that rely on the approaches developed through the national calculus reform movement.

These approaches emphasize the use of calculus in different disciplines, the appropriate use of technology, both in oral and written presentations, and students working in teams. It's a big change from my own experience in calculus, which was a solitary activity.

The final phrase of the goals statement for this conference states precisely why we are gathered here: "in order to revitalize and transform undergraduate education."

A major part of the Foundation's reason for being is to strengthen science, mathematics, and engineering education. Many people think of NSF strictly as a research agency, perhaps because our education budget is dwarfed by that of the U.S. Department of Education. I want to make clear this evening that education is at the core of our mission, and every part of the Foundation has a role in education. Education is over 20 percent of NSF's total budget.

The science and engineering enterprise is a lot like an ecosystem. All parts of it are interconnected, and the health of the entire system depends on the health of each part of the system. NSF long ago dedicated itself to the premise that science cannot live by science alone. Research needs education, just as education thrives when it is conducted in an atmosphere of inquiry and discovery. In fact, the separation of the concepts of education and research makes no sense intellectually. It is an artificial and, I believe, unhelpful separation caused by the way in which many of us in higher education have chosen to behave. This is why in all of our education programs we encourage you and your colleagues to give students hands-on experiences through which they learn science by doing science. Furthermore, since so much of research is interdisciplinary, teaching should be as well.

Within our education portfolio, our precollege programs often draw the lion's share of the public's attention. That can be both a blessing and a curse. Some of the best known programs include the Statewide Systemic Initiatives and the Urban Systemic Initiatives, through which we work closely with the nation's governors and mayors to change math and science education on a comprehensive scale. We are now in the process of launching the Rural Systemic Initiatives, which will focus on selected rural regions of the country.

Our undergraduate education programs are somewhat more modest by comparison—operating more at the grassroots level. But we nevertheless expect them—through your work—to generate an equally comprehensive and systemic level of reform.

Returning to the ecosystem metaphor I used a moment ago—undergraduate education is in many ways the sustaining life blood of the entire science and engineering enterprise. It is important to society for so many different reasons:

- Undergraduate education is the entry point for many professional careers and for graduate education.
- Undergraduate education provides professional training for future teachers. Unfortunately, this is the aspect, in my opinion, of undergraduate education that has been particularly shortchanged for a very long time. That is starting to change, I believe, but there is still much to do.
- Undergraduate education is where future scientists, engineers, mathematicians, technologists, and other science and engineering professionals learn the core scientific principles they will draw upon for the rest of their careers.
- And finally, for the overwhelming majority of college students, the undergraduate years will be the last time they devote themselves in a formal way to the study of math and science. Most will do so only to fulfill requirements, yet they will draw upon this knowledge throughout their lives as citizens in our increasingly technology-based society.

For all of these reasons, it is not surprising that members of Congress and other public officials are taking a greater interest in undergraduate science, mathematics, engineering, and technology education. NSF's authorizing legislation is currently up for renewal. Both the House of Representatives and the Senate are using the reauthorization process to explore different mechanisms for recognizing and rewarding excellence in undergraduate teaching.

I also know that many state legislatures have increased their focus on this issue. In some cases they have enacted very specific requirements for office hours, classroom time, and accessibility to students.

This interest has not arisen because our elected representatives have suddenly taken a liking to the internal workings of universities. They see the same causes for concern that we do: the perceived imbalance between teaching and research at many institutions, the high attrition rates for science and engineering courses, and the sense that undergraduate degrees are strictly passports to graduate school and not to a broader range of careers in business, government, and other professions. I also think they see another, perhaps even greater, cause for concern. There is evidence of a new and deep division emerging in our already divided society. Many of us are ready to drive full speed using our personal computers or workstations along the Information Superhighway, while others are frightened by the sight of a mouse.

Earlier this month, *The Baltimore Sun* ran a front page article on the subject of "technophobia": the fear of technology. The article cited a survey conducted by the Dell Computer Corporation. Over half of the people surveyed confessed to experiencing some degree of technophobia. Some get nervous at the thought of programming a VCR (I'm frankly sympathetic with this reaction); others bemoan the passing of the manual typewriter. How serious a problem is technophobia? That's hard to say at this point, but the initial signs are not good. I believe the problem is much more serious than just having a few VCRs constantly flash twelve o'clock.

These fears and phobias are giving rise to a confusion of fact with fiction in many circles (even among college graduates). What once looked like an innocent ignorance (if there could be such a thing) is now giving rise to a number of disturbing debates. More and more, public policy issues are being swayed by arguments for which the scientific basis is questionable at best. People seem more worried about the perils of power lines and engineered tomatoes than baking in the UV radiation of the sun. In part, these attitudes stem from a generally poor understanding of science. It is often said that we resist and fear what we don't understand. The great poet and scholar Ralph Waldo Emerson once wrote that "knowledge is the antidote to fear."

This is where all of us come in. We're in the knowledge business. The changes we are bringing to undergraduate education are helping take the mystery out of science and technology. But, in addition to raising the public's level of understanding of science, we are also challenged to improve the quality of undergraduate education for the professional workforce.

Let me give you just one example of how we are doing the latter. NSF has recently begun providing significant support for projects to improve undergraduate engineering education. These various projects give students an introduction to engineering that is very different from past traditions. They involve fewer prerequisites, less teaching by drill and practice, and moving away from the "going solo" approach to solving problems.

The emphasis instead is on teaching our future engineers to find solutions from a wide range of alternative approaches—not just those relevant to a particular type of disciplinary training. They learn how to integrate knowledge from different fields, to work in groups, and they gain the satisfaction that comes from using their engineering skills to solve problems that have a human face.

In one project that is part of an Engineering Education Coalition, instructors assigned their students the task of designing a low-cost, portable shelter that will keep homeless people warm on winter nights. That kind of project can infuse a sense of service into all of undergraduate education. It can also teach our students what might be the most important lesson we can teach them—how to put their skills to work in ways that benefit the greater community.

In conclusion, science and technology are full of mysteries—the origin of the universe, the origin of life, and the nature of the human mind. Another mystery that has bedeviled scientists and engineers throughout history is how to transform newly discovered knowledge into practical benefits. It is an inherently unpredictable process, often with frustratingly long horizons.

The United States patent for the fax machine was awarded in 1863. But it was over 100 years and several technological leaps before these machines became a fixture in the workplace.

In 1917, Albert Einstein predicted that atoms under certain conditions would emit very precise pulses of light. It was not until 35 years later that Charles Townes and his colleagues were able to harness this theory and produce the first working laser.

Just for comparison, it took the relatively short time of 13 years for the first video game, Pong, to move from the laboratory to department store shelves. Pong turns out to be another spin-off from investments in high-energy physics. It was invented in 1958 by an engineer at Brookhaven National Laboratory as a way of entertaining visitors for the lab's annual open house. It turned out to be the most popular stop on the tour, and the rest is history.

This week, we don't have 100 years, 35 years, 13 years, or even 13 days to begin moving our ideas about undergraduate education beyond the walls of this great hall. Instead, we have this evening plus the next 3 days to start the process, and they promise to be a very busy 3 days.

There is no way to predict what will happen here, because we've never done this before. We must nevertheless aim high. I have every hope that what comes out of this conference will be as practical as the fax machine, as revolutionary as the laser, and perhaps in a few cases, as entertaining as the latest video game.

I want to leave you with a few ideas to guide you for the remainder of the conference.

First, think big about how far your ideas can go. Our goal is to have a nationwide impact. Second, leave your modesty at the door. I know it is only human nature to be somewhat shy about marketing your own ideas. And finally, remember that we are all agents of change. Work with each other, pool your ideas, and push whatever you think will do the most to catalyze change in undergraduate education.

What happens over the next few days is entirely up to you. As I said earlier, I am only a very interested observer. But, one day down the road, when my government service is ended, I want to return to teaching, primarily undergraduate teaching. So, I will be anxious to put your ideas and methods to work. This is your conference, and it is your chance to reinvent how we teach science, mathematics, engineering, and technology in our colleges and universities.

Your ideas and talents are your tools. We know you are artists at your crafts. That's why we invited you. This is your chance to show the world.

Thank you.

Keynote Address

Luther S. Williams
Assistant Director of NSF
Directorate for Education and Human Resources

It is a pleasure to join you in this important conference this morning. I applaud the efforts of Robert Watson and the DUE staff and gratefully acknowledge the participation of you, the conference attendees, in this exploration of what has been accomplished and its impact on undergraduate science, engineering, mathematics, and technology education. As you learned last night from Neal Lane, under the broad rubric of program assessment, evaluations, and accountability—demanded by the Congress and the recent advent of stringent priority setting directed by the Office of Science and Technology Policy (OSTP) at the White House—we are obligated to increase the focus on program impacts, ensuring that the results of efforts supported by NSF are effectively disseminated and implemented in an array of relevant institutional settings.

From an OSTP-sponsored forum, Science in the National Interest, I quote the following statement:

> *World leadership in basic science, engineering, and technology requires well-educated and trained scientists, mathematicians, and engineers and a scientifically literate public. Clearly education is a critical investment for our society and responsibility for developing and maintaining a scientifically literate population rests broadly on the citizenry. The federal government and the research community share in that responsibility.*

From its inception over 40 years ago, the National Science Foundation has supported programs to train the nation's scientists, mathematicians, and engineers. Much of that effort occurs informally through the involvement of students, both graduate and undergraduate, in research projects funded by NSF. But, the largest education expenditures by the Foundation have been for a broad spectrum of activities intended to improve the quality of science and mathematics education in the elementary and secondary schools, to recruit talented young people to the study of these subjects, and to ensure that both the improvements and the recruitments decrease the underrepresentation in science, mathematics, and engineering careers of minorities, women, and persons with disabilities.

Historically, many stellar figures in the research community have made direct, personal contributions to these efforts. They have served as mentors for students inquiring into basic research; they have taught in summer and academic year institutes for school teachers of their subjects; they have lent their disciplinary expertise to the creation of new and effective instructional materials of every description; and they have played active and significant roles in every education program supported by the Foundation. There are many of them, but never enough of them—especially in recent years.

The pattern of NSF education activity, until very recently, has been dominated by the research project model—the "Thousand Points of Light" approach. Much of inspiring quality and impact has been accomplished here and there by the myriad projects supported by the Foundation. But "the system" has not been changed very much. It is arguable that American education in science and mathematics would be in a worse state had NSF not applied billions of taxpayer dollars to these efforts. But it is a fact that the current state is still far, in quality, effectiveness, and impact, from what is required for the 21st century.

A map of the nation's schools might look like a thousand points of light, but that is not the way the schools actually work. There is a great deal of local autonomy in American education, although not usually in areas that really matter. Education in the United States is primarily a cluster of systems of schools at the state, regional, and metropolitan levels—and it is through, with, and, in part, by those systems that lasting beneficial changes will be made. The rest of us are helpers of various kinds. Some of the help is material, some is fiscal, and some must be through backbone and leadership.

Currently (and for most of the past 3 years), the National Science Foundation is reorienting its education activities toward systemic approaches and away from the thousand points of light mode. That does not mean NSF is phasing out support of small or large projects with a well-defined but noncomprehensive scope. It does mean that a large fraction of the Foundation's increasing resources for education will be targeted on school systems, on problems that exist in essentially every school in a system, and on imbalances and shortcomings that permeate most school systems.

The Foundation's initial program with such purposes was the Statewide Systemic Initiatives (SSI) program, begun in 1990–91. Participation in SSI was limited to half the states, in part to force the dissemination of what was learned. The second program was the Urban Systemic Initiatives (USI) program; its planning activities were funded first in FY1993. USI is limited to the 25 cities with the largest number of children living in poverty. Again, it is expected that other cities will profit from what is learned from the USI implementation projects. Finally, the National Science Board has just approved inclusion in NSF's Budget Request funding for a Rural Systemic Initiatives program, which will attempt to fuse capabilities and technologies into systems of distance learning, electronic networks of teachers and students, and all-schools access to national databases and similar resources.

The world is changing and so must the nation's colleges and universities. More than ever, nations and individuals must cooperate to achieve their objectives. Increased importance has become attached to our abilities to acquire, adapt, transform, and transmit information, energy, and material resources. The networks, bridges, and highways that facilitate the cooperative exchange of information, as well as goods and services, are being improved and extended in ways previously unimaginable. From appliances in our homes, to scanners in stores and computers at our jobs, advanced technologies are central elements of our living and working environments. So too has increased appreciation been gained for the mutual influence of and need for harmony that exists between the living and working environments and the natural environment.

The promise and challenge of this new era is the development of individuals who have a variety of adaptable skills and possess an understanding of the science, mathematics, and engineering fundamentals that underlie the design, fabrication, and distribution of goods and services as varied as food, health care, consumer electronics, airports, and hazardous waste disposal. Education for employment and for living depends on a solid grounding in science and technology.

Those seeking this education have changed. The term "diversity" fails to capture the rich variety of persons seeking enhanced educational opportunity—they span ages, genders, ethnicity, regions, professional interests, aptitudes, skills, and levels of prior preparation. They have different needs, but they all must be empowered to face the same world of challenges. They must learn to comprehend basic scientific and technological principles; the interrelations among the principles; and the social, ethical, and political contexts in which the principles are applied. Furthermore, effective education should enhance students' abilities to apply and communicate their understanding by a variety of means in a variety of settings.

The primary locus of the science and technology education that prepares individuals for the complexities of modern life and work is the nation's system of undergraduate education. Yet the 2-year, 4-year, comprehensive, and doctoral institutions—whether they be public, private, or proprietary—have not yet responded substantially to the recognized need for cooperation and collaboration. Walls still exist between disciplines and academic units. These walls are ill suited to educating the many different individuals seeking preparation for a vast array of personal and professional goals in an increasingly complex world. These institutions have failed to prepare adequately for the new ways of learning that begin at the precollege level and must be continued at the undergraduate level. There is growing concern that what is taught does not adequately prepare students for the world they enter upon graduation. They have not yet begun to develop the potential of educational technologies fully, nor to apply what is known from research on teaching and learning fully. We can no longer alter students to fit the abilities of educational institutions; we must alter the institutions to fit the needs of students.

The National Science Foundation seeks to encourage the planning of the comprehensive restructuring of undergraduate education. The Foundation seeks to stimulate, at a variety of institutions, comprehensive efforts to address impediments in providing the academic environments needed for tomorrow's skilled worker, knowledgeable consumer, and responsible citizen. Creative and effective teaching, mentoring, and advising must be valued and rewarded. Recognition must be made of the entire learning environment from the classroom, to the laboratory (including practical experiences), to the dorm room. Cognizance must be taken of the financial, social, and personal pressures exerted on students.

Creative and effective learning must also be encouraged. Students must appreciate that teaming and collaboration are life skills that can be developed in the classroom, learning is enhanced by teaching, active involvement in faculty research can provide context and relevance to academic subjects, and they must ultimately assume responsibility for their own education. Finally, students must be helped to understand that learning is a lifelong activity they must vigorously pursue.

The Foundation seeks to foster planning for the restructuring of the academic and administrative systems within educational institutions so as to promote enhanced student learning and preparation for the professional challenges that exist in an increasingly interdependent global society, characterized by the pervasive nature of science and technology. Planning activities should seek to enhance (1) the nature of student–teacher interaction, (2) the complete learning environment, and (3) the relevance of the curriculum to the multi- and interdisciplinary challenges of modern society. Planning should occur in an integrated fashion within a given institutional context.

Comprehensive projects must have the following features:

- The faculty and institutional support necessary for systemic and lasting impact, including close cooperation of faculties across disciplines and academic units, as well as mechanisms to encourage and reward innovative and effective undergraduate teaching;
- An emphasis on developing students' capabilities to learn on their own as well as interpersonal skills such as teamwork, leadership, and sensitivity to multicultural considerations, while providing the foundation and flexibility to prepare students for careers in a variety of professions, including medicine, law, business, and teaching;
- Mechanisms to increase the diversity of students who are attracted to and successful in science, mathematics, engineering, and technology fields;
- Development of new instructional and staffing paradigms that optimize efficient and effective use of instructional staff and technology within the institution, as well as dissemination that facilitates widespread adaptability and increases adoption of the approaches and instructional products developed in the project.

In FY 1995, NSF expects to mount a new effort for the development of comprehensive projects. Grants will be made to a diverse set of individual institutions representative of the rich variety of organizations involved in the undergraduate education enterprise.

SECTION II

Overviews on Dissemination and Publishing

Full-Scale Implementation: The Interactive "Whole Story"

Susan B. Millar

What is full-scale implementation? The National Science Foundation's (NSF) 1994 Project Impact conference organizers asked me to write a paper that describes, "in the view of the author, key issues in moving from the development of pilot projects to full-scale implementation of major departures from traditional curricula or from traditional teaching approaches. Full-scale implementation includes, but is not limited to, adaptation/adoption of materials and approaches at other institutions, as well as in other disciplines or multiple sections of courses at the principal investigator's institution." The organizers also requested that I base the paper on both my prior knowledge of undergraduate education and what I learned attending the conference and that I emphasize "key steps which have contributed most significantly to successful implementation."

Taking the organizers at their word, I began interviews with principal investigators (PIs) at the conference by asking, "What is full-scale implementation? What are the key steps involved in getting there?" Most of the PIs had no difficulty formulating criteria for achieving full-scale implementation. Most of them also suggested various key steps that contributed significantly to this achievement. Yet, the PIs always expressed a certain hesitancy, as if I had not asked quite the right question. They did not want to suggest that, if you just complete some sequence of steps, voila, you have full-scale implementation. Art Ellis of the University of Wisconsin—Madison offered a typical response. In response to my questions, he paused, explained that there certainly were a number of steps involved, and then said, "Now that you ask me, if you really want to understand how my project achieved full-scale implementation, I think I'd have to go back to the very beginning and give you the whole story." Responses such as Ellis' led me to conclude that, while there is value in delineating a sequential set of steps critical to achieving full-scale implementation, the value is substantially lessened unless you get "the whole story." It's similar to knowing the basic plot of a movie but seeing only the last 15 minutes. While it helps to know the story line, you do not really understand because you miss all the important moments and details that appear in the beginning and the middle.

To be sure, the focus of the conference—disseminating innovation in undergraduate education—was "the last 15 minutes." While we may need to learn the whole story in order to understand the endgame fully, there is much in recommending a conference focused on the end. This said, many PIs noted that the conference organizers clearly conveyed that, in their view, the participants' exploration of the endgame was to focus on a specified range of moves. They wanted to know how best to use publishable materials to disseminate the results of education reform projects. Just as many PIs responded cautiously when I asked them to delineate the steps involved in full-scale implementation; they also resisted this program focus. Once again, PIs indicated that it just is not that simple.

In analyzing the comments I obtained from PIs—and in light of my experience evaluating undergraduate education reform programs—I realized that to limit our exploration of dissemination to a discussion of how best to utilize publications was to lose the capacity to articulate what many PIs believe is the key to their success. This key is that, yes, without products and publications (deliverables) you are unlikely to achieve full-scale implementation, but if you want to know how to achieve full-scale implementation, you need to focus on the interactions that take place during conversations and demonstrations. In so saying, I note that what matters about these interactive conversations/demonstrations is not whether they occur face-to-face or in electronic media, but whether they involve a genuine two-way exchange of knowledge and perspectives. During these interactions, reformers naturally and meaningfully present to those interested their newly developed curricular and teaching materials and their stories and data about their reengineered learning environments. Understanding these materials, stories, and data in context, the audience is more likely to shift from being merely interested to being active adopters/adapters of education reforms. Moreover, these key dissemination moments are valuable to experienced education reformers. From observing the responses of others, reformers can better understand why their new materials and approaches work and how they can help others grasp the essential features of these materials and approaches. In focusing on the central role of interaction during conversations and demonstrations, we do not diminish the importance of high-quality published materials. On the contrary, it is by bringing into focus the interactive situations in which these materials become real for others that we are able to understand how these materials actually come to be adopted/adapted widely. Without these conversations, the materials have limited value.

Principal investigators who resisted focusing on publishable materials and chose to focus on the importance of interactive conversations/demonstrations are people who apply lessons learned in their reformed classrooms to the situations they encounter in the halls of their professional meetings. Many of these PIs spent years assuming that the more carefully organized and clearly presented their lectures, the easier it would be for students to acquire the purveyed knowledge. Apparently unaware of a phenomenon confirmed by education researchers—that excellent knowledge delivery in no way ensures that students understand and can effectively use knowledge—some educators tirelessly produced and performed polished lectures. Then, for any number of reasons, they had the opportunity to observe students in active-learning environments. These moments, when they became aware of and compared the effects on students of passive and active environments, led them to change certain basic assumptions. Abandoning their content-focused/delivery-based teaching approaches, they began developing student-focused/active-learning-based environments.

In the same fashion, these PIs realized that creating and publishing a new textbook or piece of educational software and using standard traditional marketing techniques to convey new materials to their professional colleagues do not ensure effective use of these materials. As Ann McNeal, one of the conference organizers, expressed it, "I taught them but they didn't learn anything." This statement is equal to "I developed a model program, but no one adopted it" or "I wrote a great text but no one is reading it." Principal investigators have opportunities to observe and compare the circumstances that do and do not move their faculty colleagues to adopt new approaches. Greg Miller presented his analysis of these circumstances in the following lengthy interview excerpt, which captures the essence of what many other PIs said.

GM: My experience has been that, if I talk to people about it, they just nod their heads and that's about it. If I write something about it—well, people who aren't already engaged in these activities don't typically read these journals, there aren't that many [engineering education journals], and it's kind of once removed from what you are really talking about anyway. However, if someone walks into my office or watches my presentations, I can say, "Here's what we're doing," and I tell the whole story. I'm a big believer in the story and in oral communication in general. And by this I don't mean describing experiments involving inanimate objects, where the typical jargon-laden language is ineffective. I think telling and communicating the story about what you do and what the students do and how infrastructure plays into it is most effective.

SM: Do you ever notice exactly when people get on board the wave?

GM: It's when I *show* them. It's pretty much during the showing. And different people jump on at different times.

SM: Is it that you begin the story verbally and then you move to—how does this work?

GM: Usually I'll start off talking about ECSEL [one of the NSF Engineering Education Coalitions] and its goals and the overall activities. Then I say, "OK, here's what I'm doing as part of this big thing. What I have are about seven or eight components here in this course: group learning, design projects, alternative tests, etc." A lot of these components people can visualize. So if I say, "Oh, we do hands-on experiments with this," they say, "I understand. I've been in classes where we've done these sorts of things." They can understand how that's effective. Then I talk about some of the computer-augmented lecturing I do, and that makes a lot of people take note because that's something they are not familiar with. So I talk about what's effective and what's still problematic about it. That's usually when I move to my computer and demonstrate some of our directed information environments or some of our animations.

SM: HyperCard material and things like that?

GM: Things that you could not do at all with traditional media. That's often when people see a new term in the equation that puts some of the other things I've been talking about into real life and also makes them go, "Yes! I think that I could do some interesting things if I had that."

SM: So it sort of gives them a handle. Is that like a turning point?

GM: I think so. It's like when you see something that you haven't seen before but you can immediately see how it can be helpful to you. You go "Ah ha!" You get excited.

SM: I like to think of those as learning moments. The kinds of moments we want our students to have, right?

GM: Right, that's often how it comes about. And for many people, that learning doesn't happen when we show them just a couple of things. It happens when we give an indication that we've done the whole darn class this way—that you can scale it up. Unless you're able to show large-scale implementation, people will just think of it as a novelty. But when you show them that you've really institutionalized these classes, so that the same students who would normally take them are enrolling, and you aren't using an unusually high level of instructional resources, people can no longer think of it as a novelty. They get the idea that you can actually change the way you do things.

Reactions such as those expressed by educational reformer Greg Miller point to important differences in basic assumptions used to make sense of education reform activity. To wit, the conference organizers' ideas—that full-scale implementation can be understood as a definitive set of steps leading to a planned outcome and that the dissemination phase can be optimized by focusing on how best to use publishable materials—are consistent with more linear, objectivist assumptions. The ideas of the PIs I interviewed—that full-scale implementation entails "the whole story" and that efforts to isolate and understand a particular phase of dissemination should not focus on products/publications but on the interactions that take place during conversations and demonstrations—are consistent with more nonlinear, interactionist assumptions.

To convey what it means for nonlinear, interactionist assumptions to inform one's approach to a project, I will now distill hard-earned advice and wisdom, from scores of interviews and other conversations held at the Project Impact conference, into a schema that shows how moving to full-scale implementation entails a reform project's "whole story." Note that success in each phase turns upon complex interpersonal communications. It is these interactions that lead to the adaptation/adoption of materials and approaches at other institutions, as well as in other disciplines or multiple sections of courses at the PI's institution.

Phase 1. Articulate the need. Help colleagues and administrators understand that there is a gap between (1) standards and expectations for student learning held by faculty and/or students and/or society at large and (2) actual student learning experiences. For example, Jim Fasching, wanting to understand what students knew before he started teaching, began his spring-term course with a pretest consisting of the same questions used on the fall-term final. He found that his students could not answer in January the same questions they answered correctly in the previous December. More to the point, he found that telling others about this finding helped them understand that there is a gap between faculty expectations for, and the reality of, student learning. Once aware of this gap, they understood the need for reform.

Phase 2. Develop promising reform ideas and reform-ready colleagues. (1) Benchmark an existing "best practice" by reviewing the research on learning, attending conferences, and establishing informal networks of colleagues in one's own, and related, field(s). In the process, take note of people, in other departments and at other institutions, who seem particularly interested, as you may wish to involve them as beta site testers. (2) Simultaneously seek reform-ready colleagues and brainstorm ideas. Try to include high status members of your own and other departments—both senior and junior people, including graduate and undergraduate students, and people from both genders and diverse ethnicities. (I noted that PIs who had achieved full-scale implementation were quick to acknowledge that they had learned much from colleagues in other disciplines and institutions. They "walk their talk" when it comes to collaboration, teamwork, and valuing diversity.) Stay clear of the, in Rob Cole's (The Evergreen State College) phrase, "reform vampires"—people who draw their sustenance from resisting people. (3) Move back and forth between Phase 1 and 2: as those in your emerging reform team develop their own ideas, their understanding of the need for change deepens.

Phase 3. Get a plan. Produce the proposals that will provide the requisite external and internal financial, administrative, and moral support. While doing so, develop your skills as friendly but politically astute "guerrillas." Use the "public accountability factor" to your advantage by helping your colleagues, chair, dean, and provost understand that the best way to deal with external demands for accountability is to stay ahead of the problem—on your own terms. (A good strategy for bringing administrators' attention to this matter is to provide information about successes at peer institutions.) Mort Brown advised approaching administrators with the following agenda: show the problem, show the solution and make clear that your unit will make a sacrifice, and demand resources. He cautioned that the moment you demand resources, deans demand evaluation data. "While no one really is convinced by these data," he added, "deans need it in order to get the resources from their bosses. The whole process is more political than anything else." Critically assess your institution's reform readiness. Your institution is ready only if you can enlist both a group of co-reformers who share your vision and a couple of key leaders/administrators who not only understand and care about the need you have identified but also have the power to help you. Included among these leaders should be at least one person from your institution and, optimally, people from other institutions who can bring pressure to bear on your department and college. (The coalition structure is useful insofar as it automatically connects you with leaders at other institutions.) If you encounter major resistance in your own department, seek support for a pilot project that may be used at some institution, leaving it to your colleagues to decide at a later time if they would like to adopt your approach. If you are at a research institution, involve graduate students as much as possible. As several put it, "Graduate students are the future." During this phase you should also work with an evaluator who can help clarify research questions, plan how to acquire baseline data, and design your reform so that evaluation data are optimally useful. Meanwhile, keep benchmarking others' best-case practices.

Phase 4. Engage in initial implementation. Work with your reform colleagues to develop new materials, develop your new teaching methods, and so forth. Of special note, Joe Lagowski of the University of Texas stressed the importance of developing examinations and assessments that "put a measure on" the new kinds of knowledge and skills that your reform seeks to help students develop. He emphasized that, to achieve full-scale implementation, colleagues who remain outside the reform effort must come to understand and accept these new assessments. Often this initial implementation phase involves interactions with a range of people—such as department chairs, registrars, student advisors, computer technicians, and space management personnel—and entails finding ways to simplify frustratingly complex implementation processes. Sustain your "friendly guerrilla" orientation by learning about and becoming facile in the politics of organizational change. Priscilla Laws of Dickinson College advised holding workshops on technique, philosophy, and the politics of change. All the while, continue benchmarking others' best-case practices.

Phase 5. Implement and evaluate the reform on a pilot basis. During the pilot stage, arrange for your evaluator to provide real-time formative feedback on student learning experiences, and/or use informal classroom assessment processes. Along these lines, Mort Brown advised, "Don't employ researchers who want to do evaluations in order to satisfy their own scientific criteria. You want to get the evaluation work out into someone else's hands, but make sure the evaluators understand your mission." Meet frequently with your co-reformers—including any graduate and undergraduate teaching assistants—to describe and reflect on your experiences and make midcourse corrections. Continue benchmarking others' best-case practices.

Phase 6. Revise and beta test the reform. Engage interested colleagues to work with you as beta site testers. In selecting beta sites, be aware of the "prophet in his/her own land" syndrome: you are likely to have more trouble convincing your own colleagues than people in other disciplines at your institution or in your discipline elsewhere in the country. A second reason to conduct beta tests elsewhere is to assess whether your reform is robust in different environments and to learn how to adapt it to diverse environments without sacrificing essential features. Continue to obtain formative evaluation, meet frequently with your local and test site reform colleagues, and benchmark others' best-case practices.

Phase 7. Locate and work with a publisher. Assess whether you are producing materials that others may want copies of and begin looking for a publisher. Publishers may include the full range of commercial print establishments; organizations specializing in electronic, video, and audio media; and not-for-profit organizations such as your professional society or a campus education research center, or even your own reform team. Evaluate potential publishers in terms of their willingness and ability to work collaboratively with you. Project Impact participants stressed that they particularly valued publishers who have characteristics such as:

- The capacity to build flexibility into your materials and approach so that users can modify them to suit their local needs.
- The ability to arrange situations that give you the best opportunities to interact with potential users with the least expenditure of your time. (Bear in mind that the highest cost of effective dissemination is in faculty time—on the phone, on e-mail, in hallways and workshops—and that faculty receive no tenure and promotion rewards for spending time in this way.) For example, your publisher might develop two or more workshop formats: a 1/2-day format for interested others who are still "scanning the options" and a 3-day format for people who are sold on your approach and want to learn how to implement it.
- The capacity to engage others at a sophisticated level. The publisher assumes that your new approach will attract only a portion of the potential users and that these users might be alienated by broad spectrum advertisements and missionary zeal. He/she ascertains what kind of person your reform is likely to attract and approaches these people with materials carefully designed to interest them. For example, Art Ellis (acting in this instance as his own publisher) is always ready to pull from his pocket little strips of "memory metal" which he uses to demonstrate how solid materials can provide superb ways to illustrate chemical principles. He has found that a little sample of metal acts as a hook that helps people make surprisingly sophisticated connections between everyday experiences and scientific abstractions. Another example is the low-budget video. Low-budget videos of, for instance, conference talks by known reformers, are more credible to professors than more glossy presentations. Easily able to imagine themselves in the everyday spaces featured in such videos, faculty get involved in them as if they had been there.
- Appropriate attitudes toward on-line electronic media. Your publisher should view on-line electronic media not as "the answer" but as a new kind of space in which interactive conversations/demonstrations can occur. In this regard, several PIs emphasized that the availability of the World Wide Web does not, by itself, motivate others to use them and that students respond to these pages as yet another passive text. (While locating and working with your publisher, continue with iterations of Phase 6.)

Phase 8. Hand-off to the Publisher. Turn your materials and process over to the publisher as soon as you can bear to let them go.

There is much a new PI can achieve by attending to the accumulated wisdom and advice of the Project Impact participants who contributed to this eight-phase schema. As noted above, each of these phases depends on interaction. The phases themselves interact and double back on each other. Taken together, they compose a "whole story." But they do not compose *the* whole story. Each local reform story is played out within the larger structure of higher education, a structure which no single reform project team, or single institution, or all the publishers together can change. Attuned to the opportunities and constraints of this encompassing structure, many Project Impact participants saw the need for systemic change in how institutions of higher education promote educational reform. In particular, they found that their efforts to achieve full-scale implementation were seriously hampered because faculty lack opportunities to function on a sustained basis in change-agent roles. To make this point, I return to my interview with Greg Miller, who explained that an effect of demonstrating his new materials is that people "get the idea that you can actually change the way you do things." In his continuing remarks, he shifted to the systemic level:

GM: It [demonstrating the project] gets them thinking. And probably a large percentage of people look at the project and say, "Wow, that'd be great! But I don't have the time to learn how to do that." They still see a steep learning curve . . . and they want to have a workshop. That's the point where I've always had to kind of go, "Uh, we'll try to put together a workshop. Uh, um, . . ." That's when I stop. They are interested, but the next step isn't there—beyond me, saying, "Oh, I'll teach you how to do all this stuff." There are just no good procedures and means that allow me to say, "Yeah! Get involved. Here's where all these resources are, it's not just me, it's all these people working. Take our stuff. Add your own things . . ." The infrastructure isn't there. I mean, I can't individually train 40 instructors all over the country to do these things.

Similarly, Charles Patton of Oregon State University explained, "We need to address the issue of supporting people whose entire job, entire project, is taking somebody else's material, and somebody else's pedagogy, and moving it to other contexts. It was hoped that publishers would do this, and they have to a certain extent. But still the person who stands up there is Tom Dick of Oregon State University, or Greg Foley of Sam Houston State University, or me. And there are only so many bodies. So money is one issue. But another issue is there are only so many bodies. Consortiums work well because you have a lot more bodies and you can share the training work. But it's still not self-sustaining."

Phase 9. Work for change on the national level. Greg Miller's and Charles Patton's analyses suggest an additional phase in which PIs must engage in order to achieve full-scale implementation: work for change on the national level. With the addition of this phase, we find that full-scale implementation not only involves more than the "last 15 minutes" of your project but also involves more than just your local "whole story." All too frequently I hear faculty tell of how 10 years later there is either no trace of an education reform effort or only a few isolated courses or minor innovations. To move beyond this local and short-lived approach to full-scale implementation, PIs and others must work together to modify the opportunity structure within all of higher education. If we work collectively, we may be able to develop an infrastructure that allows each project team to teach others across the nation and allows teams to learn about and implement what other education reformers have learned. In this regard, it is very encouraging that NSF, aware that individual universities and colleges offer faculty little to no incentive to engage in systemic, large-scale dissemination work, is taking steps to remedy the situation. NSF provides dissemination funds to projects that show evidence that their products and approaches are of interest to the academic community. These funds can be used for workshops, training workshop leaders, providing newly trained individuals with money to run their own workshops, and providing loanable equipment and field test sites that agree to provide feedback. Finally, the success of this ninth, as well as all other phases, depend on making the most of the interactive conversations/demonstrations in which the value of your work becomes real for others.

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Awareness, Access, Assistance: Dissemination Reconsidered

Donald P. Ely

. . . I am absolutely convinced that there is not a single, solitary problem in American education that has not been solved by somebody, somewhere . . . What we have done as a nation is to resist institutionalizing change, to resist, therefore, holding ourselves accountable for results as a nation . . . in every state, people . . . repeatedly resist learning from each other, borrowing from each other, capturing each other's best ideas.

—President Clinton, May 16, 1994, on the occasion of signing the Goals 2000 legislation

This is clearly a time for dissemination. The time has passed when the knowledge and products developed through National Science Foundation (NSF) grants are unknown or unused. Of course, many efforts are made by principal investigators (PIs) to inform the science, mathematics, and engineering communities of research and development findings. Many of these efforts were demonstrated at a conference sponsored by NSF's Division of Undergraduate Education (DUE) in June 1994. Project Impact: Disseminating Innovation in Undergraduate Education brought together PIs, NSF program officers, publishers and producers of educational materials, and a group of observer/writers for an intensive exploration of both the processes and products of dissemination. This paper describes the current status of project dissemination, identifies promising practices, raises several issues regarding current practices, and makes recommendations for future efforts. First, it is necessary to define the concept of dissemination in light of its many interpretations.

The Evolution of Dissemination

The distribution of information to colleagues or the public has traditionally been called "dissemination." The difficulty in understanding dissemination may begin with its traditional definition: spreading the word. In academic circles dissemination is usually manifested through the printing of professional journal articles or the presentation of formal papers at professional meetings. The assumption has been that if "the word" is printed or spoken, dissemination has taken place. In the sense of distribution, the word has been announced and any further action is up to the individual. But many professionals are beginning to realize that the traditional approach is no longer sufficient in bringing about important changes in teaching and learning science, mathematics, and engineering. The very concept of dissemination has been broadened.

K.M. Stokking (1994), in the paper "Dissemination and Diffusion of Knowledge and Innovation," calls for a distinction between dissemination as an activity, a process, and a result. "Activity" is an awareness function with the purpose of informing potential users in a conscious manner, for example, a journal article. "Process" involves the transfer of knowledge and/or materials to potential users. As an access function, it helps potential users become more familiar with new products and encourages them to use them in the future. An example is the acquisition of the University of Nebraska Cinema Classics videodisc that can be used in a physics class or laboratory. "Result" is a change function whereby new knowledge or materials are used by individuals and groups that will use them in teaching and learning procedures. An example is the use of laboratories created by Bowdoin College for the Duke University Project CALC program.

The broadening concept of dissemination has led to a widely accepted multiple definition now acknowledged by professionals in the scientific community. The definition describes four goals of dissemination: spread of information, choice of alternative products or procedures, exchange of information, and implementation of new processes or procedures (Klein, 1992). These goals are evident in DUE-sponsored projects as well as in other science, mathematics, and engineering programs. One of the first steps in planning dissemination is determining the goal(s).

Audience: Who Are the Constituents?

Once the goals have been described, consider the audience. Each audience may require unique methods. Consider for instance the national curriculum reform in calculus as compared with the needs of biology departments. Or think about chemistry professors who communicate information about new approaches to teaching as compared with the astronomy professor who needs laboratory materials for her teaching.

Each of these instances requires a different dissemination strategy, which begins with defining the audience.

What Is Being Disseminated?

Dissemination often involves instructional innovations: new knowledge and ideas about teaching and learning (process innovations) and new materials (product innovations). Process innovations include new teaching methodologies such as collaborative learning and inquiry-based laboratory exercises. Product innovations include individual "stand alone" products like CD-ROMs, computer software, and laboratory manuals. Combinations are found in comprehensive modules and course reconfigurations. Sometimes an entire curriculum is involved.

The Current Status of NSF Dissemination

After identifying the importance of goal-setting, audience identification, and the substance of the process or product being disseminated, the PI or dissemination agent considers techniques for reaching the intended audience. NSF projects illustrate a wide variety of these techniques.

- The use of newsletters and e-mail has created networks. Every successful project that continues to provide leadership has a regular newsletter, an active listserv, or both. *Calculus Currents* is a newsletter for individuals involved in the calculus reform movement. The mailing list for Project CALC at Duke University numbers more than 28,000 names. The publisher, D.C. Heath, also provides a toll free telephone number for assistance.
- Software for computers as well as CD-ROMs is an integral part of many courses and curricula. Software is available on floppy disks and on network sites for downloading. CD-ROMs such as Metazoa: Vanishing Kingdom are available.
- Videodiscs, videotapes, and slides have been developed and field tested. The Physics InfoMall offers a selection of resources to assist teachers and learners. The developers at Kansas State University have involved users in field testing.
- Workshops are held on college and university campuses and at national and regional professional meetings. The Wetlands project at Colorado State University uses a "multiplier approach" in its workshops. Individuals who are trained to use modules developed by the project are expected to offer similar workshops in their region.
- Videoconferences have been held using satellite communication systems. California State University at Fullerton has coordinated videoconferences highlighting successful NSF projects of national interest such as Uri Treisman's approach to increasing minority participation in mathematics and the calculus reform effort.
- Cooperative and/or collaborative arrangements exist among programs with similar goals and special audiences. The Southern California Coalition in Education in Manufacturing Engineering involves six universities in partnership with several industrial organizations. The departments of physics, mathematics, and computer science at the University of Hartford are working with 18 institutions to revise existing teaching materials in these fields and assisting in implementation throughout Connecticut.
- Local and national mass media have been employed by some projects. Others use professional journals to promote programs, materials, and workshops. Some projects have used local public relations personnel to promote the activities and findings of NSF projects that later appear in the local and national press and broadcast media. The *Journal of Chemical Education* has a column each month that highlights two or three exemplary NSF-sponsored programs in undergraduate chemical education.
- Computer networks are used not only for e-mail but also as file transfer protocol (ftp) sites to make materials and information available. The Coalition for Ordinary Differential Equations Experiments (C-ODE-E) at Harvey Mudd College now offers its resources through World Wide Web and Mosaic on the Internet. The seven-institution consortium disseminates specific problems and graphics. Their effort has led to a theme issue of the *College Mathematics Journal* and workshops at the Mathematical Association of America annual meeting.
- Textbooks, readers, laboratory manuals, instructor's manuals, exercises, and combinations of printed resources are published, marketed, and distributed to users across the nation by commercial publishers. Some text materials are accompanied by computer software that is integral to the text or references. Some publishers produce "non-revenue" publications at the request of the PI to insure better utilization of the total publications package.
- Combinations of the various dissemination vehicles are often employed. Such packages are likely to produce more than the sum of the parts. The Washington Center at Evergreen State College performs individual consultations on the improvement of mathematics and science teaching with 44 colleges and universities in the northwest region. There are follow-up workshops based on local needs. An active network permits continuing interaction between the center and the institutions and among interested people in the institutions.

The best dissemination efforts make potential users aware of new resources, provide access to materials, and assist in using materials (Ely and Huberman, 1994).

Promising Practices: Trends

The success of dissemination practices is judged by divergent criteria. One criterion used by commercial publishers and producers is the number of items sold and the extent to which second and third editions are released. Other criteria measure the amount of change that has occurred. Such data are not easy to tabulate but personal interviews indicate the occurrence of change through new course syllabi, new laboratory arrangements, and new problem-solving protocols.

J.M. Cousins and K.A. Leithwood (1993) in *Knowledge: Creation, Diffusion, Utilization*, created a list of factors that impact the extent to which disseminated information is used:

(1) Informational needs—gaps in personal knowledge and expertise of the intended audience.

(2) Focus for improvement—resolution of issues concerning dissemination effort,

(3) Political climate—the explicit and implicit priorities established within the school setting and the associated weight attributed to varying information,

(4) Competing information—information, in addition to the focus for dissemination, that may influence decisions or thinking (e.g., practical knowledge).

(5) Personal characteristics of users—gender, experience, prior history of information use, and leadership style, all of which may influence response to disseminated information,

(6) Commitment/receptiveness of users—the extent to which the audience's attitudes will facilitate the intake of the disseminated information.

Discussion groups at the 1994 NSF Project Impact conference confirmed the above list and identified a host of promising practices that follow the awareness, access, and assistance pattern.

Awareness

If a new idea or material is not known, it cannot be considered for adoption. Awareness is the provision of information to specific audiences for the purpose of informing. Here are ways in which some projects are accomplishing this function:

- Placing announcements in professional journals and sending advertising material to individuals on targeted mailing lists has been effective. Publishers often join with authors and developers to distribute newsletters on a regular basis.
- Disseminating over the Internet, computer bulletin boards, listservs, and special interest groups (SIGs) reaches out to people who may not receive information from other sources.
- Involving institutions in testing creates awareness and ownership.
- Planning marketing strategies for new materials with publishers and producers creates close working relationships. Commercial publishers assist by publishing non-revenue support materials and sponsoring workshops featuring authors and product developers.
- Using popular mass media, such as *Astronomy, Scientific American, Chronicle of Higher Education*, and others, informs the general public. Especially noteworthy is publicity in major U.S. newspapers and on news stations such as CNN.
- Presenting videoconferences through satellite communication has alerted professionals to new developments. A 1993 videoconference, sponsored by NSF, reached more than 250 sites in 49 states.

Access

A teacher–scientist cannot use innovative materials and procedures if access is difficult or unavailable. Access takes many forms. Conference participants shared some of their knowledge about this important factor:

- Publishers and distributors are the most organized and motivated people in providing the resources for innovative programs. It is in their best interest to stock materials and fill orders promptly. They usually succeed and are highly reliable.
- Some projects place materials on Internet sites. The University of Arizona placed math tools on ftp. Queens College loaded their QStat programs, and Harvey Mudd College provides differential equation problems in the same way.
- Computer-based materials such as Kansas State's Physics InfoMall CD-ROM and the ChemScholar tutorial developed at the University of Rhode Island join a "catalog" of software created through the NSF projects. The University of Rhode Island includes on-line help as part of its software package.

Assistance

Awareness of and access to information, as important as they might be, must be connected to a source of assistance if change is to occur. Assistance is the function that helps individual adopters learn how to use innovative materials or practices. It is an "800" number by telephone or a computer connected to an information source or helpline. Assistance is one of the most important aspects of dissemination at the time of implementation. Without it, many adopters would give up or misuse the new resources. Listed below are some forms of assistance that were recommended at the Project Impact conference:

- Workshops, faculty development strategies, and workshops at professional conferences are some of the most frequently used and most effective assistance strategies. Beloit College's BioQuest program offers workshops at annual meetings of biology teachers. Gettysburg College offers similar opportunities at the meetings of the American Astronomical Society.
- Coalitions and other collaborative efforts provide assistance through a formal network of professionals and institutions that are dedicated to bringing about change in their fields. Regular communication among individuals within these cooperative arrangements gives assistance to colleagues. The California State University Science Teaching Development Project involves 20 institutions that share instructional modules and research reports. Collaborative Curriculum Development at the University of Washington includes seven universities.

Beyond Awareness, Access, and Assistance

Professional literature describes factors that promote the utilization of new knowledge and products that go beyond awareness, access, and assistance. Factors enumerated in a recent NSF publication (Hutchinson and Huberman, 1993) were confirmed by PIs at the Project Impact conference. Among the most important are:

(1) **Relevance and compatibility.** Users want flexibility when adopting new materials and procedures; in fact, they want to adapt materials to their own style and courses. Modular resources are more acceptable than rigid protocols that cannot be bent to serve local needs.

(2) **Quality.** Expected through documentation of results, field test data, and other forms of validation. "Empirical studies show, however, that people will not automatically use knowledge because of its quality or because of its lack thereof" (Hutchinson and Huberman, 1993). Factors associated with quality, identified by Cousins and Leithwood (1993) are useful in assessing product quality:

- Sophistication—the perceived quality of the source of information, including its technical sophistication, appropriateness, rigor, and the like.
- Credibility—the perceived believability and validity of the source of help and of those responsible for dissemination (i.e., track record).
- Relevance—the extent to which the audience for whom it was intended perceives the knowledge to be pertinent to their needs (defined especially in terms of practicality).
- Communication quality—the perceived clarity, style, readability, flair, and the like, with which the knowledge is conveyed to the intended audience.
- Content—the nature and substance of the actual knowledge being disseminated. Especially important is whether or not the content is perceived to be congruent with existing knowledge as valued, positive, and of sufficient scope.
- Timeliness—the extent to which knowledge is perceived to be disseminated at an appropriate time and delivered in an ongoing manner.

(3) **Linkage among users.** Closely related to networking. These are interpersonal exchanges that support new and continuing users of specific innovative programs or materials. Users often employ e-mail or meet in special interest groups at professional meetings. They are usually on the same listserv and mailing lists and become tutors for new users and leaders in bringing about change

(4) **Engagement.** Occurs through participation in field testing, workshops, and other activities that permit hands-on use of innovative materials. Such activities help users become comfortable with new procedures and, in some cases, permit reinvention for local use.

(5) **Sustained activity.** The frequency, as well as the intensity, of the contact between the developer (or dissemination agent) and the receiver of the new information and materials is an excellent predictor of continued use leading to institutionalization.

Issues

On the surface, dissemination seems very simple. A new product or process is created and works well. How do others become aware of it and begin to use it? Is this a simple marketing problem? Is it a matter of scholarly communication? How does the message reach those who ought to know about it? There are many questions that should be asked before launching into a full-scale dissemination effort:

(1) **Quality.** What should be disseminated? How can quality be determined? Who will determine the standards? Who will evaluate the standards and the proj-

ect? What information is required prior to dissemination?

(2) **Public domain.** New materials and procedures are developed with government funds. Some users believe that all of these materials should be available as public domain resources. When commercial publishers and producers become the marketing organizations for these materials, they sell them to users. How can NSF-funded products be made available at little or no cost?

(3) **Product vs. process dissemination.** Products are fairly easy to disseminate since they often are tangible items of hardware and software. How are innovative processes and practices disseminated? How are such learning methods as discovery learning and team approaches communicated? These are activities and procedures that are difficult to transfer. What is the most efficient way to achieve effective dissemination?

(4) **Perception of dissemination.** How can the perception of dissemination as one-way communication be changed? "Spreading the word" has been the common understanding of "dissemination" but, in a time of multiple means of reaching audiences, there needs to be a broader concept that embraces choice of alternatives, exchange of information, and implementation of new processes and procedures.

(5) **Impact.** How can impact be measured? Is the investment in NSF-funded projects intended to make a difference in learning and scientific discoveries? The impact of a project cannot be measured at its immediate conclusion. The impact is usually seen years after individuals have been exposed to innovations.

(6) **Coverage.** How broadly should the results of NSF projects be reported? Should dissemination go beyond the target audience? Some projects have had exceptional success in disseminating through the public mass media, such as newspapers, television, and popular magazines.

The systemic reform of science, mathematics, and engineering education at all levels depends on the creative interaction of content specialists and educators. It requires vision and ways to develop the means for facilitating innovation. The Division of Undergraduate Education of the National Science Foundation has funded projects acknowledged to be among the best that American scholarship can offer. Implicit in each of the projects is the improvement of undergraduate education in science, mathematics, and engineering. Once completed, the projects offer some of the finest innovative materials and practices available. There is no single formula for dissemination, as each innovation is idiosyncratic and each setting is unique. Teachers, professors, and instructors should adapt innovative materials and practices to meet local goals and specific audiences. If these efforts are to make a difference in education, the dissemination process is critical, and attention to it must be a top priority.

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Getting the Word Out: Disseminating Innovation by Means of Traditional and Electronic Publishing

Jay Sivin-Kachala and Maryellen Kohn

Results of the Project Impact Conference: A Summary

During the 4 days of the 1994 Project Impact conference, principal investigators (PIs) had a rare opportunity to interact with one another and with commercial publishers. The conference provided a variety of meeting opportunities. One of the most successful was the exhibit hall, which offered all participants the opportunity to become aware of one another's work and aware of one another as resources. PIs were able to find potential test sites for their projects as well as a ready audience and support for adoption of innovative projects. Publishers were able to get first-hand and hands-on experience with a wide variety of innovative projects funded by the National Science Foundation (NSF).

Plenary sessions provided a venue for NSF to clarify and reiterate its mission—to promote the successful dissemination and adoption of the work of its PIs. Group discussions were structured to enable participants to discuss dissemination issues within their particular discipline and across disciplines. Workshops enabled all participants to gain a maximum of information about all forms of dissemination, including pros and cons.

There were also many informal opportunities to network and meet. On-site meals and coffee breaks helped to ensure that participants would continue thinking and interacting within the theme of the conference and would be able to take advantage of the proximity of their peers.

Outcomes of the Conference

The major outcomes of the Project Impact conference were that the participants shared information, defined problems, and proposed solutions that should result in greater dissemination of NSF-funded work.

PIs discussed the best routes to dissemination, the pitfalls to dissemination, and the effects of technology on dissemination. This sharing of information increased the understanding of software and multimedia publishing and of the current state of print publishing. The option to disseminate via the Internet was also discussed. Much of the discussion between PIs centered on the best ways to work with publishers, including finding a publisher, developing a contract, and dividing the responsibilities in the author–publisher relationship.

Participants were able to define and clarify common problems. Chief among these was the difficulty of disseminating innovative projects. The majority of PIs acknowledged the difficulties posed by the lack of a ready market, the lack of innovative and profitable dissemination channels, and the underlying knowledge that resistance to innovation is automatic. Participants also acknowledged that their unfamiliarity with software and multimedia publishing necessitates further discussion of the industries.

Participants identified another common problem—that most innovators resist publishing for profit, preferring free access to their work. This stems from a number of factors: fear of loss of control over projects; the lack of project funding and support for dissemination activities; and the availability of "alternative" distribution channels, such as workshops, minicourses, word of mouth, distribution of kits, and the Internet. Innovators and publishers also acknowledged the need to work together to develop new strategies and paths to adoption.

Suggestions for Solutions

A long list of suggestions was proposed as a result of the Project Impact conference. There was broad agreement on the need to institute an annual or biannual Project Impact conference that would include administrators and more publishers. In addition, participants want to establish a telecommunications-based electronic forum to ensure ongoing communication and awareness of one another's work.

PIs expressed the need for NSF to institute a clearinghouse for innovation resources. They also suggested that NSF employ a three-phase evaluation process, which would encourage the support of those projects most likely to be widely adopted.

PIs encouraged NSF to adapt the funding structure to increase support for dissemination activities. They also recommended that NSF increase its efforts to put innovation in the limelight with the use of a strong presence at professional meetings, computer conferences, and other public venues.

Publishers were encouraged to help "make a market" for innovation. Innovators were advised to focus on "customer-driven" innovation. It was recommended that innovators build consensus for innovation among their colleagues and within their institutions.

All participants agreed to continue working together to find ways to make the adoption of innovation "worth the cost." They acknowledged that change is difficult and resolved to find ways to make the path to educational reform smoother for all.

Introduction

When the Division of Undergraduate Education (DUE) of NSF brought 250 of its most promising educational reformers to meet with a group of commercial publishers for the Project Impact conference, the focus was on dissemination of instructional innovation and, where appropriate, publication through commercial and noncommercial channels.

The mission of DUE is to improve undergraduate education in mathematics, science, engineering, and technology, on a national scale. The Project Impact conference was an important part of DUE's effort to ensure that funds for educational improvement have the greatest possible impact, especially during a time of fiscal restraint.

To that end, the PIs of NSF-funded projects spent 4 days with one another and with publishers to:

- Observe and appreciate one another's work.
- Improve their understanding of the nature of dissemination of instructional innovation in today's world.
- Define problems inherent in disseminating innovative curricula and instructional approaches.
- Develop concrete plans to spread effective educational innovation throughout the nation.

Before one can fully understand the issues related to the dissemination and publication of educational innovations, it is necessary to understand what the innovators mean by "reform." It is the goal of many PIs to reform education not just by changing the tools that educators and students use, but by changing the whole curriculum and the pedagogy. Their goals include:

- Empowering students to construct their own knowledge bases so as to acquire and use knowledge rather than just "receive" it;
- Encouraging hands-on learning;
- Providing real-world contexts to mathematics, science, engineering, and technology education;
- Helping students visualize abstract concepts;
- Addressing the particular needs of incoming undergraduates (especially freshmen and students who may be academically underprepared).

An important part of the challenge of bringing about educational reform is that innovators often find themselves at odds with their institutions and peers. In the current academic environment, great research is valued more than great teaching. Research receives support and acknowledgment while teaching is often looked upon as a necessary evil (e.g., references to research "opportunities" and teaching "loadsÓ). PIs at the Project Impact conference acknowledged this challenge and stressed the need to change the campus culture and the very definition of scholarship so that great teachers are valued as greatly as researchers.

The remainder of this report is divided into two parts.

(1) Publishing Instructional Innovations: Traditional Methods and Electronic Alternatives

(2) Recommendations to Conference Participants

Publishing Instructional Innovations: Traditional Methods and Electronic Alternatives

Many educators think of mass dissemination of innovation strictly in terms of print publishing, principally in the form of journal articles and textbooks. While print-based dissemination remains important, other publication methods and formats are growing significantly within the academic community. A broad range of publishing options was discussed during the Project Impact conference, including print, software, multimedia, and distribution via telecommunications using the Information Superhighway.

Print Publishing

One of the most often heard questions from PIs was, "How do I find a publisher in my field?" The Association of American Publishers (AAP) was suggested as a good starting point, but as an industry trade association the AAP *cannot* provide specific recommendations. Mary Walling of the AAP suggests that the best place to locate a publisher is in the "bible" of the industry—*The Literary Marketplace* (LMP), published by R.R. Bowker. "The LMP can be found in any good reference library. It lists all publishers, in alphabetical order and cross-referenced by state, subject area, and product type (textbook, software, multimedia, etc.). It includes publishers in the U.S. and Canada. It also includes listings of agents, organizations, editors, translators, paper manufacturers—anyone involved in the publishing industry," Walling said.

Conventions or meetings were also recommended as good places to find a broad selection of potential publishers. Another suggested path was to make use of an established contact with a publisher's sales representative. Getting the name of a contact within the publishing organization from a sales representative can help PIs to avoid "blind letters [that] are usually a waste of time."

The Choice of a publisher. PIs and publishers worked together at the conference to develop guidelines for choosing the best publisher for innovative curricula or instructional approaches.

- Know how each publisher deals with the kind of material the innovator wishes to disseminate. Check the company's track record with innovative products. Look for an organization that has previously published similar work and talk to authors about their experiences.
- Know what the publisher can do for the innovator and his or her work—including marketing, design and layout, editing, sales, and customer support. When it comes to marketing, the publisher "should shape demand, not just meet it." The publisher should also help the innovator create a product that reflects changing classroom dynamics (e.g., integrating technology with the curriculum, incorporating cooperative learning strategies).
- Check a company's turnover rate for editors and sales force. Having the same editor on board throughout the life of the project helps ensure consistency and avoids wasting time. Having a consistent sales force gives a company legitimacy in the eyes of prospective purchasers.
- After the field is narrowed to a few potential publishers, it is important to check the quality of the editor and of the entire project team (marketing, design, administration, etc.).

The author–publisher relationship. What should one expect of the author–publisher relationship after a publisher has been chosen? Innovators with prior publishing experience and publishers at the conference offered the following advice:

- Start early in the process to establish a *shared vision* of the final product.
- Expect that the publisher will analyze the market and will make important decisions about the product, such as where and how it should be shown and advertised, its price structure, and the packaging design and configuration.
- It is in both the publisher's and the author's interest for the publisher to test the materials with students and teachers prior to publication.
- Expect that the publisher may seek to revise work that has taken years to develop.

A common stumbling block in the PI–publisher relationship can be the development of a contract. Many PIs voiced the opinion that contracts appear to favor publishers. The point was stressed that it is vital for PIs to seek legal help and guidance from a lawyer specializing in copyright and intellectual property issues. They should establish their rights and/or the rights of their institution to the concept, content, and design of the project so that those rights can be adequately protected in a publishing contract. If the PI's college or university has a legal stake in the project, the institution's legal staff should be involved in the negotiations with the publisher.

The impacts of technology on print publishing. Publishers attending the conference discussed the effects of technology on all aspects of print publishing. The publishing industry has changed dramatically with the advent of such innovations as custom publishing and on-line distribution.

Custom publishing enables publishers to produce unique editions of textbooks and other printed teaching materials in small quantities. Rather than adapting a course to fit a mass market textbook, educators can order custom versions of teaching material to fit the particular requirements of their school or course.

On-line distribution enables college book stores to order materials for delivery via computer. The book store then becomes the publisher and distributor, "printing" enough copies to satisfy the demands of educators and students. The publishing company eliminates the expense of paper, printing, binding, shipping, and returns. The book store eliminates inventory, overstock, and theft. Educators and students benefit from availability (the book store can "stock" many more titles and can't run out) and continued updating of materials.

PIs were curious to know how their work might fit into these new formats. Such custom and quick-print options open the door to new, innovative teaching materials that would not support a mass market. These innovations enable publishers to serve small markets as they develop and grow.

Publishing Software

Personal computers make it possible for faculty and students in undergraduate education to explore subject areas and experiment in ways unimagined just 10 years ago. The widespread and growing use of computers in undergraduate education was reflected at the Project Impact conference. Most of the projects utilize computers and software. And most participants indicated that school administrations perceive technology as critical to attracting students.

The high interest in software publishing was tempered by fear of the complexity involved and several unavoidable, ongoing problems:

- Software products that are rich in content become obsolete as soon as they are published.
- Software that is not developed to be compatible with all versions of a computer (older models and newer ones) cannot reach the largest possible market, but software that is compatible with older computer versions often cannot take advantage of newer models' most advanced features (e.g., video and human speech).
- Software products must be regularly upgraded to eliminate technical problems and to keep pace with hardware advancements.
- An important component of the software publishing enterprise is customer service. This requires financial and human resources to keep pace with customer questions and problems.

Concerns and expectations. Software publishers share some of the same concerns as traditional print publishers when it comes to innovative products for education:

- Is the size of the market sufficient to justify the cost of development? If not, how might the market be further developed?
- Will the product be adopted by a large segment of the market?
- Is the content sufficiently unique so as not to compete with any of the publisher's other products?
- How does the product compare with the competition? Are there similar products already on the market or is the product easily distinguished?
- Is the product inherently useful to the student and the educator? Does it support and enhance the curriculum?
- What is the expected life of the product? How long will it remain viable? What is the cycle for revision? What is the projected profitability of the product over its expected life?
- What kind of relationship can be established between the author/innovator and the publisher? How willing is the author to provide product support over the life of the product (e.g., participation in workshops, promotional activities)?

Publishers also identified new issues unique to software publishing:

- What is the product's level of completeness? How much time, money, and effort are required to bring it to market? What are the costs of development tools or licensing?
- Is there a plan for support and maintenance of the product that includes participation of the author/innovator? Or is support and maintenance solely the responsibility of the publisher?
- Does the design of the user interface meet the expectations of the market? Or does it need to be redesigned and tested?
- Does the product use the most popular operating environments and computer platforms? Does it take into account upcoming changes in those environments and platforms? Has it been tested for downward compatibility with earlier systems?
- Is the product designed for distribution on the most appropriate media (computer diskette, CD-ROM)?
- What testing has the product received?
- Who owns the rights to the product, both the computer code and any content (including text, graphics, video segments, and sound)?
- What plan is in place to combat software piracy? Should the product be encrypted?

Publishers and PIs acknowledged that in recent years the nature of the product delivered to classrooms has changed, from textbook only, to:

- Textbook + ancillaries (supplementary materials, such as books, journal articles, study guides, charts, kits),
- Textbook + ancillaries + software,
- Ancillaries + software + textbook,
- Software + ancillaries + textbook,
- Software + ancillaries,
- Software only.

These variations make it even more difficult for PIs and publishers to determine if the product they are offering will satisfy the needs of the market.

An underlying conflict. Though PIs know that publishers bring expertise, money, time, and the profit motive to the enterprise, they worry that publishers might take control of the project—and most of the profits. In fact, profit is a major source of conflict between publishers and PIs. While the publishers' goal is to make a profit, most PIs want to offer free access to their work. Many feel that since the work was created using public funds, there is an obligation to give the work back without seeking profit.

In the case of software publishing, the problem seems more pronounced. With a traditional print product, PIs can see the need for a publisher to produce the product and to distribute and promote it to the widest possible audience. With software, the availability of electronic distribution makes a traditional publisher seem unnecessary to many PIs. However, the cost of product development, testing, distribution, and continued customer service of software is high and makes a relationship with a software publisher highly desirable to ensure successful distribution.

The appeal of turning over software dissemination problems to publishers is growing. For example, one PI noted that she began with the goal of free distribution but was quickly overwhelmed with providing technical support for her software products; she eventually decided that if she were to continue to serve as a software developer (her primary interest), she could not continue to be a software distributor.

The "do" list. At the conference, software publishers and PIs who have already developed successful relationships with publishers identified the following ingredients of successful PI-developed software products:

(1) **Transportability.** The product should be useful on a national or international level. Ideally, it should be relevant to more than one discipline.

(2) **Realistic time frame.** The creator and publisher should be able to agree on a development cycle that delivers a quality product in a reasonable length of time. Creators have to plan sufficient time to be involved with product development. Publishers have to avoid the tendency to push products to market before they are ready.

(3) **Engaging presentation.** Lively, attractive, and well-designed content is essential to the adoption and continued successful use of the product.

(4) **Personal demonstration of usefulness.** The creator should be able to prove that successful implementation of the software with students in a learning environment is likely.

(5) **Ready market.** The creator should be able to demonstrate that people want to use the product, including students, faculty, and key decision makers within the college or university administration.

(6) **Pilot testing program.** The creator should be able to provide documentation of the results of pilot testing or should have a plan for such testing. Department seminars, student clubs, and personal contacts are all good sources of potential pilot test sites.

(7) **Documentation.** A well-organized, easy-to-use instructor's manual is essential. Demonstration software and sample materials will improve the chances of a successful marketing effort.

Publishing Multimedia

The popularity of multimedia software products for education—those that employ a combination of text, graphics, sound, and video—is growing. Conference participants attributed this growth to several factors. One factor is the awareness that people think and learn in different ways. For example, one student might be considered a visual learner while another might be an auditory learner. In fact, educators have found that most learners experience success when information is presented in a combination of formats. When multiple media are combined, the potential for learning is at its maximum.

Many PIs believe that students are ready for the random access to information resources offered by multimedia. They also believe that many colleges and universities are technologically ready for interactive, individualized instruction. PIs look at the rapid growth of videodisc players and CD-ROMs in undergraduate institutions as an indication that the time is right for the development and use of more multimedia products. Edward Warnshuis, publisher of *T.H.E. Journal*, estimates that there are more than 100,000 videodisc players and 250,000 or more CD-ROM drives in colleges and universities throughout the United States. He estimates that the rate of growth in acquiring of CD-ROM drives was almost 400 percent from 1991 to 1994 and over 80 percent from 1993 to 1994.

Asking key questions. PIs and publishers identified some key questions about preparing products for the market, and provided some answers as well:

- Who will use the product? Is it intended as an aid for the professor giving a lecture or as an exploratory tool for students in a lab, or both?
- What is the time frame for development? It may take as long as 3 or 4 years of development and testing to create a high-quality product.
- What are the standards for high-quality multimedia products?
  - (1) High-quality products exhibit effective use of technology, including:
    - —Unique content. The product's array of information resources and ways of combining them should offer something beyond what is available in a textbook or in other computer-based products.
    - —Ease of use. Users should be able to enter, use, and leave the product with a minimum of instruction. On-line, context-sensitive help should be available at all times. Users should never feel trapped or lost.

—High level of interactivity. Users should be able to explore the product at their own pace and level. Products should go well beyond the level of interactivity provided in books (i.e., reading and turning pages).

—Open-endedness. Users should be able to add information to the content of the product. Tools for word processing, spreadsheet development, database construction, drawing, and graphics enhance the product's value.

(2) High-quality products serve special needs.

—They serve a sensory-deprived audience by using sight and sound to develop concepts.

—They include optional captioning of information provided by human speech.

(3) High-quality products generate positive effects.

—Users are able to accomplish more in less time through the use of the product.

—Students demonstrate increased understanding and retention.

—Students demonstrate higher motivation.

- How should multimedia products address the assessment needs of educators? Educators agree that assessment is an important aspect of instruction, but no one knows if an assessment component will improve the marketability of multimedia products. If assessment is built-in, it should reflect what instructors actually want to know about student performance. The system for accessing and interpreting assessment data must be easy to use or educators will avoid it.

- What are the problems associated with copyrights? The content of a multimedia product is its heart and soul. Assembling a broad and rich assortment of information is costly and time-consuming. Add to that the necessity of determining the ownership of each piece of information and then obtaining permission to use it in the product.

  The United States Copyright Act of 1976 (17 U.S.C. Sec.107) refers to "fair use" exceptions to the rights of copyright holders. While "fair use" is not defined by federal statute, accepted guidelines suggest that reproduction of a *print* source may be considered fair, depending on four factors:

  (1) The purpose of the use (nonprofit educational purposes are usually considered acceptable).

  (2) The nature of the copyrighted work.

  (3) The amount and proportion of the whole copyrighted work used (the smaller the proportion, the more likely the use will be considered fair).

  (4) The effect the use might have on the copyrighted work's market potential or value (U.S. Congress, Office of Technology Assessment, April 1986).

  It is unknown at this time how "fair use" will be applied to electronically reproduced works, especially to graphics, sound, music, and video. As a precaution, developers of multimedia projects should meticulously research the copyright status of each information resource to be included and should obtain reproduction and distribution rights. Such rights are often available on a fee basis and for only a limited duration. It takes time to research ownership of content, make contact with copyright holders or their agents, and obtain the needed rights.

  For content items that clearly fall within "fair use" guidelines, the product developers must be sure to properly cite the copyright holder or the source of the content. The alternative of creating all content from scratch is equally time consuming and expensive but assures the creator and the publisher of clear rights to use the material in the product.

- What criteria should be considered when choosing multimedia development tools? The term "multimedia development tools" refers to programs specifically designed to combine and organize the text, graphics, sound, and video content of a multimedia product.

  For the novice developer—or someone simply wanting to create a product prototype—there are basic development tools that sequence the content elements and provide ways to link them for interactive exploration. Basic development tools are easy to learn, and they require little, if any, scripting or programming skill. Most assume that the content elements have been created elsewhere using compatible software and can be imported into the development package. Developers choosing this path will need to consider compatible graphics, video editing, scanning, and other types of software used to develop content for the multimedia product.

  For more advanced users, or for those creating a product intended for commercial release, high-end development tools are more appropriate. Most high-end development tools enable the user to create, edit, and manipulate content elements and combine them in complex and interesting ways. The learning curve on high-end programs may be more difficult, but can save time and money over the long term. Most high-end tools require scripting or programming, but the most sophisticated are icon-driven, employing "visual programming" (using a graphic metaphor for the process of assembling the program). Most include a "run-time module" which allows end-users to run multimedia programs created with the development tool *without* owning a copy of the development tool itself. Most run-time versions are now provided royalty-free as part of development tool packages. Debugging tools are usually included in high-end packages.

The ultimate choice of tools will depend on three factors: the type of project, the skill level of the developer, and the budget. Whatever the type of product, the creator or publisher should choose development tools that are easy to learn and that speed development. The tools should make it possible to develop versions of the product that run on most popular computers using a reasonable amount of memory. Finally, the cost of the development tools should be reasonable. Many development packages offer a discount to educational developers.

According to the August 1994 issue of *Windows Magazine*, some of the leading multimedia development packages include *Authorware Professional* (Macromedia), *IconAuthor* (AimTech), *Macromedia Director* (Macromedia), *Multimedia ToolBook* (Asymetrix), and *Multimedia Viewer* (Microsoft).

Prices vary widely, from thousands of dollars to a few hundred. Most are available to educators at a discount. The developer's package for *Authorware Professional* sells for $4,995 retail, but is sold to educators for $995. *Macromedia Director* is priced at $1,195 retail and is sold to educators for $598. Both products are available for Macintosh or Windows. *Multimedia Viewer* (a Windows-only product) costs around $500 retail. *Multimedia ToolBook* (a Windows-only product) costs $895 retail and is sold to educators for $532.

Among the less-well-known packages, *HyperWriter Professional* from Ntergaid (a Windows-only product) sells for $4,000 retail, but costs $2,400 for educators. *Q/Media* from Q/Media Software (another Windows-only product) sells for $199 retail and does not offer a discount.

The range of prices reflects the level of features and support available with each package. It is important to research development tools thoroughly before making a choice, keeping in mind not just price and current needs, but the possible future needs of the multimedia program being developed. Popular computing magazines are good sources for the latest reviews and comparisons of multimedia authoring products. Specialized magazines, such as *NewMedia* and *The World of Macintosh Multimedia*, focus directly on multimedia authoring products.

Choosing a multimedia publisher. Determining what to look for in a multimedia publisher is difficult since commercial publishing of multimedia is in its infancy and, thus, few publishers have established a track record. However, PIs and publishers at the conference did agree that a multimedia publisher should provide:

- Expertise to determine the market for the product;
- A team to convert concepts to product, including visual and audio experts, content developers, technology expertise, and professionals experienced in acquiring permission to use multimedia information resources;
- Assistance to identify the best technology platforms and development strategy;
- Product support, including marketing, advertising, training of sales representatives, workshops, videotapes, and demonstration versions;
- Customer support, including telephone and/or on-line support, return policies, free or low-cost upgrades for product owners, lab-packs, and other educational discount plans.

Working with a publisher. The publisher is not the only one who must bring something to the table in a multimedia publishing venture. To work successfully with a multimedia publisher, authors should plan to:

- Contact a publisher early,
- Have a prototype,
- Make sure that the product warrants national distribution, providing evidence of this if possible,
- Provide a directory of all software used to develop the product and all people involved in the process.

Authors should also realize that many publishers will expect to design the product, with the author acting as a content consultant. In general, academic authors should not go to a publisher if they do not want their projects to be edited.

Since some academic authors have already developed a product or are in the process of developing a product, they seek an alternative to the standard process in which the publisher serves as designer and developer. In this case, the role of the publisher and the author are as follows:

(1) The publisher
- Develops standards for products designed and developed by academic authors,
- Reviews draft versions of products and decides to accept for publication and/or makes recommendations for revisions,
- Provides the production services (design and printing of package components), dissemination system (e.g., catalogues, order fulfillment), and customer service support.

(2) The author
- Maintains prime responsibility for design and development and aids in customer service support.

Facing the problems for authors. Regardless of the publishing model, multimedia publishing poses some problems for academic authors. At the Project Impact conference, many PIs had the impression that publishers do not yet know how to sell multimedia in general, let alone multimedia for innovative curricula. The PIs believe that publishers tend to concentrate on one type of thing (e.g., just mathematics, just textbooks). This is generally a misperception, since most college publishers service multiple disciplines and some traditional textbook publishers are currently exploring multimedia publishing.

The nature of multimedia development may also mean less financial compensation for authors, since a percentage of royalty payments must be reserved for the technology provider (the programmer or licenser) and the copyright holders of multimedia content materials (e.g., photos and video clips).

Dissemination via the Information Superhighway

At many of the sessions of the Project Impact conference, there was keen interest in the telecommunications-based Information Superhighway and its role in:

- The exchange of information in academia,
- The development and dissemination of innovative educational products.

The Information Superhighway refers to a digital data network of computer networks used by educators and others seeking to exchange information nationally or internationally. In the not-too-distant future, the superhighway will make long-distance text, voice, graphic, and video communication between individuals and among groups easy and commonplace. For now, the superhighway refers to the Internet, which relies primarily on text-based communication, with some exchange of nontext files (e.g., software programs, databases, graphics).

Most PIs at the conference had had some experience with the Internet and were eager to find out more about its potential. Current usage of the Internet in academia focuses on communication and research. The most popular features of the Internet for faculty and students are:

- Electronic mail—providing instant written communication within an institution and among all connected institutions around the world,
- On-line research—enabling users to tap into a wide array of libraries, archives, and databases.

All participants expressed some general concerns about the Internet. Many commented on the sheer volume of information accumulating on the Internet and the lack of any monitor or referee to ensure organization and quality control and to keep redundancy to a minimum. Many participants suggested professional societies as a good source for standard setting and maintenance on the Internet.

Many educators came to the conference with the mistaken belief that the Internet is a cost-free environment. They learned that institutions, corporations, individuals, and the federal government all pay fees for the development, use, and maintenance of the Internet. The fees are charged according to the level of access, the kind of use involved (e.g., corporate vs. personal), the time of day (peak business hours vs. off hours), and the amount of time used.

Many educators at the conference had questions about getting started on the Internet. Such questions can best be answered in one of the many books of instruction that are now available. (The article, "INTERNET expedition maps," in the April 1994 edition of *NewMedia* provides a valuable overview of these publications.) Many PIs believed that step-by-step guidelines are needed to help save time and ensure good results. Whether experienced or inexperienced, they all wanted to know:

- How to find out what resources are available on the Internet,
- How to locate a resource and make use of it,
- How to join in the exchange of information and ideas pertaining to innovation and reform in education.

These questions were difficult to answer because, as yet, there is no central clearinghouse of information about what or who is on the Internet and because of the rapid growth of the system.

Internet publishing issues. Most PIs also wondered how publishing via Internet compares with traditional publishing. Discussion among PIs and publishers centered around the issues of product review, testing, marketing, and intellectual property.

PIs generally believed that the Internet had the potential to improve their ability to get their products reviewed and to test and market them. Easy, quick, and direct access to educational innovators should provide a ready pool of reviewers and test groups, and a receptive market for innovative products. Providing on-line training tools, supplementary teaching materials, customer service bulletin boards, and user group lists could ensure a level of customer support that builds a loyal following for the product.

The issue of intellectual property continues to confound both PIs and publishers. Some worried that the Internet is "the ultimate copy machine." Publishers and PIs wondered how the system can ensure that creators are fairly compensated for their efforts. And as products are increasingly developed by groups of contributors along the Information Superhighway, innovators expressed concern about authorship.

Emerging author–publisher relationships. PIs and publishers also wondered what kind of author–publisher relationships will emerge from network publishing. Some participants even wondered if the advent of the Internet will bring academic print publishing to an end.

To publish or not to publish via the Internet. The question of whether to publish software on the Internet received a variety of responses. There was general agreement that the Internet is a good mechanism for the broad dissemination of materials for "free." (Although there are costs involved for the institutions that utilize the Internet, most PIs and the academic audience they seek to reach experience the Internet as a free service.)

Some PIs have attempted to distribute software via the Internet as shareware. "Shareware" is a distribution scheme in which prospective customers download products from a computer network, sample them, and pay for them only if they decide to continue using them. Many developers of academic software who publish shareware view it as a way to generate enough income to support continued development of the software, not as a way to profit by their work. Most PIs who had explored this method viewed it as very time-consuming and, ultimately, unsuccessful. Serving as one's own software distributor requires a high level of customer service and continual upgrades, which leaves less time available for software development. Besides, few academics support this distribution method in their role as software consumers. One PI noted, XXX"If I publish shareware, my colleagues think I'm trying to make money, so they won't use it."

Another method of distribution is emerging on the Internet. Some on-line services provide access to materials on a fee or prepay basis. Those who join the service pay a membership fee and receive a password that gives access to a database of downloadable materials. In some instances, members may try the software on-line before deciding to download it. Once the material is downloaded, the cost is charged to the member's credit card or account number. This is one method that publishers may employ to distribute software broadly, quickly, and at a reasonable cost. Electronic distribution eliminates packaging and shipping costs, as well as theft and returns of unsold copies. Software and documentation can be upgraded as often as needed. As PIs turn to software publishers to disseminate their work and as more publishers decide to use the Internet as a means of distribution on a fee basis, the Internet may become the distribution method of choice.

Internet consensus. The concensus on the Internet's value to educators as a vehicle for information exchange was positive. Many participants pointed to the Internet as a place where there is enough room to accommodate small interest groups that might otherwise be unable to sustain themselves. They also noted the capacity of the Internet to encourage the growth of vigorous technical societies. Most believed that the ultimate benefit of the Internet is its ability to "level the playing field" for educators and students by providing broad access to the same resources and communications channels for all.

Recommendations to Conference Participants

The commercial publishers, PIs, and NSF staff shared the sense that a continued cooperative effort among all parties is needed. All of the participants offered specific feedback that they believed would result in greater dissemination of projects and information into the higher education market.

Advice for Educational Innovators

Publishers offered many solid suggestions for ways that PIs could help ensure successful publication and adoption of their work. First and foremost, they want PIs to base their work on ongoing testing and educational research. They also strongly suggested that innovators work incrementally, keeping in mind that sweeping change does not occur overnight and may be counterproductive.

Publishers encouraged PIs to make their material flexible so it can be individualized—an important feature for success. They also encouraged an emphasis on changes driven by customer demand (student or instructor), which will ensure a ready market.

Publishers want PIs to "go out and preach to the unconverted." They believe PIs should be motivated to give workshops and talks and to publish information about their work in journals. In addition, publishers believe that PIs can create an environment to encourage faculty members to change. They recommended that PIs actively encourage faculty to attend faculty enhancement workshops. They also suggested that PIs work with other technologically proficient faculty members to offer workshops for senior faculty who are not up to speed.

Publishers want PIs to "build bridges in lots of different directions." To this end, they encouraged building consensus on need—convincing the administration, firing-up department heads, and inviting department heads and key administrative personnel (e.g., dean of academic affairs) to become partners in innovative projects. Publishers reminded PIs that it is important to "get people to understand what you are really doing, not what they think you are doing." Publishers believe that an important step in "building bridges" is to involve a high-profile faculty member in the project. They believe that senior faculty must endorse reform and be supportive if innovative products are to be successfully adopted.

Visibility is important to publishers. To that end, they encouraged innovators to hold exhibits (similar to those available at the Project Impact conference) at department meetings. Publishers also encouraged PIs to create videos showing the changes in educational content and methodologies in their disciplines over the decades to "minimize the fear of change by seeing the history of change in education."

In general, publishers believe that teaching institutions bear the primary responsibility to create a market for innovative teaching techniques and materials. Publishers urged institutions of higher education to emphasize the development of strong teaching skills as part of graduate education—so that professors-in-training will emerge as excellent instructors and will value improved teaching materials.

Advice for Publishers

PIs want publishers to use more imaginative marketing surveys to identify unmet needs and market niches that may nurture innovation. They believe that publishers can help to ease the pain of innovation by encouraging evolutionary change—introducing some elements of reform in established products.

PIs hope that publishers can be flexible in the product development process, allotting more time for innovative product development. They also hope that publishers can develop or adapt marketing strategies to accommodate those projects that may take some time to establish a market. For example, PIs suggested that publishers might develop and conduct educational innovation workshops. The workshops could be used to help authors spread the news about innovation and to train instructors in the use of innovative products. One publisher suggested that it might make sense to establish separate electronic forums to build "mindshare"—a cadre of educators who are receptive to a general direction in educational reform or to specific innovations.

There were many suggestions related to improvement of the review process. PIs hope that publishers will choose reviewers for innovative projects more wisely, looking for those reviewers who have a track record with innovation and who can fairly evaluate the merits and shortcomings of a project. PIs also suggested that a higher rate of pay for reviewers would bring more qualified people into the pool and generate better results of the review process.

Overall, PIs hope that publishers will show more willingness to take some risks with innovative products and that short-term profit will not be their only goal.

Recommendations to NSF

Participants at the Project Impact conference offered a wide variety of recommendations to NSF. Some mirror actions already being taken. Many other valuable suggestions are currently under review.

Actions NSF is already taking. As recommended by conference participants, NSF will continue to:

- Serve as a catalyst for the transfer of knowledge and technologies created in academia to the marketplace.
- Require that grant proposals include a review of relevant past literature (journals and other media). New innovative efforts are more likely to be productive and successful if the new investigators profit from the lessons of their predecessors. It often does not occur to curriculum reformers that others may have tried similar things in the past. Furthermore, linking a reform to past reforms may tap an audience of potential adopters—educators who are already sympathetic to past reforms.
- Maintain elements of NSF's existing proposal process that encourage broad dissemination.
  - —Continue to require innovators to explain how the project's utility will be demonstrated and how feedback will be obtained.
  - —Continue to require a detailed dissemination plan. Dissemination is expected of all grant recipients and cannot be an afterthought. A plan to test ideas and materials at other institutions, including identification of collaborators, is required as part of the dissemination plan. This requirement develops champions for the innovation at other institutions and ensures that the ideas and materials are transportable.

    Assistance in developing dissemination plans will be continued through publications such as the *User-Friendly Handbook for Project Dissemination*, published by NSF (Ely and Huberman, 1993).
  - —If dissemination is not an integral part of a proposal, "add-on" funding can be considered. Once project materials have been tested and validated, assistance may be provided to make potential users aware of the new resources and establish access points for these new materials.
- Facilitate communication with professional societies since most of these organizations have dissemination as a major objective. Close association with professional societies has proven to be one of the best mechanisms for dissemination. Continued and enhanced participation at professional society conferences and meetings through workshops, presentations, and "education expos" and through periodical publications (columns, news briefs) can be effective and often inexpensive ways to disseminate new ideas and products. Exhibits at these meetings offer still another channel.
- Submit abstracts and status reports of NSF projects to higher education newsletters on a continuing basis.

- Expand the horizons for dissemination mechanisms beyond the current emphasis on textbooks and other print publications to include:
  - —Electronic repositories accessible via the Internet. A recently funded NSF project to establish a central repository for computer science course materials should be a great help in accessing course materials from various repositories by providing a single entry point. A general problem, however, is having materials maintained after a repository is initially established. Other problems include determining which items in a repository are still current and providing reviews that indicate the value of available items. Funding should be provided to address these problems.
  - —Workshops to review project results and to provide peer feedback.
  - —Presentations at conferences (e.g., national and regional educational computing conferences) and at other institutions.
- Fund more projects dealing with higher level courses. The goal is to encourage some projects that specifically target upperclass major courses.
- Take affirmative action to include the 2-year colleges and predominantly minority institutions in an investment in educational research.

Recommendations currently under review. Conference participants recommended that NSF:

- Hold more Project Impact conferences—perhaps one every 2 years. Conferences should include PIs, administrators (provosts and deans), and more publishing industry representatives.

  Getting innovators, administrators, and publishers together and talking with one another for a few days is an effective way of making the professoriate and other participants in educational innovation aware of the variety of creative work that is going on around the country.
- Improve future Project Impact conferences as follows:
  - —Consider broadening the emphasis of future conferences to include not just dissemination but adoption and incorporation of one another's work. Also emphasize the lessons that can be learned about better dissemination from the experience of adopting the innovations of others.
  - —Provide workshop discussion leaders with more direction on how to perform their role effectively.
  - —Make the conference longer to give attendees more time to explore the project presentation booths. After much time and effort was expended to set up the booths, most attendees had time to visit only a tiny fraction of the displays.
  - —Invite assistant professors who show interest in but have no NSF funding to attend as conference guests. The opportunity to observe the size, diversity, and expertise of the DUE community and to appreciate NSF's commitment to education could help legitimize these activities in the eyes of younger faculty members.
  - —Encourage PIs to bring students along as conference participants who can speak about educational reform from the standpoint of the final "customers."
- Whenever an education reform grant is awarded, ask the recipient institution's deans and administrators to explain to NSF how they plan to help the faculty diffuse their work across campus. Suggest that, just as institutions have found it necessary to provide an infrastructure to support their faculty's research activities, they need to provide an infrastructure to support their faculty's education reform and improvement activities.
- Hold regional workshops where administrators, researchers, and faculty are invited to discuss the strategic initiatives and the incentives available to catalyze long-term transformation of undergraduate curricula and instruction.
- Work with various publishing associations (e.g., Association of American Publishers, Software Publishers Association) to establish ongoing dialogues and a system of informing publishers of creative innovations available for publication.
- Extend incentives to influence continued development and adoption of innovations, including adequate rewards for teaching as a component of scholarship.
- Increase funding support for substantive project evaluation. Available funding levels are generally insufficient to allow extensive assessment efforts. As part of its evaluation efforts, NSF should use external evaluators to receive early feedback and assessment of the direction and progress of each project so as to determine the likelihood of its success.
- Provide guidelines for successful publishing to those PIs without prior academic publication experience (especially PIs whose focus has been software and multimedia development). For example, let them know that they should conduct a professional literature search, explain why and how their efforts could be implemented elsewhere, and provide evidence as to the success of the innovation in terms of student performance.
- Foster the establishment of a regular electronic forum and, ideally, a central clearinghouse for considering and critically evaluating innovative approaches to teaching

college science, mathematics, engineering, and technology. Use the forum to air and evaluate the issues of intellectual property rights and copyright protection, and to work with other federal agencies to help resolve these problems. The clearinghouse could be in the form of an electronic database of NSF-funded and other innovative projects and products, as well as information for contacting innovators. This will ensure awareness of and access to previously unknown resources. The mathematics archive at the University of Tennessee and the Eisenhower National Clearinghouse on Mathematics and Science Instructional Materials at Ohio State University could serve as models for adaptation.

Also encourage the establishment of an electronic bulletin board for rapidly disseminating small-scale innovative ideas for changing science courses or, conceivably, for updating popular textbooks.

- Revise NSF proposal requirements to include the following.
  - —Provide guidance to future PIs through final reports on NSF grant projects. In particular, reports should include a section on goals accomplished and future plans for dissemination.
  - —Consider at least brief dissemination of reports on unsuccessful projects. The information that something did not work—that students exposed to the innovative approach did no better or perhaps did worse than the control group—is data that will be useful to others.

    PIs should be assured that the more effectively they describe and analyze efforts that did not work, the more likely it is that NSF reviewers will value their project highly. In particular, PIs should be encouraged to develop powerful cautionary stories that are based on data and that convey the wisdom of experience.
  - —Require that transportability be planned from the start. Instructional innovators should plan to expose ideas early and often during the project to the scrutiny of other educators who might eventually adopt the innovation. Project team members should plan to attend national conferences and regional meetings, and to participate in electronic network list servers. Plans should include video recording students using the innovative materials or approach, as a means of sharing the learning environment with other educators. Plans should always include pilot testing at other sites.
  - —Provide a plan for reform that addresses not just sweeping change, but modular change that would appeal to conservative professors and limited budgets.
  - —Establish quality control procedures for project outputs prior to dissemination. In his report on the Project Impact conference, Don Ely of Syracuse University makes a strong case for quality controls based not just on empirical data but on the subjective opinions of a sampling of potential users (both instructors and students) concerning:
    - The project's level of sophistication;
    - The believability and validity of the source (e.g., the innovators' track record);
    - The project's pertinence to the needs of the audience (i.e., practicality);
    - The work's clarity, style, readability, and flair in communication;
    - The quality and substance of the content;
    - The timeliness of the innovation.

    NSF should consider the review procedures used by the National Diffusion Network and Project Kaleidoscope as resources for developing its own procedures.
- Consider shifting the focus of project evaluation and continued NSF funding to the probability of successful adoption, using a three phase approach:
  - —Phase 1: Fund preliminary research and work with a pilot audience of students and faculty. Make it clear to PIs that continued funding beyond Phase 1 will focus on replication of the innovation and, ultimately, large-scale dissemination.
  - —Phase 2: Submit the Phase 1 project, along with a plan for beta testing at other sites, to peer review. Fund the beta test only if the PI can convince the review panel that the project is highly likely to be successfully replicated at other sites. If the panel is unconvinced, discontinue the project. Conduct beta testing of a scale replica at other sites. Assess the ultimate outcomes of the project and its potential for broad dissemination.
  - —Phase 3: Submit the results of Phase 2, along with a plan for national distribution, to peer review. Fund dissemination only if Phase 2 was successful and if the distribution plan identifies a clearinghouse mechanism for expertise and dissemination that will support all those who seek to adopt the new innovation.

  The result of this shift in focus would be more funds for Phase 2 and 3, limiting the number of Phase 1 projects. However, it would result in greater dissemination and adoption of those projects most likely to succeed.
- Shift a greater proportion of funds to long-term projects, thereby giving PIs the space to make the kinds of mistakes that are inevitable when trying things that are genuinely innovative and difficult. NSF should make it clear that the slow progress of educational reform indicates not that reformers are doing a poor job but that this is work

fraught with difficulty and a high likelihood of false starts and problems.

- Look for links between current grants and facilitate contacts among PIs. Increase PIs' awareness of others doing similar work. All need to read the reports of abstracts of funded projects published by NSF and other sources (e.g., *UME Trends*) and to establish contact with personnel working on similar projects.

  Closer relationships should also be developed between course/curriculum development projects and faculty enhancement projects within NSF. A dissemination officer within NSF could help to develop dissemination plans, set standards, coordinate efforts among projects, and perform outreach activities to professional organizations, university administrators, and the public mass media.

- Facilitate public domain sharing of new materials developed with NSF funds to encourage participation in field testing by potential users. Some projects are already making materials available to users at little or no cost. Cost is sometimes an impediment to acquisition, and NSF should do everything in its power to facilitate access to materials produced by projects it funds.

  Once materials are validated, negotiations can proceed with commercial organizations, which are more likely to support curriculum materials over the long term than are the university-based developers. This type of cooperative effort among developers, users, and commercial vendors offers a balanced approach to access.

- Create a network of PIs to continue and follow up the positive outcomes of the Project Impact conference. Such a network could be developed on the Internet and/or by publication of abstracts with indexes to PIs, institution, discipline, and products and instructional approaches. From such a network, subsets of individuals with similar specific interests would likely form. If the Internet is used, NSF should consider organizing and funding on-line forums of PIs with similar interests. Such PI interest groups could become potential beta test sites and dissemination contact points for one another's innovation.

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SECTION III

The Disciplines

The Nature of Efforts To Effect Interdisciplinary Reform: Drivers, Barriers, and Strategies for Dissemination

Steve Landry

The Backdrop for Interdisciplinary Innovation

Momentum can be a great influence, and it can be difficult to overcome. Over the past century, the increased movement toward concentration within an academic discipline has taken charge of the curriculum, as well as serving to compartmentalize the professoriate and the institution. Consider, for example, the extent to which an academic discipline results in the compartmentalizing, specializing, and vocationalizing of today's academic pursuits. The first question asked of most college-bound students is "What is your major?"; for the graduate the question is "What was your major?"; and for the graduate student, there is even more specialization. Professors are hired within a discipline, are tenured into departments within a discipline, advise students within their academic discipline, and are responsible for expanding the knowledge base within a discipline, publishing in a discipline, and serving as mentors for the next generation of specialists in that discipline.

Even in the midst of this massive flow toward 24-karat purified disciplines, many social, technological, and academic forces press us to introduce cross-disciplinary influences. As a chronicler of the 1994 Project Impact conference and having been asked to restrict my consideration to multidisciplinary projects, I set out to discover and organize what I call the "drivers" of the research, i.e., those forces, beyond pure academic curiosity, that prompt researchers to seek innovation in science, mathematics, and engineering education. Such drivers are somewhat obvious and hence easy to identify. Yet, for me, they seemed the appropriate organizers for this report.

Drivers for Educational Innovation

Within the context of the Project Impact conference, I observed what seemed to be natural distinctions that partitioned the projects. Some were immediately obvious and others quite subtle. For the sake of this paper, recognizing

that I restricted my review to only 65 projects, I have elected to partition them based on the force or driver that creates the impetus for the innovation. These drivers are:

- The arising of new knowledge or improved content,
- The desire for improved pedagogy, better resources for teaching, or new courses,
- The changes in social and demographic considerations,
- The desire to consider the integrating factors among the disciplines,
- The need to keep the professoriate current.

In each of the following subsections I present a brief framework for the grouping and then briefly identify sample projects highlighted at the conference.

Drivers: New Knowledge or Improved Content

An explosion of new knowledge, as well as a constant synthesis of the old with the new, propels much of the disciplinary and interdisciplinary innovation. The first subcategory includes projects that introduce new topics into traditional courses and those that advance new courses within a discipline. Another subcategory includes ventures that promote new courses outside of any traditional discipline. These include efforts to introduce thematic courses that apply to many disciplines and stress general skills such as problem-solving skills or invention and design skills. Also included in this category are those projects that synthesize new degree programs, such as one in "regulatory science."

Sample projects seeking to introduce new knowledge or improve courses within a single discipline include:

- Introducing modern genetic engineering into traditional biochemical engineering is David Graves' goal at the University of Pennsylvania. He is creating experiments and apparatuses to integrate topics related to genetic engineering into a new lab.
- At the University of California at Los Angeles, Harold Monbouquette, with the assistance of an interdisciplinary team, is developing lab experiences and curriculum materials to expose students to the challenges and opportunities involved in culturing and purifying products from seldom-studied micro-organisms.
- At State University of New York College at Brockport, John Hubbard, developed a faculty enhancement workshop in contemporary hydrology issues for instructors of college-level introductory courses with water resources content. A wide variety of resources, including information databases of the U.S. Geological Survey and interactive computer-based teaching modules, are utilized.
- To help faculty keep up with the rapidly changing field of computer graphics, G. Scott Owen and Valerie Miller at Georgia State offer relevant undergraduate faculty workshops. Participants receive CD-ROM-based software.
- Patricia Morse, Northeastern University, and Barbara Thorne, University of Maryland, have organized a series of symposia to disseminate current research and ideas concerning biodiversity. In addition, materials such as references, visual aides, and support resources assist educators in improving their courses.
- The new field of microelectromechanical systems is the focus of a team of engineering faculty at the University of Minnesota. Six new academic courses and a hands-on lab have been developed.

Sample projects seeking to introduce new knowledge or improve courses outside a traditional discipline include:

- A laboratory for exploring new ways of teaching invention and design is the goal of a project by Michael Gorman, Larry Richards, and William Scherer at the University of Virginia.
- A multimedia-based curriculum that seeks to improve computational problem-solving skills is the goal of Daniel Friedman, Susan Bard, and Russel Poch at Howard Community College. Particular attention is given to problems from biology, chemistry, and physics.
- The team developing the "Linguistic Semantics as Science" project proposes that linguistics provides a unique medium for introducing students from a wide variety of academic backgrounds to principles of scientific reasoning and method. The research team at SUNY—Stony Brook includes Richard Larson, David Warren, Kostis Sagonas, and Juliana Lima.

Drivers: Improved Pedagogy

Sterile lectures and lack of relevance are sources of much of the dismay and unhappiness directed toward higher education. At some level, most of the innovations discussed throughout this chapter address these issues, at least indirectly. Several projects have set out to reach new levels of effectiveness in pedagogy. I have divided research projects in this classification into three subcategories: Improved Methods, Improved Resources and Materials, and Improved Course or Curriculum Designs.

Drivers: improved methods. Projects in this category attempt to strike at pedagogical disenchantment by paying attention to all of the elements that give life to learning: students, teachers, and the connections between learning and teaching. The recurring themes here are active learning, cooperative learning, inquiry/discovery-based learning, and hands-on learning. All of these methods attempt to engage the student as a full and active participant in the whole process of the learning–teaching connection.

Sample projects seeking to deliver improved pedagogical methods include:

- Two semester-long, student-centered, active learning courses that integrate the study of the physical and life sciences and emphasize scientific inquiry were integrated into the curriculum at Nassau Community College by Rhoda Berenson, Shirley Aronson-Unger, Maureen Daddona, and Tom O'Brien. The courses build on observation and experimentation and rely heavily on collaborative student activities and on nontextbook sources.
- At Lehman College of the City University of New York, a two-semester integrated mathematics and science program is run entirely as a hands-on laboratory. The program begins at the student's current level and uses a discovery-based methodology. Investigators are Jack Ullman, Ronald Ellis, and Jerome Epstein.
- A project seeking to replace lectures with an active/cooperative learning format using small-group problem-solving activities was undertaken by Judith Miller, John Wilkes, and Ronald Cheetham at Worcester Polytechnic Institute.

Drivers: improved resources and materials. The purpose here is to leverage new technology effectively. Computers, digital networks, and multimedia aides are among the most obvious technological advancements that assist the teacher and the student.

For the teacher, these aides facilitate the presentation of knowledge and enliven the teaching event through visualization and sound. For the student, these new resources mean contemporary, fresh, and more relevant materials.

Sample projects seeking to deliver new teaching resources include:

- Computer-based tools, particularly multimedia, which are being used in a large number of projects to aid the professor in delivering more spirited and visually stimulating presentations and to empower students with interactive lab environments. In physics, Ronald Thornton *et al.* at Tufts University, Jan Tobochnik *et al.* at Kalamazoo College, Jack Wilson at Rensselaer Polytechnic Institute, and a large team of colleagues from many universities are using computer-based systems to provide hands-on, interactive, and simulation-based learning tools. In mathematics, Gareth Williams, *et al.* at Stetson University and Edmund Lamagna *et al.* at the University of Rhode Island are developing interactive environments to support the teaching of linear algebra and of calculus, respectively. Also in mathematics, Thomas Banchoff at Brown University is applying interactive computer graphics to differential geometry of curves and surfaces. Numerous other projects are bringing new tools to the professoriate.

Drivers: improved course or curriculum design. As observed earlier, knowledge, society, and demands on the curriculum change over time. Projects placed in this grouping are those that seek to improve the curriculum or a given course explicitly through their distinct designs. In most cases, the reverse of compartmentalization—integration or broadening beyond a single discipline—is put forth. Additionally, new courses and curricula are being developed because it is perceived that there is a community that will benefit from them.

Sample projects seeking to deliver improved course or curriculum design include:

- By integrating a common set of computer-aided tools and reporting procedures upward through the curriculum from the sophomore year to the senior year, John Uhran and Eugene Henry at the University of Notre Dame, have introduced vertical curriculum lab support to enhance the student's design capacity and experience.
- A sample of a new interdisciplinary course based on contemporary perspectives is under development at Thiel College. There, Guru Rattan Kaur Khalsa *et al.* have designed a course that examines pressing global issues and ways in which the rich natural and cultural heritage of the Earth can be sustained. The focus is on Nigeria, India, China, and Brazil.
- New York University is developing an integrated three-course math/science sequence, a Science Core Program that will be taken by all non-science-majors. Courses will be sequential, becoming gradually more sophisticated, and multidisciplinary. All courses will have substantial quantitative content. The students are prepared in quantitative methods by the first core course, "which explores connections between math and scientific inquiry."
- A sample of a new curriculum, developed in response to a perceived economic and social need, is under way at Illinois Institute of Technology. Sudhir Kumar, Jotin Khisty, and M. Shahidehpour are developing a curriculum in Railroad Transportation.

Drivers: Social/Demographic Issues

The observation has been made that, in proportion to their populations, minorities and women are not present in the science and engineering fields. In addition, this group is quickly becoming a large component of the available student population and workforce. The big questions are "How can we recruit women and minorities into science and engineering? Once recruited, how can we retain them in science and engineering?" Another important question is "What are the barriers, and how can they be eliminated?"

Sample projects seeking to attack social and demographic issues include:

- At Carlow College, Charlotte Zalewsky and Elaine Lees have created a 1-semester introductory course specifically designed to address the needs of African–American women who find science courses a roadblock in their academic path and a place for failure. Numerous innovations close the gap between the content and pedagogical style of the course and the student's experiences.
- The Women and Science program conducted within the University of Wisconsin System is using the talent and mentoring capacity of Distinguished Visiting Professors in Women and Science to reach students in order to address the underrepresentation of women and minorities in science. This project appears to be an excellent model for faculty development and new and revised course development. The project is under the direction of Jacqueline Ross.
- A new course for enhancing the Three-Dimensional Spatial Visualization Skills of students is under development by Beverly Gimmestad and Sheryl Sorby-Marlor at

Michigan Technological University. All freshmen engineering students with weak three-dimensional spatial skills are the target audience. However, the PIs note that, since "women are about three times less likely than men to have these prerequisite skills, it is anticipated that this course will increase the accessibility of engineering studies to women."

Drivers: Integrating Disciplines

In his book, *Curriculum*, Frederick Rudolph draws upon a professorial quote from 1901 to characterize the academic malaise of that time. It states that "Young doctors of philosophy, fresh from the prolonged study of some remote nook of science or literature, have been turned loose on freshmen and sophomores and have bored them to desperation with minutiae." While this is not the full characterization of the ills for which reintegration of the disciplines is intended to cure, I believe it captures much of the spirit.

Numerous projects seek to acknowledge, and hence teach from the standpoint of, the connections between disciplines in order to avoid "desperation with minutiae." In some projects the connections are concentrated around a unifying theme, but others concentrate on enhancing the student's understanding of the connections inherent among disciplines.

Sample projects seeking to reintegrate traditional disciplines include:

- Holding that, for the most part, "students of science and engineering . . . have a very shallow idea of their own disciplines' connection to the common culture," Stephen Weininger and David Samson, at Worcester Polytechnic Institute, designed and implemented a junior–senior seminar that draws on physics, philosophy, biology, art history, history of science, mathematics, and computer science. The seminar is divided into four units: (1) Assumptions and Intuition in Science, Knowledge and Method in Art, (2) Perspective in Art and Science: The Shared Metaphor, (3) Reductionism: Diffraction of Light, Fragmentation of Perception, and (4) Active or Passive? How We Understand What We See.
- The border between the United States and Mexico is a zone of influence that magnifies the environmental, demographic, economic, and cultural differences of the countries. A new course developed by Elizabeth Braker, Manuel Pastor, and Raul Villa at Occidental College integrates science, social science, and the humanities to study relevant issues such as immigration, agriculture, industry, and public health.
- Modern manufacturing is the integrating theme for the project undertaken by Judith Tavel *et al.* at Dutchess Community College. The project's goal is to design a "single, unified course integrating elements from what are currently separate courses in introductory mathematics, chemistry, physics, English, and reading" to educate personnel working in industry.

Drivers: Keeping the Professoriate Current

Not only must courses and curricula evolve but the professoriate must also in order to cope with an expanding knowledge base, new technologies, and advances in pedagogy. The following collection of projects sought to provide learning opportunities for college professors so they could enhance their own classes.

Sample projects seeking to advance the learning of professors include both discipline-based projects and outside-of-discipline projects.

Discipline-based projects. These projects seek to enrich a teacher's knowledge in his/her own discipline and are particularly influenced by new developments and the need for expertise and specially equipped laboratories:

- An Undergraduate Faculty Enhancement short-course that focuses on lasers and their application to solving chemical problems has been designed and implemented by Ben DeGraff, Dorn Peterson, and David Horner at James Madison University.
- An interdisciplinary (biology, geography, and chemistry) workshop on the Chesapeake Bay has been designed and implemented by Patricia Cunniff *et al.* at Prince George's Community College and the Chesapeake Research Consortium.

Outside-of-discipline projects. Those projects that seek to advance a teacher's knowledge in an area other than his/her primary discipline include:

- The objective of the project by Clayton Ruud *et al.* at Pennsylvania State University is to use manufacturing to illustrate principles of science, mathematics, and engineering. Faculty from these disciplines are exposed to metal casting, machining, electronics, assembly, and numerically controlled dimensioning and milling. The goal is for the faculty to use these experiences to add vitality and relevance to their own teaching.

Dissemination

The Changing Landscape

There is an evolution going on. The primary medium of distribution is changing from textbooks to software. It is happening slowly when compared with expectations generated by the current public hype. At the same time, it is happening rapidly when compared against the hundreds of years during which the printed text was the primary medium of dissemination. In one of the discussion groups on software publishing, the following observation was presented to represent the changing of teachers' support materials:

The traditional form: the book only

- Add additional support: book + ancillaries;
- Add dynamic support: book + ancillaries + software;
- Change focus: ancillaries + software + book
- Change focus more: software + ancillaries + book;
- Integrate: software + ancillaries;
- Integrate more: software.

This evolution is neither linear nor monotonic. However, the tendencies are obvious and persistent. Technological advances in computing, multimedia, voice recognition, and networking continue to reach new thresholds that beg for new applications in teaching.

Barriers to Dissemination

While progress invites new applications, it is apparent that many barriers must be confronted by the disseminator of innovation. Some barriers are technological, such as a lack of standards and many different platforms. Some result from the cost of putting enough systems in classrooms and in labs. Other barriers stem from the lack of expertise in developing fully effective materials. Some simply arise as a broad, diverse, and in some cases stubborn or fearful, professoriate avoids change or becomes lethargic when confronted with attempts to integrate new tools and methods into crammed courses and jammed curricula. The differences between the academic cultures at 2-year institutions, 4-year undergraduate institutions, and research universities introduce complications to the broad acceptance of some innovations.

In addition, the issues associated with transfer credits for an innovative interdisciplinary course can be a real obstacle. For multidisciplinary innovations, the existing disciplinary organization, and in some cases accreditation, poses an inherent impediment to adoption.

For the reformers—those individuals or teams attempting to disseminate an innovation—obstacles and barriers are sometimes close at home. Existing reward systems often demand research that advances the discipline. Also, faculty often meet with resistance from administrators who choose not to support advancing pedagogy, in favor of other activities.

Attending to Dissemination

From the beginning. If dissemination is to be effective, it should be considered an integral part of a project from the beginning. Much of the success of dissemination depends on the initial reformer or the designer of the project. Dissemination will often depend on his/her willingness to propagate the results. However, this is also a process that requires considering the needs of those who might adopt the innovation. In short, if dissemination is to be successful, there must often be a willingness to carry the ball and to accept feedback. At the outset, the innovator should think about how the project's utility will be demonstrated and how feedback will be obtained.

A key result of considering dissemination early in the process can be transportability. Front-end steps should include consulting with someone who knows about dissemination. Involving a publisher can be an effective means to improving the likelihood of successful dissemination. As one would suspect, it is wise to cast the nets broadly and be discerning when selecting a publisher. The publisher's experience should be used to get a deep understanding of what dissemination will require and to get support for marketing, layout, permissions, editing, and other aspects of developing project results. This is particularly important for multimedia projects that require a diverse set of talents. An advisory board may also be useful.

Throughout the project. During the developmental phase of the project, it is easy to overlook activities related to dissemination because of the focus on developing results. However, a few simple activities accomplished concurrently (and even in support of development) can improve the dissemination results. It is valuable to expose ideas early and frequently to obtain feedback. At the local level, it can be useful to use local departmental seminars or student clubs as sounding boards. A broader range of endeavors to consider are national conferences, regional meetings, and electronic network list servers. Keep in mind that some specifications for the project may change through usage and may require consideration and implementation before dissemination is possible.

Throughout development, it is important to look ahead to devices such as videotapes of students in labs and journals from teams working on the project that will support dissemination at a later stage. As the end of the project approaches, it is important to develop pilot testing programs. Regionally based colleagues often serve as the most effective beta sites because they are nearby and can easily be obtained through personal contacts.

Actions for dissemination. It is clear that excellent and worthy results alone will not guarantee quick and broad dissemination. Indeed, it is necessary to prove that your results will be of value to others. To this end, it is worthwhile to identify willing listeners, give personal demonstrations of an innovation, and develop a network of satisfied users. The source of assistance for building an effective network can often begin with enrolling a senior and recognized colleague to endorse and assist with the project. Increasingly, free media such as electronic network list servers, electronic mail, workshops, and visiting lectures are effective ways to publicize results and their potential for application. In some instances, newsletters, minicourses, or teleconferencing are effective promotional mechanisms. Obviously, when a publisher is involved, an outreach potential is already established. When software or multimedia is the medium of delivery, plugging into existing user groups can provide an instant dissemination network. Another option for software and multimedia is the distribution of samples.

There are indeed trade-offs between producing a complete package that is ready for adoption versus providing a framework that permits the adopter to customize the product. In general, however, innovations that have been developed with dissemination in mind will be easier for others to adopt if they are (1) transportable, modular, and flexible; (2) scalable and adaptable for incremental use; (3) well documented, including instructors manual, demonstration software, sample materials, and tutorials; and (4) low in cost.

For initiatives that involve software and multimedia, much of the publishing context is the same as for traditional text. That is, one must consider market size, content uniqueness, and the competition. Items that are of particular concern for these media are completeness, maintenance, user interface, operating environment, distribution media, and the need for additional support products.

On the emerging frontier of distribution over the Internet, numerous key parameters are evolving quickly and can pose unique problems. Among these are pricing/payment, piracy, encryption, general availability, and access.

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Current Trends in Undergraduate Biology

Jeffrey L. Fox

Introduction

Diverse efforts are under way to improve the teaching of undergraduate biology in the United States. Two broad trends are particularly noteworthy—one emphasizing researchlike laboratory experiences and the other the increased use of computers to supplement classroom and laboratory teaching. Other smaller-scale changes are also being implemented in undergraduate biology courses. Many of these changes are aimed at non-science-majors who need to develop a basic science literacy and an appreciation of modern biology.

Diversity is an overall strength of the U.S. educational syst m. However, many college-level biology faculty members are concerned that the teaching of their discipline is too diverse. Critically, biology lacks a central clearinghouse for evaluating, recognizing, and rapidly distributing outstanding new ideas about teaching as well as new teaching materials that spring up at the hundreds of universities, colleges, community colleges, and other higher education facilities around the country. Hence, many biologists are wondering how promising new software packages or curriculum supplements can best be evaluated and, once accepted, efficiently disseminated to maximize the impact of these innovative developments on undergraduate students.

In courses for biology majors, the main focus of change is the laboratory, and an important secondary focus is the increased use of computers and specialized software. For example, software is being developed to extend the conventional laboratory course, including programs that create "virtual" data sets that simulate what would otherwise require students to do time-consuming, costly repeats of many experiments. Although the current emphasis is on training undergraduate students how to think about biological systems, biology faculty members continue to develop innovative ways for helping biology majors to appreciate the breadth and depth of the field. Here, too, computer-assisted approaches are proving helpful, particularly for students taking courses in esoteric subspecialties of biology.

NSF-sponsored innovations aimed at making biology more interesting and accessible to undergraduate non-science-majors, are taking many directions. Sometimes courses emphasize historical approaches or develop other strategies to make biology more immediately relevant and engaging for such students. For example, some courses

draw attention to human biology or other health and environmental issues and then explain the underlying biology with examples taken from current issues and events. For instance, several new biology courses for nonmajors feature an increased emphasis on computer simulations of population dynamics or large-scale environmental phenomena. In some cases, biology faculty members are developing query-based ways to engage both majors and nonmajors with relatively simple laboratory exercises designed to be unintimidating, effective teaching devices.

In this brief overview of current trends in teaching undergraduate biology, faculty experts outline common problems and some of the new materials being developed for classroom and laboratory use; new strategies to teach biology majors using specialized software or revamped courses that emphasize innovative approaches to the general subject, such as teaching biology through women's health issues; new approaches to teaching nonmajors, including courses that emphasize Darwin or other historical figures and laboratory workshops showing the importance of the experimental approach in biology; and the general value of query-based approaches in biology courses for both majors and nonmajors.

Analysis of Common Problems, Trends in Teaching College Biology

The teaching of undergraduate biology is changing dynamically. Faculty members throughout the United States say their efforts to reform biology curricula would benefit from a forum for exchanging and evaluating new ideas and approaches to teaching courses for both majors and nonmajors. Although a central clearinghouse might best serve this purpose, an annual meeting or regular series of NSF-sponsored workshops at which biologists could discuss such matters would be a useful step toward realizing this concept. In any case, a concerted effort is needed to keep pace with new and changing approaches, particularly with the growing emphasis on the use of computer-based materials to supplement traditional forms of instruction. Moreover, these changes will require enhanced cooperation and understanding between biologists and commercial publishers.

Because biology is such a sprawling field, biology teachers find it difficult to speak with a common voice. Moreover, they have no central group to which they can turn for advice on teaching. Not only is there no central mechanism but also no regular forum for discussing issues such as ideal course content, critical goals, and innovative strategies for teaching biology at the college level.

To a certain extent, the professional societies, such as the American Society for Microbiology and the American Society of Zoologists, have recognized and are trying to fill this gap, but their efforts are fragmentary because they are limited by disciplinary focus. Hence, many college-level biology teachers agree that developing some form of a central clearinghouse to review new publications—such as textbooks and software packages—and to provide information about new approaches to teaching and developing a means for evaluating those approaches, would be welcome.

Although some careful review of new teaching materials is conducted on an ad hoc basis, a central clearinghouse could institute systematic reviews to ensure the consistent high quality of such new materials. It might also help shorten the lag time before teaching innovations are widely adopted. One key to shortening this lag may be to focus initially on the middle tier of institutions that are sympathetic to new teaching approaches rather than on those either bound to traditional approaches or those in the vanguard of change. Moreover, appealing to administrators and even the surrounding community, where appropriate, may be useful in overcoming barriers for such innovations.

In the absence of a central clearinghouse for information, national and regional workshops devoted to educational themes are viewed as helpful devices. Many biologists espouse the notion of a regular conference on biology education, similar to the Gordon Conference—a well-established annual series of week-long meetings where specialists gather to discuss recent scientific developments informally. The liberal use of electronic bulletin boards is also regarded as a useful means for sharing at least the outlines of new programs and curricula. The more traditional journals, although potentially useful for distributing information on such topics, have an important drawback in that not one reaches the full audience biology educators seek.

Expanded cooperation with commercial publishers is viewed as another important means of achieving educational reforms in biology, but there is wariness on both sides of this potential partnership. Innovative tools developed in colleges or universities may have little impact unless they are widely disseminated by the private sector. Yet, some educators resist commercial development. Some biologists developing innovative approaches for teaching general and specialized courses say they are not sure which efforts are ready for wholesale adoption and which require further work. This uncertainty makes some of them reluctant to approach commercial publishers.

Some educators prefer to distribute materials they develop freely—often haphazardly relying on word of mouth to alert others that the material is available—without copyright protection, commercial backing, or expectations of profits. Others simply do not care to take the extra responsibility that goes with commercial development: the refinements, commitment to making revisions, and so forth.

At the same time, many educators question publishers' commitment to innovative teaching approaches because so many biology textbooks look alike. Some educators thus question whether unusual approaches recommended from some academic centers—such as greater reliance on CD-ROM and piecing together materials from separate textbooks—will become acceptable to publishers. Throughout these discussions, educators emphasize the value and importance of peer review for new materials being considered for wide use, and some of them express explicit qualms over the substitution of marketing analysis for genuine peer review.

Meanwhile, growing interest in and increasing reliance on electronic communication and electronic teaching tools are changing the way publishers in the private sector conduct their business. These rapid-fire developments have put publishing in a state of flux that has many publishers perplexed over several attendant issues, such as the disposition of intellectual property rights and the anticipated change in relative roles of electronic versus printed texts over the next decade.

Several new forces are at work, but their impact on the teaching of biology is still uncertain. For instance, some educators are experimenting with exchanges of course materials over the Internet. This communication process easily bypasses traditional commercial publishers but, at least in some cases, may entail forfeiting copyright protection. Publishers are wondering how these changes will affect them if and when they try to incorporate materials into conventional textbooks or other commercially marketable materials for college-level biology courses.

Despite these complications, many academic biologists recognize that publishers in the private sector can add value to good products and certainly help with the dissemination and wide adoption of those products through marketing efforts.

Innovations Aimed Primarily at Biology Majors

The main focus of change for biology majors is the laboratory. Educators generally agree that students benefit greatly from lab work when it fits the research mode. Achieving that goal requires resources for equipment and supplies and puts heavy demands on faculty members for their time and expertise in design of the students' researchlike undertakings. Implementing researchlike approaches in more undergraduate biology lab courses is viewed as a major challenge.

Even when resources for meeting this challenge are relatively plentiful, adjunct materials are helpful, if not vital, for rounding out the learning experience of biology students. For instance, various software packages are being developed or already are being used to broaden students' laboratory experience and make it more researchlike in ways that would otherwise be prohibitively expensive.

(1) **Software that simulates researchlike approach.** Since 1986, a group of faculty members from more than a dozen institutions, primarily in the Midwest, has cooperated in developing and critically reviewing software prototype laboratory simulations—known as BioQUEST—that foster a researchlike approach to learning biology. In a conventional laboratory students might perform one or two good experiments. According to John Jungck of Beloit College, one of the principal developers of this approach, BioQUEST enables students to analyze data as if they had done dozens of such experiments, thereby allowing them to generate hypotheses and think like researchers. "This material is supplementary to wet lab and field experiments, not a replacement," he says.

About a dozen high-quality simulations covering a wide variety of research specialties are now available through BioQUEST, including packages for microbial genetics, axon physiology, fruit fly genetics, and protein sequences. Although the materials were designed primarily for college-level majors, they can be used by nonmajors and even high school students. According to Jungck, these software packages are now used in 50 to 100 colleges and universities.

In a similar but independent effort, Brad Kincaid and Peg Johnson of Mesa Community College and Anton Lawson of Arizona State University are incorporating a computer software package as part of an inquiry-oriented approach to teaching biology. The computer phase of the students' activities reinforces their laboratory exploration of new concepts. Early in the course, the program emphasizes palpable elements of biology rather than its abstract molecular and cellular underpinnings. Computer materials enable students to follow a line of thought from the laboratory work or to examine diagrams and micrographs—readily accessible on-screen—describing a particularly interesting creature in depth, through the review of detailed images or analytic readings on the laboratory's subject.

(2) **Women's health.** Instead of teaching biology with the traditional lectures that focus first on chemistry, cell biology, and basic physiology, the biology faculty at the College of St. Catherine are experimenting with a course based on two themes—the biology of women and women's health and the biology of the environment. The goal is to spark student interest in biology by teaching cellular, molecular, and physiological details in the context of their own bodies and in the larger social frameworks surrounding these issues.

For example, during the first semester, the class spends about 4 weeks studying the menstrual cycle and reproductive biology—covering hormones, cellular changes, reproductive anatomy, and some neurobiology on early nervous system and brain development. Once this segment is complete, the traditional subject of genetics is presented also in terms of sex differences between males and females, inherited tendencies to develop breast, ovarian, or cervical cancer, and so forth. Although this format does not cover as much content as the traditional approach, St. Catherine's Deborah Wygal says it generates greater interest among their students.

The laboratory approach for this course is also nontraditional, with students doing full-semester projects on a general topic that fits with the course theme. For instance, students study vaginal microflora for the first semester and acid rain for the second term. The biggest problem here, and elsewhere, is finding workable group dynamics in a four- or five-person team.

(3) **Invertebrate biology by hypertext.** Although many teachers of introductory courses in biology are moving away from an emphasis on content, some teachers say this option will not work for specialized courses. Regardless of time compression, they still want their students to learn the complete body of material. For one such course in invertebrate zoology, Kerry Clark of the Florida Institute of Technology has been adapting computer hypertext to be an enrichment tool and a "hook" to catch the interests of his students. Often several students hover together at a computer terminal, working cooperatively to master the material. His initial focus on developing the software materials eventually led him to revise and "groom" course lectures, making them compatible with the material used on the computer.

Clark's long-term project is full of gimmicks and humor, including t-shirt contests, computer-generated correct pronunciations of multisyllable species names, software-embedded "treasure hunts" that serve as learning tools, detailed color diagrams and micrographs, and much more. Some 1,500 cards are entered in the system, which he continues to expand and improve. Clark began selling the system at cost in 1993, but he has little interest in marketing the material, saying that "debugging" efforts are more important.

(4) **Learning of advances in particular fields.** For a decade, the zoologists who established "Science as a Way of Knowing" have assembled materials from a symposium they periodically convene into a journal supplement. According to Patricia Morse of Northeastern University this material is then used by teachers to enrich specialized classes, acquainting students with developments in a particular field of interest in biology. The symposia are intended for undergraduate-level students but can be used at the high school and graduate levels. Materials from a recent symposium on biodiversity could be used as a module in an introductory college-level course in biology, Morse notes.

Innovations For Nonmajors

The innovations aimed at making biology more interesting and accessible to nonmajors are highly diverse. There is no obvious way to classify or evaluate these efforts, many of which are brand new and admittedly tentative. Moreover, some efforts are geared to specific student bodies with special needs or interests. The following descriptions provide a representative sampling of approaches being tried around the country.

(1) **Darwinism from varied perspectives.** A group of faculty members from approximately 10 different departments at Baruch College is developing an unusual nonmajors' course focusing on Darwinism. The course typically has 3,000 students per year, many of whom are business and accounting majors. The approach will be to describe how Darwin's findings in natural biology and his theory of evolution have affected far-flung disciplines, including social and political science as well as economics and philosophy.

An important element of this course is the presentation of Darwin as a person, points out John Wahlect of Baruch, one of two biologists who is helping teach the course. The subject matter becomes more interesting and accessible to the students, who see Darwin as an "appealing character," he says. Discussions throughout the course have proved more lively, engaging students who tend not to participate in other settings where biology is taught.

(2) **Historical case studies.** In a similar vein, the biology faculty at Radford College are using a series of historical case studies to present—and "humanize"—important concepts, mainly from 20th-century biology, for nonmajors. The typical course enrolls 2,000 students in sections of 125, according to Radford's Joel Hagen. He points out that the course itself is still in an "experimental state." In particular, he and his colleagues are trying to integrate laboratory exercises with the discussion side of the course. Nonetheless, Hagen says students who were previously "turned off" by science now say they "really like" this approach.

Students discuss the process leading up to a scientific discovery or the development of a particular theory in a broad context. For example, students review the observations, including some of the dead-end paths, that led to the realization early this century that particular chromosomes are the critical sex determinants. They also discuss the fact that a woman, Nettie Stevens, was a key figure in this realization but that she did not receive appropriate credit for her efforts.

(3) **Anthropocentric/anthropologic approach.** A laboratory course for nonmajors at the University of Colorado unintentionally recaptures some of the features of the course on women's health and biology now being taught at the College of St. Catherine. According to Colorado's Darna Dufair, men and women students at the University of Colorado work in groups of four examining questions such as the relationship of muscle size and strength to gender; eye color, ear lobe attachment, tongue dexterity, blood type, and heritable traits; or diet as a way of recognizing biological patterns. Although students may begin with a seemingly simple assignment, they are encouraged to ask more questions about each topic so as to integrate processes with content. In general, Dufair points out that students "really like learning about themselves."

(4) **Laboratory/workshops.** The University of Oregon has developed a series of workshop exercises as part of the laboratory side of the introductory biology course for nonmajors. According to Oregon faculty member Daniel Udovic the workshops rely heavily on computers, but also involve other nontraditional approaches, such as creating posters on public policy issues. The format works well with classes of about 180 students, who meet in smaller discussion groups of 30 and even smaller workshop groups. "We place high value on students' being able to make good decisions on matters pertaining to science," Udovic says. "We want students not just to buy a big textbook but also to look at literature of some sort, even if it's just a weekly news magazine."

One component of the course requires students to manipulate population data by computer, adjusting variables such as life expectancy to visualize their impact on population dynamics. The students make comparisons between different cultures on different continents and are then asked to generate hypotheses and see the effects variables such as infancy death rates have on overall life expectancy. He notes that as the course progresses most students tend to focus on nonenvironmental issues, although some students do perform projects outdoors.

(5) **Laboratory made more accessible and engaging.** Like many conference participants, Jo Handlesman of the University of Wisconsin is concerned about attracting more women and minority students to biology. She and her colleagues use an assortment of props and humorous approaches to overcome students' fears about biology and finding out firsthand how the scientific process works. For instance, students are handed a "pet" microbe at the beginning of the laboratory course and are told they are to learn empirically how to take care of it—keep it alive and in pure culture and determine what its traits are as far as possible. They also work extensively with plants and insects during the course.

(6) **Global perspective.** Thiel College has developed a course in biology that presents a global, ecological perspective. During the year, the course looks broadly at several problems, treating each with a particular global region in mind, such as biodiversity in Brazil or food in India. Laboratory exercises are geared to each unit, so students may grow mung beans to appreciate some of their properties and to value how a specific type of food can meet nutritional needs in a particular geographic and cultural setting.

Special Query-Based Approaches/Evaluative Efforts

Some approaches to learning biology aim to help students discover ideas for themselves instead of the more conventional approach of studying and memorizing what others have uncovered. On occasion, these precepts are further extrapolated to help teachers gain insights into how their new teaching approaches are working and in what areas their students show particular strengths or weaknesses.

For example, Nancy Walker and her colleagues at Baylor University set a theatrical tableau for students in introductory biology labs, using simple props and sparse explanatory material that force students to follow their instincts and curiosity to discover basic principles for themselves. In one such setting, the students are given art reproductions to view—objects to observe through a microscope and describe for a partner to draw without viewing it him or herself—unlabeled jars to sniff, and other objects to touch. After examining the array of objects, the students then describe their experiences and observations with guidance from an instructor. In the process, they come to realize that they can examine their environment with care and intelligence, but often their descriptions may not be altogether objective. The approach "works and can be astonishingly effective," Walker says.

Kathleen Fisher of San Diego State University describes the use of a software package that enables users to assemble ideas and concepts depicting their relationships in networks. Applying this program to exercises where students describe relationships of organ systems in the human body can help to reveal unusual weaknesses in students' backgrounds and, of course, can be used to set misguided ideas straight. Fisher says this commercially available software helps students "integrate ideas."

The growing emphasis on computers and on researchlike laboratory work in biology accentuates an issue—group dynamics among students—and typically represents a bonus from the education reform movement. Most general biology lab courses are organized so that students work in groups of two or four. Often these groupings carry over—sometimes by necessity but often by choice—when students move to the computer segment of their courses. When a course is going well, group dynamics play a valuable and often synergistic role for student participants. Sometimes, however, faculty see that particular groupings do not work well and may even hamper learning, points out Lynda Harding of California State University Fresno. Hence, faculty members need to be prepared to deal adroitly with such problems so that students are not bogged down in these situations.

Much of the time, faculty deal with these problems by relying on intuition and the practical wisdom they have gained from their teaching experience. However, a few small-scale systematic efforts are under way to treat such issues as social science problems and use analytic methods from the social sciences to describe the elements undergirding problematic group dynamics and other factors affecting biology students.

For example, John Wilkes of Worcester Polytechnic Institute is working with biology colleagues to classify students by "cognitive type" as part of an effort to evaluate changes in the biology curriculum. Over a several year period, he finds it helpful and effective to accommodate course changes to the types of learner who may be enrolled. "We can profile a class pretty quickly," he says. No matter how the makeup of the student body shifts in a particular year, it helps to have students from past years to assist groups of students seeing course material for the first time.

As another example of such an assessment, Diane Ebert-May and her colleagues at Northern Arizona University have begun a several year evaluative effort called "A Slice of Life." The laboratory side of the introductory biology course is being divided into two broad segments. In one, students will follow tradition, doing exercises described in a standard laboratory manual. In the other, however, students will ask their own questions and design their own experiments. As this teaching experiment goes forth, Ebert and her colleagues will test the students before the course, during the course, and a year later to see how well members of the two groups do and therefore which of the two laboratory formats works better. Plans call for conducting a similar evaluation for the lecture course.

Conclusion

Biologists involved in reforming undergraduate curricula in this discipline recommend establishing a regular forum under NSF auspices and, ideally, a central clearinghouse for considering and critically evaluating innovative approaches for teaching college biology. Not only is peer review essential, but some other sign of quality—a "seal of approval"—for new materials should be considered.

Biologists also recommend closer cooperation with commercial publishers, particularly as both educatc.s and publishers are faced with fast-paced changes brought about by advances in computers and electronic publishing. Not every useful change should or will be considered for commercial publication. The challenge is to find equitable and efficient ways of using new technologies that promote the rapid dissemination of ideas.

For example, some biologists recommend that NSF establish an electronic bulletin board that can rapidly disseminate small-scale innovative ideas for changing biology courses or, conceivably, for updating popular textbooks. However, once such information is introduced by electronic bulletin boards, what are the next appropriate steps for implementing those recommended changes? Also, how are intellectual property rights, including commercial copyright protection, affected by such a system? Because such questions need to be fully addressed, both biologists and publishers recommend that NSF and other federal agencies help air these issues so that they can be fully evaluated.

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Chemistry Education: Innovations and Dissemination

T. L. Nally

Introduction

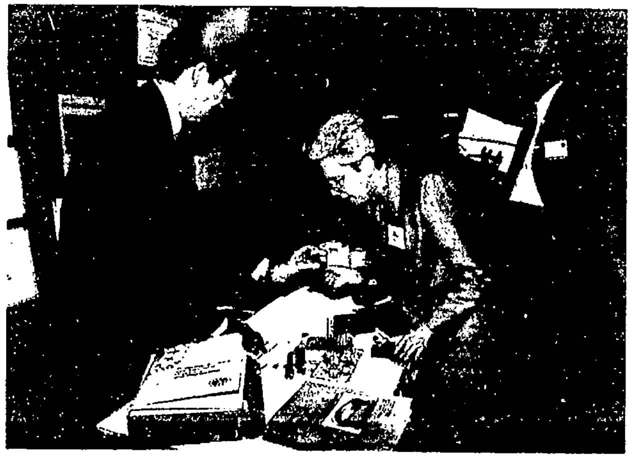
The call for accountability in federally funded science fuels and coincides with a reform movement in undergraduate chemistry education. An openness to change is seen on many fronts. For example, in the private sector, industry has articulated a need for a differently prepared chemistry graduate and seeks a chemist with a broad base of skills. Industry needs graduates with critical thinking and problem-solving abilities who are also able to work on multidisciplinary teams within a diverse workplace and a global context.

In the academic sector, administrators and chemistry faculty are altering the undergraduate curriculum and how it is taught. Also driving the need for a metamorphosis in the curriculum are changing demographics, levels of student preparedness, and mandates about quality raised by students and parents. Commercial publishers are looking for fresh approaches in chemistry. New technologies and their potential for attracting students to the school are significant incentives for institutional modifications in chemistry. The prestigious Gordon Conferences recently have devoted a conference to improving chemistry education. Academia is reexamining the definition of scholarship and expanding it to legitimate chemistry's multiple missions to the discipline, the profession, and those in the public who do not understand chemistry. To be a vitally functioning chemistry department, faculty must nurture all the activities supporting the missions of chemistry, including teaching and outreach.

The National Science Foundation (NSF) has been instrumental in promoting change in undergraduate chemistry education. Through NSF's investments in educational research, administered by the Division of Undergraduate Education (DUE), transformation and revitalization are occurring in the following three areas:

(1) **Technologies**, such as communication networks, computers, and multimedia, to enhance current teaching approaches and to alter the methods used in the classroom and laboratory;

(2) **Content**, which includes new subjects, topic-oriented curricular materials to introduce chemical concepts on a need-to-know basis, and interdisciplinary courses; and



(3) **Pedagogy**, to engage students actively in the learning process through various techniques, such as cooperative learning, guided inquiry experiments, problem solving, and interactive lectures.

Innovations in these areas, funded by DUE and other federal agencies, were highlighted at the Project Impact conference. This chapter reports on some of the changes that the federal government is supporting in chemistry education, the growth areas for curriculum reform, and the important dissemination and implementation strategies that may effect change. This chapter is written to assist future chemistry education grantees in developing and disseminating their research. It also offers policy options for consideration in enhancing dissemination and increasing the value-added return on the federal educational research investments.

Technologies and Dissemination Strategies that Work

Computers and related technology strongly influence chemistry curriculum development, and the use of these technologies will increase in the years to come. Many reformers can envision an undergraduate chemistry education in which a computer link between students and teachers may deemphasize extensive lectures in favor of discovering chemical principles using software tools.

Computers have been used for many years to acquire and analyze data in the laboratory. Many academics have held that, since industries use these techniques, students should be trained on computers, appropriate software, and computer-interfaced equipment. **Kutztown University**[1] has developed the LIMSport System, providing data acquisition commands for Lotus 1-2-3 so that the spreadsheet can be used for both data acquisition and data reduction in general chemistry and all other courses that follow. Use of this standard spreadsheet prepares students for the workplace. Moreover, use of a standard software increases the dissemination potential as it makes the system transportable and resistant to obsolescence, two factors that are barriers to bringing information technologies to a profitable market.

East Carolina University[2] also is developing its software for computer-aided chemistry experiments, which is sellable in a larger market. The software, designed for students with visual impairments, will run on a personal computer equipped with low-cost and easily accessible, adapted outputs (e.g., synthetic speech, electronic music, enlarged text, and graphics). The software will be usable at any educational level at which instrumental measurements are performed, and it should be readily adaptable to disciplines other than chemistry. Using this type of software tool to reach a precollege market is particularly critical for attracting and retaining in science physically disabled students, who otherwise might be counseled to avoid science because of inaccessibility to performing in experimental disciplines. Using this software to reach niches outside the undergraduate chemistry market makes the innovation a more financially viable proposition for commercial investors.

Tutorial software holds the promise of offering new approaches to chemistry, including providing new methods of investigating chemical processes and allowing teachers to ask more meaningful questions of the student. **California State University, Fullerton**[3] is developing interactive instructional materials to enhance the comprehension of molecular processes covered in beginning chemistry courses. With this software, which correlates macroscopic, molecular, mathematical, and graphical representations of chemical phenomena, students can visualize structures and chemical processes and draw more substantive conclusions than in the past when line drawings were used. This software has commercial potential because it can be used in the lecture as well as by students for tutorials. The material is not boring to the student. It is user-friendly and provides a good, uncluttered visual.

Publishers caution, however, that software cannot be just a virtuoso performance; rather, the material must be meaningful. The **Iowa State University of Science and Technology**[4] is developing an interactive, multimedia software program for exploring electrochemical cells. The software is being developed based on an analysis of students' errors and misconceptions on exam problems, interview tasks, and laboratory work. Data also are being compiled and analyzed to determine how the use of the software affects students' conceptual and mathematical solutions to electrochemical cell exam problems, as well as how it has improved the quality of instruction in lectures, laboratory activities, recitation sections, and resource rooms. Evaluation regarding the quality and effectiveness of the software is an important element for a prospectus given to potential publishers and potential users of the product.

Innovations are being created that are very good for one or two lectures, but a small piece of a course in the absence of other compatible modules may not provide enough incentive for a school to invest in the resource. Software that is comprehensive and integral to the curriculum as a whole has the possibility of a large enough market to sustain development and marketing costs. The **Montana State University**[5] CCLI Initiative—Computers in Chemistry Laboratory Instruction—is overcoming the barrier of incompleteness with a consortium of 11 colleges and universities working to develop a laboratory curriculum using computers. Knitting together innovations from diverse sources also may help to ensure that products will be useful for many markets, such as 2- and 4-year colleges, research universities, and predominantly minority institutions.

Another method of building a comprehensive software program is to work with a publisher as a partner early in development. Publishers are beginning to allocate substantial investments particularly in CD-ROM technology, which is viewed as having the power, flexibility, and storage capabilities to enable students to approach subjects on a more individual basis than do textbooks. In addition to assisting in development, the publisher may have the wherewithal to pull together a package of software and hardware in order to promote adoption to users who otherwise may not be able to purchase equipment and maintain it. Also, the publisher may be an active partner in reviewing the innovation and in conducting the necessary field tests of the developing product, if these steps were not already taken in building the prospectus.

Publishers are seeking pedagogically useful software that is interactive. ChemScholar, developed by the **University of Rhode Island**,[6] is a unique program for self-instruction that provides guided practice in solving problems typically encountered throughout a first-year chemistry course. ChemScholar gives the student a set of easy-to-use tools (e.g., arithmetic expression tool, chemical equation tool, and electron configuration tool) and chemical reference tools (e.g., constants, periodic table, and unit conversions) to help in solving both simple and complex problems. This individually paced program has a tutor that monitors the student's work and offers hints and immediate feedback appropriate to each student's rate of progress and problem-solving style. ChemScholar has the potential to fit several niches because it is flexible, which is a critical component in promoting commercial viability. This software is designed to complement the way instructors wish to teach. Through an accompanying program called ChemScholar Instructor, the teacher can customize ChemScholar's syllabus of chapters and topics, edit new and existing problems, and tailor the program to any textbook, syllabus, or need of a student. Flexibility built into an innovation relinquishes insistence on epistemological alignment and, instead, gives the user ownership over the product as the user integrates the product into each unique need and practice.

Other Technology Dissemination Issues

Several other issues need to be examined in optimizing dissemination of information technology innovations. Considerable discussion evolves around the issue of consistency in platforms, establishment of basic protocols for all software, and compatibility with hardware. In studying innovations, some thinkers believe that market forces will allow good products to catch on. The advice is to continue development, as market forces also will shape ways in which innovations will be used once developed. For implementation potential to be maximized, it is important to build from the start the potential for upgrades. By the time software is brought to the market, it is highly likely that the hardware platform already has evolved from the point at which the initial software development began.

Cost considerations inhibit implementation of computing innovations into the undergraduate curriculum. Some schools believe that they cannot afford to not promote the use of computers in education, as students are choosing colleges where use of technology is integral to the coursework. But for those institutions where funds are not readily available for equipment purchases and maintenance, there is a reluctance to make the investment. One challenge to implementation is to demonstrate that computers and related technologies are flexible and have value-added qualities to the extent that they can be used in libraries, among many disciplines, and in many ways in the curriculum.

The institutionalization of an innovation is facilitated over time when customer and technical support systems are available. Support systems (e.g., hotlines, short courses and teacher workshops, and user networks) provided by a publisher and focused on the user/customer accept feedback with the intent that specifications of the product must change with usage. Support systems improve the potential for long-term organizational use by sustaining the interaction between the innovator and the user, thus allowing change to be phased in as the user reconfigures the new knowledge and practices for unique needs and conditions.

Some controversy exists as to the benefits of product distribution over computer networks such as Internet. The possibility of copyright infringement exists, and computer networks are not recognized as an ideal medium for conveying innovations. Users rarely adopt an innovation solely from reading about it. Typically, the strategies that are most effective in implementation are those involving personal contact (e.g., workshops, hotlines, and presentations). Computer networks are seen as valuable technologies for sharing and accessing information and for promoting collaboration among faculty and students.

Course Content and Dissemination Strategies that Work

An important trend in undergraduate chemistry curriculum reform revolves around course content. Innovators in this area are working to develop materials that

- Incorporate leading-edge research into the curriculum, to stimulate student interest and prepare students better for the workplace;
- Focus on applications, to establish the fundamental interconnections and dialectic relationships in chemistry, among chemistry and other disciplines, and within the societal context;
- Use current knowledge of cognitive psychology and learning theory to shape curricula.

James Madison University[7] has developed lecture notes and 18 laboratory experiments on lasers and their applications to solving chemical problems in all branches of chemistry. The lecture notes were designed for a joint chemistry/physics course and several of the experiments can be used in other laboratory courses, including physical chemistry, instrumental analysis, and biochemistry. Adaptability in applying these materials to diverse courses increases the potential for implementation of the innovation. The materials have received special attention, not only because they center on front-edge innovations but because several of the experiments can be conducted at a low cost and set up easily. Innovations such as materials are prime candidates for dissemination as they address the current challenge of limited academic budgets by demonstrating how chemistry can be taught better and cheaper.

Implementing substantive change in the chemistry curriculum presents the challenge of choosing which concepts to use and which to leave out. The **University of Wisconsin—Madison**[8] initiated its project of a materials-oriented general chemistry course by holding a meeting with several leading researchers in materials science. Bringing thought-provoking research into the curriculum lends credibility to educational innovation as a scholarly activity and makes the materials developed more attractive for adoption. Incorporating solids, including metals, semiconductors, superconductors, and minerals, into the introductory chemistry course makes chemical concepts more relevant to the real world and visually accessible to the student. The likelihood of faculty using this material is increased because the project contains a comprehensive package of instructional materials comprising a book with text, exercises, over 50 demonstrations and 15 lab experiments, an optical transformation kit, and a solid-state model kit. The package also includes a matrix identifying in which chapter of the book the chemical concepts are covered. Matrices are important tools to help teachers see the connections between the innovative curriculum and the traditional course materials.

The Wisconsin instructional materials are available at affordable prices because they are provided through educational, nonprofit organizations—viable alternatives to the commercial publisher. The kits are supplied by the Institute for Chemical Education and the book, *Teaching General Chemistry: A Materials Science Companion*, is published by the American Chemical Society (ACS). The ACS' Committee on Education provided funding for the initial meeting with the leading researchers in the field and is featuring this materials science approach in a satellite TV conference for teachers during National Chemistry Week 1994. A videotape of the conference, which will serve to disseminate the project further, will be available through the ACS. Leveraging the resources and prestige of a cognizant professional society potentially has substantive payoffs for disseminating a new product.

Learning theory supports the idea that concepts are learned in problem contexts with topics that are familiar to students. The **University of Rochester**[9] has developed a new freshman chemistry course that uses topics or themes as the conduit for introducing important chemical concepts, which emerge on a need-to-know basis. The course is an alternative to traditional general chemistry courses, which discuss concepts and provide topics as an adjunct to illustrate individual concepts. The University of Rochester's course uses current issues and problems in energy and the environment, which are the unifying themes that drive the science content, including the weekly laboratory.

The University of Rochester developed the course in response to student need. Experiencing science as it is found in the world motivated students to learn and transcend the discipline's artificial boundaries. The student learns about relationships and interface, interdependence and interconnectedness. A course on the history of science and the development of scientific thought reinforces the limits of uncertainty within the field of science. The chemistry curriculum package also comes with a writing course offered by the Philosophy Department. The course reinforces analytical skills and constructing an argument. Tying the chemistry course in to courses in other departments ensures the permanency of the reform.

"Light, Vision, and Understanding," developed at **Worcester Polytechnic Institute**,[10] also uses a contextual approach to understanding science and its limits. By using themes to make connections among various science and humanistic disciplines, the student builds a foundation for reexamining the fundamentals of causality, the measures of scientific validity, and the basic tenets of science methodology. This 1-semester junior–senior seminar, which includes experiments for science, engineering, and management students, was designed in response the typically superficial understanding science and engineering students have of how science is intertwined with, and shaped by, culture.

The Worcester Polytechnic Institute's course is provocative and demands a high level of intellectual activity. In effect, it acknowledges that science teaching is not a neutral conveyance of thought. Rather, teaching creates a worldview that is a filtering system, internalizing a habit of thought that tacitly categorizes, abstracts, and assumes relationships. Traditional science courses do not explore the unarticulated assumptions (e.g., positivism, reductionism, and objectivism) that underlie Occidental science and its scientific models. The Worcester Polytechnic approach examines the explanatory powers of the Newtonian–Cartesian paradigm of science, which has been challenged in this century by theories of chaos, relativity, quantum phenomena, and quantum field phenomena. Within this transforming scientific context, what we "know" of matter is replaced by concepts of organization, complexity, and information. Innovative courses such as "Light, Vision, and Understanding" may offer important growth areas for chemistry curriculum reform in preparing students with critical thinking skills for an emerging worldview, for continued advances in science and technology fields, and for work in a diverse and global context.

Carroll College[11] uses the topic-oriented approach in the laboratory component of its introductory chemistry course. The approach prepares students for the workplace through experiments that involve chemical problems extracted from local industrial and community settings. The existing experiments remain, but the students are asked to imagine the work as a step in an interesting application of chemistry, with consideration of additional real constraints such as safety, regulations, economics, and time efficiency. A 1993 study from the ACS' Committee on Professional Training detected, from 1988–1992, a steady growth in chemistry course enrollments, resulting in an approximate 3.5-percent nationwide increase in chemical sciences majors. Anecdotal data from other sources seem to indicate that two factors contributing to gains in matriculation are the student perception that chemistry is integral to problem-solving and the student desire to contribute to solutions to societal problems. Carroll College's "Helping People Through Chemistry" laboratory course is drawing an enthusiastic response from students and motivating them to study chemistry further.

This project is attractive for the teacher because it adapts easily to any local setting and the time needed to modify the traditional laboratory course is not burdensome. The likelihood of adopting this innovation is increased with its readily accessible instructional materials.

Since the topic-oriented approach is a substantive change from the current curriculum, its acceptance requires mixed implementation strategies. **Prince George's Community College**[12] developed a course that relates chemistry to biology and geography by studying it within the context of the Chesapeake Bay ecology. The project included a 6-day interactive workshop for 24 community college and small college faculty from states surrounding the Bay's watershed. The workshop was held on-site at the University of Maryland's Chesapeake Biological Laboratory, where faculty constructed an understanding of the material through an active learning process. The workshop was supplemented with a rich assortment of media for dissemination. These materials included a set of slides (with narration), a two-part videotape, a videoconference, a photography exhibit, and a book. With the development of a follow-up book, the potential for product dissemination expanded within a localized support network. Working on innovations with a network, rather than in isolation, is key to implementation.

The context-oriented way of delivering chemical concepts is also an effective and attractive approach to teaching non-science-majors, who constitute another audience of chemistry's mission. Examining the interaction of chemistry with the world demands that each student contribute the knowledge and sophistication of analysis indicative of her or his own field of study, thus making the learning process more meaningful for each student. **Columbia College's**[13] "From Ozone to Oil Spills: Chemistry, the Environment, and You" provides various mechanisms for students to contribute their knowledge. Students incorporate skills representative of their majors, interests, and cultural backgrounds in course projects, such as videotapes, magazine articles, theater scripts, paintings, posters, and sculptures. Through these activities, students are valued for the wide range of knowledge they bring to the course, and each student has an equal chance to participate regardless of science proficiency or personality. The course was developed as a collaborative effort to produce a model program adaptable for any institution, with students of diverse academic, economic, and cultural backgrounds. The flexibility of the topic-oriented approach provides extended access to students of all backgrounds and life experiences.

"Chemistry of Art," developed at **Brandeis University**,[14] is another example of using a topic-oriented approach for non-science-majors to overcome the tendency to compartmentalize knowledge. The course essentially is a materials science program applied to the fabrication, examination, conservation, and authentication of artifacts. The project is seeking to develop a text, successful laboratory experiments introducing chemical microscopy for pigment and fiber characterization, and a CD-ROM with the scientific and conservation data needed to investigate a famous and problematic artwork. Dissemination of the current project's product has been through distribution of course materials (e.g., video bibliographies and laboratory manuals) and presentations at various symposia. Another strategy that this project has used for dissemination is building a network by championing users through providing on-site presentations at other chemistry departments. Oftentimes changes in the curriculum can be catalyzed and legitimated when a party from outside the department is invited to offer pertinent expertise.

Pedagogy and Dissemination Strategies that Work

The desire to improve student learning has also found a focus in modifying pedagogy. Pedagogy is perhaps the area in curriculum reform that is the most resistant to change. Transforming pedagogy involves redefining the instructional paradigm, the role of the student, and the identity of the teacher.

The notion of teaching as a transference of knowledge to the passive, but receptive, student is being relinquished. In its place is a growing acceptance of a constructivist epistemology that involves the student as an active participant in the process of understanding. This process is itself one which, in effect, requires the knower and the known to undergo transformation. In this new context, the student—not the teacher—is insinuated to the center of learning. The student is believed to learn chemistry best when actively engaged with the material and with the process materialized. This approach makes education a lively dialectic dedicated to the authority of the learner to interact, articulate reality, and interpret events, therein giving the experience meaning. It is a radically empirical process addressing the totality of the experience.

Role-playing and discovery are two techniques being used as innovative instructional strategies. **Williams College**[15] uses these methods in a forensic science course for non-science-majors. The course teaches the principles of basic, analytical, and organic chemistry, as well as biochemistry, toxicology, pharmacology, and serology, by using the fascination with crime detection. The laboratory program involves processing a crime scene and analyzing the collected evidence in the "crime lab" (e.g., high-performance liquid chromatography separation and identification of anabolic steroids from urine of suspects, FT–infrared identification of drugs in samples confiscated at drug busts, and fabric identification by differential staining and infrared analysis).

Through role-playing and discovery techniques, students in this course are motivated to learn and, more importantly, to develop critical thinking skills, such as framing a problem and using deductive and inductive reasoning for solution identification. Instituting any new type of teaching has its difficulties. Since chemistry faculty in general are not as proprietary with non-science-majors' courses, there may be more latitude for taking the necessary risks to develop and refine new pedagogy in these classes. Moreover, the outcomes of the innovations in the non-science-majors' courses may prove to be incentives for extending the new instructional strategies to the chemistry curriculum for science majors.

Implementation of innovations is enhanced when research and development in pedagogy are viewed as a scholarly activity. Dissemination of results of the innovations and transportability of the products are recognized as key components of scholarship. The importance of scholarship is measured by peer-reviewed publications, recognition by colleagues (e.g., invited presentations at colloquia and meetings), and financial support. The **State University of New York—Stony Brook**[16] uses all these legitimated means of disseminating scholarship to strengthen the credibility of, and to institutionalize, the innovations developed. The project addresses improving student attitudes toward science, chemistry in particular. The project involves a "Reduce Your Lab Anxiety" workshop in which science students learn that laboratory techniques are not esoteric rituals, but are closely related to everyday skills. The project also includes a 1-semester elementary "Chemistry in Practice" laboratory course. In this course, students function as scientists discovering for themselves how scientists acquire information through experimentation and recognizing that knowledge of chemistry is not simply memorizing facts, but is knowing how facts are uncovered. To disseminate these novel approaches, the PI has worked with two commercial publishers to produce a manual and a module of experiments. The module format advances the possibility of implementation as it inherently provides flexibility to fit a number of niches, as well as fit the constructivist view of how a product is adopted. Papers about the project also have been published in peer-reviewed journals and have been presented at professional society meetings.

Another effective dissemination strategy for a new teaching method is the use of videotape, such as that presented by **The City College of the City University of New York.**[17] The videotape captured the cooperative learning technique that City College, a predominantly minority institution, has explored in its general chemistry course. The videotape also shows the level of student interest in, and the high degree of student engagement in, the learning process. Once a week the class breaks up into workshops in which small groups of students are guided by other students to solve problems collaboratively. Successes through this alternative teaching and learning process have steered City College to employ student-led problem-solving workshops in other chemistry courses. Surveys of students have shown strong approval of the peer problem-solving workshops. They also show improvement in social skills and community building, development of the notion that science is a social enterprise, and recognition of group work as an effective method of problem solving. Cooperative learning techniques seem to be effective instructional methods for the typically underrepresented student in science and, as such, hold high growth potential for further research and development.

Evaluation of pedagogy and student assessment are critical to the innovation, dissemination, and implementation processes. Measurements of efficacy and effectiveness must be rethought in order to develop appropriate instruments for the pedagogical processes employed. Student assessment may be more relevant if desired student outcomes are measured. For example, standardized tests to assess individual accomplishment in a competitive environment may not be transportable to a cooperative learning environment in which the abilities to work with groups and to solve problems are important skills to develop for the modern chemical professional.

The **College-University Resource Institute, Inc.**[18] project has strengthened its program evaluation and potential applicability to diverse institutions by testing its newly developed instructional materials at seven institutions and by adding nine more colleges and universities for field testing. The project involves the development of hands-on, open-ended, collaborative modules for restructuring the general chemistry curriculum. These societal-issues-based experiments also may be adapted for environmental chemistry, upper-division integrated laboratories, or other upper-level courses.

Successful collaborative learning is more difficult and time-consuming than traditional courses. Each experiment in this project requires 2 to 4 weeks to guide students through discovery. Since each experiment can proceed in several directions, this project is appealing because it provides the necessary documentation for the instructor to handle the many directions and extend the experiments in other areas. Moreover, the instructional materials are comprehensive and, therefore, more marketable. The materials suggest use of available instruments from G-C to FT-IR to AA, as well as other options. Sources for specific equipment, amounts of chemicals, safety instructions, use of computers to treat data, and suggestions for spreadsheet display of data from a whole class are included in the materials. This project provides a how-to in maintaining a laboratory notebook and in writing laboratories as a team and in an unstructured format in order to assist the student through the discovery process.

Clemson University[19] has also developed cooperative chemistry laboratories in general chemistry. This project, called SuperChemLab, presents a viable plan for large enrollment (i.e., 1,500 students) courses. Students work in groups to apply their problem-solving skills to projects that approximate the research process. SuperChemLab is designed for students to learn techniques not as ends in themselves, but as means to ends. SuperChemLab guides students through the thought processes and procedures necessary for students to devise their own experiments and grow into complex analyses. Students obtain information about laboratory techniques and their applications by accessing a HyperCard stack. They use written and oral communication skills to plan, critique, and evaluate their experiments.

Although there is less emphasis on facts and theories in a cooperative learning course and more emphasis on ways of knowing and tools of learning, students have more sophisticated experiences with science. Their abilities to retrieve and evaluate information, to work usefully with facts, and to think creatively and independently are increased. Students in SuperChemLab are encouraged to accept responsibility for self-instruction and to collaborate productively among team members. To make cooperative learning successful, the instructor must change his or her role to that of designer and coach. The instructor must narrow the concepts covered in favor of identifying ways to engage all students in the learning process and in building problem-solving skills—always listening and meeting students where they are found.

Other Pedagogy Dissemination Issues

Identifying a suitable publisher requires extensive discussion in order to determine whether the goals and plans of the publisher are compatible with the innovator's goals and expectations. Dissemination strategies (e.g., teacher workshops, booths at ACS meetings, videotapes, and marketing brochures), technical support systems (e.g., hotlines and newsletters), evaluation and assessment, and future revisions are all important topics for discussion with a publisher. The innovator should provide necessary permissions for intellectual property reproduced in the new product. A demonstration of product quality and effectiveness, perhaps through field test data, shoulu be presented by the innovator to the publisher.

Innovations by themselves will not produce long-lasting change in the curriculum. An infrastructure, including a broad base of support, needs to be constructed in order to maintain permanent reform. Inviting senior staff and key people into the development process creates potential for adoption. Distributing to colleagues the outcomes of the innovations in the classroom builds a database of persuasive information. Holding seminars or workshops on the project and inviting users or expert guest speakers also increase the project's visibility and enable other faculty to exchange ideas about the material. The implementation phase is as critical as the development phase.

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Education Projects in Computer Science

A. Joe Turner

Introduction

Note: The terms "computing" and "computer science" refer to the discipline of computing. The discussion generally applies to such degree programs as "computer science," "computer engineering," "information systems," "information science," and others.

Programs in computing differ from programs in most other disciplines in that they are relatively young. Because computing is so young and has changed so rapidly, computing curricula have changed continuously since their introduction approximately 30 years ago. Even though efforts in curriculum development have always been high, there has been a significant increase during the past 5 years or so. There has also been an increasing focus on methods of instruction, rather than focusing primarily on curriculum content and sequencing.

Many of the most significant projects at the Project Impact conference were made possible by support from the National Science Foundation's (NSF) Division of Undergraduate Education (DUE). These projects are the primary focus of this report. Generally the projects supported by DUE are either curriculum development efforts, supported through the Undergraduate Course and Curriculum Development (UCCD) or Instrumentation and Laboratory Improvement (ILI) programs, or faculty development efforts, supported through the Undergraduate Faculty Enhancement (UFE) program. Curriculum development projects generally either (1) develop, implement, test, and disseminate new curriculum material, organization, or delivery or (2) develop and disseminate materials to support generally accepted curriculum enhancements. Faculty development projects provide workshops or other mechanisms to familiarize faculty with new curriculum content or instructional methods.

Trends in Computing Curriculum Development

Most curriculum development projects in computer science can be categorized as follows:

(1) **Modifications to core courses.** These projects aim to improve the introductory (first three to five) computing courses. Most of these projects can be further classified as one of:

- Adding breadth to the core courses. Two curriculum reports, "Computing as a Discipline" (Denning *et al.*, 1989) and "Computing Curricula 1991" (Tucker *et al.*, 1991), suggest that education in computing could be improved by providing students with an overview of the discipline in the first few courses, similar to what is usually done in an introductory course sequence in, for example, physics. The objective is for students to gain a better understanding of, and appreciation for, the discipline of computing after the first three or four courses than was provided by previous programs.
- Structuring the introductory courses around current state-of-the-art practices. Traditionally, computing education has been structured along the lines of other sciences and engineering: first establish basic foundations and then develop practical capabilities. Some projects are investigating the practicality and effectiveness of providing basic foundations within a context of accepted state-of-the-art practices.

(2) **Addition of structured labs to computing courses.** This has also been suggested by the above-mentioned curriculum reports. The idea is to have students perform activities in a structured, supervised laboratory setting (often called a "closed lab") to help them learn skills and understand concepts more efficiently and effectively.

(3) **Development of advanced course material.** This category mostly involves coursework in new areas not generally found in computing programs or new approaches to existing course material.

Some more recent projects also address pedagogical issues, such as collaborative learning and the use of technology in improving instruction and learning. Given the effort required just to keep course material current, it is especially impressive to observe the level of additional interest and effort by so many computing faculty to develop and test curricular innovations that go well beyond what is required to update course material.

NSF-Supported Projects

Many beneficial education projects in computing have been completed or are underway because of NSF support. Some examples of NSF-supported projects are given in this section.

Several projects focus on introductory courses, not only for majors in computing, but also elective courses for students in other majors. For example, the Duke University project "Visualizing Computation: An Automated Tutor," directed by Alan Biermann, is concerned with a general education course in computing for any major. This project has developed a very impressive computer-based system that illustrates relationships among a program in a language such as Pascal, a machine language equivalent of the program, and circuitry that allows a computer to perform a machine language instruction. The process of translating (compiling) from Pascal to machine (assembly) language is also illustrated, as well as the process for executing a machine language program. The system very effectively illustrates rather complex ideas and relationships that are often difficult to teach, and its use should be a big help to students in understanding many fundamental concepts of computers.

An early project that incorporated breadth and closed labs into its introductory courses was the project "Adding Breadth and Laboratories to the Introductory Computer Science Courses" at Bowdoin College, Clemson University, and the University of Connecticut. Project leaders at the three institutions developed and tested course materials and labs in three different academic contexts—liberal arts college, college of sciences, and college of engineering. This project followed the basic suggestions of the curriculum reports previously referenced. Good experience has been gained as to reasonable and effective approaches for incorporating breadth and laboratories into introductory courses, and the project reports and course materials should assist curriculum developers at other institutions. Summer workshops were successful in involving faculty from 30 other institutions, and workshop participants provided valuable feedback on project activities, as well as contributed results from their own programs.

An alternative approach to incorporating breadth into introductory courses is being investigated in "Development of Science of Computing Courses 1 and 2" at the State University of New York at Geneseo, directed by Doug Baldwin, Johannes Koomen, and Greg Scragg. The investigators' approach to breadth is to incorporate three "methods of inquiry" (design, theory, and empirical analysis) into introductory courses in such a way that almost every topic includes components based on each of the three methods. The investigators are also developing closed labs to support the courses. In addition a collection of "gateway labs" have been developed to provide interactive computer-based tutorials on fundamental concepts.

Still another approach in incorporating breadth into the curriculum is under way at Louisiana Tech. The project "An Interdisciplinary, Laboratory-Oriented Course for Computer-Based Problem Solving," directed by Barry Kurtz, is an effort to develop an introductory course that provides students with an introduction to a broad range of abstract concepts and practical capabilities in computer science. The project is also heavily oriented toward the development of computer-based laboratory demonstrations and exercises to help students learn the concepts. The software that supports the labs makes excellent use of graphics to illustrate concepts and facilitate interaction. The software is being developed for common computing platforms.

As anyone who has attempted the development of laboratories for introductory computing courses knows, the greatest effort required is the development of supporting software. The project "A Dynamic Computer Science Laboratory," directed by Rockford Ross at Montana State University, is developing software to support program animation, algorithm animation, and concept animation. The program animation component, which is almost complete, provides execution animation for Pascal programs and includes the ability for reverse execution. Tools such as this facilitate the development of a variety of labs that teach skills and concepts. The objective of the project is to provide a tool to assist in developing labs more easily.

Three NSF-supported projects aim to restructure the introductory courses around alternative themes. One very extensive project is "Development of a Set of 'Closed Laboratories' for an Undergraduate Computer Science Curriculum," directed by William Wulf at the University of Virginia. This project is developing and evaluating a new curriculum based on current state-of-the-art software development practices with the intention of making the curriculum exportable to other computing programs. The curriculum is focused on laboratories, and the lecture materials primarily support the laboratories, rather than the other way around. The results at the midpoint of the project indicate a significant improvement in the capabilities of the students who complete the new courses and in their attitudes toward the program. The results of this project could significantly affect the orientation of computer science programs in the future.

A smaller project with objectives similar to the University of Virginia project is "Incorporating Object-Oriented Concepts in the Introductory Computer Science Sequence" at Temple University. The directors of this project, Frank Friedman and Rajiv Tewari, are restructuring three of their introductory courses so that they emphasize object-oriented methodology and concepts beginning with the first course. A textbook has been written to support the first course, and class libraries and application frameworks are being developed to support object-oriented software development in all courses. Object-oriented methodology is generally recognized as the most promising general approach to software development, but object-oriented concepts are often not introduced until later courses. In fact, many educators are skeptical as to whether the early introduction of extensive material on object-oriented methodology is beneficial to students. This project should provide results that will help determine whether useful concepts can be introduced effectively and beneficially early in the curriculum.

A quite different approach is "Restructuring and Coordinating the Introductory Courses for Computer Science and Mathematics Majors," directed by Juris Reinfelds at New Mexico State University. The objective of this project is the restructuring of the first two courses around logic programming, functional programming, and imperative programming as a seamless sequence of problem-solving concepts and methods. A paperless hypertext-based software system to support laboratories is also under development.

The need to try different approaches to curriculum content and laboratories was emphasized in the most recent comprehensive curriculum recommendations for programs in computing—"Computing Curricula 1991." It is important that new ideas be tested on a small scale before they are implemented in a broad range of programs. Results from the diverse projects mentioned above will be valuable in determining how well various alternatives provide improvement in computing curricula.

Not all NSF-supported projects in computing are concerned with the introductory courses, even though the introductory courses have been a special focus for DUE. For example, the project "Using a Computer-Supported Cooperative Problem Solving Environment To Teach Undergraduate Computer Science Students Cooperative Skills and Requirements Elicitation" at the University of North Texas seeks to teach programmers how to work together, which is an important topic of substantial current interest. This project, directed by Kathleen Swigger, has developed a computer-supported cooperative environment designed to facilitate identifying the requirements of software development. Students use the software system to develop requirements specification using a cooperative elicitation approach.

One objective of most curriculum projects is the development of materials and ideas that can be transported to other programs. One useful approach to facilitate portability is to have one or more collaborators at other institutions test the project results. Although this approach can be effective, it usually increases substantially the level of effort for the investigators. Collaboration should be carefully planned and arranged prior to the start of a project.

With the rapid changes in course content, curriculum organization, and instructional delivery methods, it is important that computing instructors have a way to learn new material and teaching methods efficiently. DUE's Undergraduate Faculty Enhancement program sponsors many projects that are intended for this purpose. Most of these projects conduct summer workshops for faculty to learn about new subject material, curriculum developments, or teaching methods.

Two UFE projects focused on teaching parallel computation, an increasingly important, but relatively new, area of computing. Workshops designed to help faculty gain proficiency in teaching parallel computation and to develop materials to support the teaching of parallel computation have been conducted by Janet Hartman, at Illinois State University, and by Chris Nevison, at Colgate University.

Other workshops designed to improve teaching capabilities are those conducted by Herman Hughes, of Michigan State University, and Fred Kollett, of Wheaton College. Hughes' workshops addressed the important area of computer networks, while Kollett's provided instruction in the use of four paradigms—functional, logic, object-oriented, and procedural—in the undergraduate curriculum.

Workshops conducted by Scott Owen of Georgia State University were designed to update faculty on current concepts and methods in the more traditional area of graphics. This project is noteworthy not only for its success in introducing new subject material to faculty, but also for its extensive use of a hypertext system for instructional delivery as well as for student investigation. The hypertext system and instructional approach are available to others who wish to use them.

Finally, new approaches to curriculum organization and delivery also require faculty development. One such project at Clemson University conducted workshops to prepare faculty to create effective labs for use in various courses. The inclusion of laboratories in computing courses, especially introductory courses, has generally become accepted as beneficial, but because the use of closed labs is new in computing courses, faculty often have difficulty in designing effective labs. The objective of these workshops was to help faculty learn how to develop labs by sharing their experiences and working with other faculty who have developed successful labs.

A general observation made by PIs is that it is important to have at least one follow-up workshop with the original workshop participants. This provides an opportunity for the participants to share their experiences and have the concepts that were presented at the workshop reinforced and extended.

Dissemination of Project Results

Dissemination methods currently include:

- Repositories accessible via the Internet,
- Workshops to review project results and to provide peer feedback,
- Presentations at conferences and at other institutions,
- Publication of papers and course materials,
- Publication of textbooks.

Almost all projects use more than one of these methods, and some use all of them.

The trend is clearly toward the use of repositories of materials in electronic form such as the Internet. This option allows materials to be available faster than in paper form, to be updated at any time, and for new modules to be added as they become available. Furthermore, materials obtained in electronic form can be modified relatively easily for local use.

With NSF funding, a central repository for computer science course materials is currently being established. This provides a single entry point from which various repositories can be retrieved as well as a place to receive contributed materials from a variety of sources. A general problem with repositories, however, is maintaining materials once one is initially established. This includes determining which items in a repository are still current and providing reviews to indicate the value of available items. Funding has not been provided to address these problems.

Workshops represent a valuable tool for obtaining peer evaluation of a project's progress and provide a means of obtaining suggestions for future direction. PIs should not overlook workshops as a valuable dissemination and evaluation mechanism.

Presentations at conferences and at other institutions and publishing papers and course materials are standards for most projects. Presenting a project's results and plans provides some of the same benefits of workshops in providing peer feedback.

Textbooks are important in providing new course material to students; however, they are of limited value in addressing many pedagogical issues. Furthermore, textbooks are usually not easy to tailor to local needs. NSF's primary focus in disseminating materials has been on textbooks, but in many, if not most, cases other mechanisms are at least as beneficial.

Summary

These are exciting times for computer science education. More reform programs are under way than ever before. Much of the credit goes to the availability of NSF educational funding. The Project Impact conference clearly demonstrated excellent products that would be useful in improving computer science education. It was unfortunate, however, that the only faculty who saw the demonstrations were those who already have projects. Demonstrations such as those at the conference would be extremely valuable to many faculty who are looking for materials and ideas to improve their own programs.

One problem that plagues most curriculum development projects, as well as proposal writers, is the assessment of project effectiveness. Standard procedures, such as the use of control groups, usually are not feasible. Most attempts to measure improvement in student performance are subject to so many factors that could bias the results that the results are of questionable validity at best. Furthermore, funding generally does not allow for extensive assessment efforts. It may be the case that the most efficient, and possibly most effective, assessment mechanism is to use evaluation by a group of knowledgeable peers.

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Engineering Curricula: Beginning a New Era

Lyle D. Feisel

Introduction

Whenever you put more than 300 creative people under one roof for 3 days and conduct activities that mix them together in large and small groups, ideas will pop out like mushrooms on a warm June morning. The National Science Foundation (NSF) Project Impact conference did just that; it brought together the principal investigators (PIs) from most of the currently funded undergraduate education projects. As one might expect, there was no dearth of ideas on how to improve education, but as far as how to get others to use your ideas . . . that was a tougher nut to crack.

Engineers, however, are up to almost any challenge, and this was no exception. The engineering educators at the conference made a lot of progress toward solving the problem of disseminating great educational innovations. Ideas, some spoken and some implied, were many and varied, and I was challenged and invigorated by my assigned task of collecting, collating, analyzing, and recording the best thinking of this talented group.

In this brief paper, I would like to do two things. First, I will try to analyze the general drift of the projects that were presented and identify a few trends that seem to be developing in engineering education. Second, I will share what I learned about disseminating ideas and products and getting other people to adopt them.

Trends in Engineering Education

A lot is happening in engineering education today, such as an increased emphasis on teaching in all institutions, including major research universities. This emphasis is directing a lot of attention to NSF's education divisions and is helping to determine the direction in which education research and development are going. It's always a bit dangerous to try to get too specific in identifying trends, but let me at least express one person's opinion.

Ongoing Trends

Some general areas of educational development promise to be with us for some time. While they are not new, they are

at the center of what we do as engineering educators and so deserve to survive—at least for a while.

(1) **Design**. It has been said that design is the essence of engineering. If "design" is broadly construed to include not only the initial design of a product or process but also its development and improvement as well as its broader impact, I would certainly concur with that assessment. Obviously, many of the PIs at the conference also recognized the importance of design, not only as a skill that our graduates will require, but also as a mechanism by which students can be motivated to learn the fundamentals of engineering and engineering science. (I hope that no one minds that I distinguish between those two areas.)

Over a quarter of the projects at the conference were directed toward the teaching of design, and many others at least mentioned design in their description. An example of an evolving senior design course is "Design of Mechatronic Systems," being developed at Rensselaer Polytechnic Institute under the direction of Kevin Craig. This course has some very good features, such as the involvement of industry and the requirement to produce a working prototype. At the University of Michigan, H. Scott Fogler is directing a project called "A Focus on Developing Innovative Engineers." In addition to the development of interactive instructional modules, this project concentrates on open-ended problems and problem-solving strategies.

One of the interesting aspects of design, at least for most people, is how its definition has broadened over the years. Twenty years ago, design was generally held to be more or less synonymous with synthesis. A design problem would be stated as "Here is a set of specifications. Define a system that will meet them." In the more current understanding of design, a problem would more likely be stated as "Here is a situation. Determine the specifications of a system that will describe that situation, and then define a system that will meet those specifications." And in doing so, consider the aesthetic, ethical, economic, safety, and other conditions that exist in what we call the real world.

A project at Georgia Tech, "The Integration of Economic Principles with Design in the Engineering Science Component of the Undergraduate Curriculum," directed by Gerald Thuesen, brings the real world into the design process with a dollar sign. Integration of these three areas—design, economics, and engineering science—appears to improve efficiency in the teaching of all three and also gives the students a more realistic picture of engineering practice.

Most of the projects appeared to adopt this more modern view of design education, although a few were really teaching synthesis. Although both are useful, I believe the trend is toward the broader interpretation, and I would expect to see some interesting work done in the teaching of broad-based design at all levels.

There is also a continuing trend of introducing design into the lower division courses. Some educators are approaching this as a motivational activity to increase retention. Certainly this is a worthy goal. I believe, however, that bona fide design education can begin during a student's first year and continue to graduation, growing in sophistication. I think we will see some new thought in this area.

(2) **Introduction of new knowledge into the curriculum.** East is East and West is West, and sometimes it seems that those twain shall meet before we can succeed in reliably linking research with the undergraduate curriculum. Yet that is an absolutely essential function of the faculty. A large number of projects (almost one third) were devoted to this goal, primarily, I suppose, because this has been a major funding category for NSF.

"The Integration of Sensors into the Electrical Engineering Curriculum," directed by Ryszard Lec at the University of Maine—Orono, is one example of many such projects. They have developed a laboratory in which students actually build sensors from unprocessed materials and then test and apply them. Another project, which brings new knowledge to the classroom, is "A New Paradigm for Teaching Undergraduate Materials Synthesis and Processing." In this project, Krishna Vedula and Kristen Constant of Iowa State University are developing a series of modules that are current in content and can be updated. Jeffrey Gray of Purdue University is developing "An Integrated Undergraduate Program on Semiconductor Devices for Power Flow Control." As the project name suggests, they are combining semiconductor device physics, power electronic circuits, and power distribution systems. The material is probably not new, but the integration is.

We must continue this trend of integrating research results into the curriculum. After all, if we do not move the results of our research activity into the classroom, it would probably be more efficient to perform research in an institute dedicated to that particular purpose and not muck up the universities by having two unrelated missions—teaching and research. Fortunately, I believe that most faculty think those two missions not only are related but are inseparable, and they work hard to tie them together.

While there were many projects in the area of engineering, I was a bit disappointed in the narrowness of vision that some of them exhibited. The faculty were certainly trying to integrate their special knowledge into their own courses, but many had no real interest in getting it into courses taught in other institutions. In the past, this process was carried out at a semi-glacial-pace, as individuals eventually wrote textbooks containing new material. I fear that this process is too slow for today's frenetic rate of development. We might do well to investigate means of hastening this process.

(3) **Overall curriculum development.** Fundamental change in curriculum is hard to achieve, but we have to say that the NSF-funded coalitions are striving mightily to bring it about. It remains to be seen which of their many innovations will be deemed fundamental and, indeed, desirable and are adopted by the wider community.

There are also a number of individual projects that are bringing about curricular change. At Texas A&M University, Carl Erdman and Charles Glover's project "A Restructured Engineering Science Core with a Design Component" has resulted in curricular change on that campus and is having an impact on several others as well. In New England, an ambitious project directed by Harold Brody is bringing together four institutions—University of Connecticut, University of Massachusetts at Amherst, University of Rhode Island, and Hartford Graduate Center—to join with industry not only in developing a manufacturing-based curriculum but to develop other aspects of engineering education as well.

It seems safe to say that the trend toward curricular improvement will continue and that NSF will continue to support, in some fashion, projects in this area. Indeed, one might venture to suggest that we are ready to embark on a new era of curricular experimentation in engineering. I am emboldened to make this suggestion by recent actions of the Accreditation Board for Engineering and Technology (ABET) that are expected to lead to both simpler accreditation procedures and more broadly defined criteria. Rightly or wrongly—I believe the latter—ABET has long been regarded as a serious impediment to curricular innovation. If ABET follows through as expected, institutions will be encouraged to experiment at will. I look for this ongoing trend to expand.

(4) **Instructional software.** The engineer's love affair with the computer continues. Almost since the computer first came on the scene, we have been sure that it has the ability to provide effective, efficient educational activities for our students. We still have the faith, and we are finally starting to get results. For example, a project at Vanderbilt University, "Intelligent Computer-Based Learning Environments for Undergraduate Engineering Laboratories," under the direction of John Bourne, promises to increase significantly the efficiency of laboratory instruction and the learning that takes place in the laboratory. At Stanford University, John Eaton is developing "Interactive Software for Self-Paced Instruction on Laboratory Instrumentation and Computerized Data Acquisition." The resultant material is appropriate for either classroom or individualized instruction.

"Interactive Computer-Based Instruction and Testing in Engineering Statics" directed by Helen Kuznetsov at the University of Illinois provides both instruction and testing with the use of the computer.

Some of the software that is being developed has considerable potential in and out of the classroom. On the other hand, some of it is so highly specialized that it probably will not be used very much. I predict, however, that we will keep trying and, with the development of CD-ROM, authoring languages, faster computers, and high-resolution graphics, our success ratio is sure to increase.

It might be wise to pay a little more attention to what educational psychologists have learned about the way people learn and try to integrate that knowledge into our educational software. In some cases, we have produced software that simply solves equations and displays the results while the student learns little more than how to operate the program. The potential is much greater than that.

Growing Trends

While these trends did not show up explicitly in many of the current projects, they were often present in some fashion. Furthermore, any reading of the academic literature or a conversation with any educational leader will demonstrate that the following trends are coming fast.

(1) **Collaborative learning.** This category might be called cooperative learning, if you wish. They are different but not sufficiently so that we need to worry about the distinction here. We have long advised our students to study in groups, get together with friends to do homework, etc. We have not, however, really done much to organize, manage, or even facilitate such collaborative learning activities. Now, a number of educators are studying the process and are learning how to make a collaborative learning system work. For example, Richard Felder at North Carolina State University, has worked extensively in this area and is evaluating the effectiveness of his methods in the project "Longitudinal Effects of Innovative Instructional Methods in the Undergraduate Engineering Curriculum." I expect that we will see increased activity in engineering education to experiment with and develop some of those methods.

I will admit to a prejudice here and suggest that engineers are particularly well qualified to develop collaborative learning methods. Most of us are not well versed in psychology, but we do generally have a good sense of causal relations and excellent design skills. We need to design an educational process that involves students in one another's learning and rewards mutual accomplishment. NSF should be looking for people who want to do that.

(2) **Teamwork.** At first blush, this might seem to be the same as collaborative learning. Certainly the two are related, but they are sufficiently different that I think they deserve separate mention. While collaborative learning is an efficient, effective way to learn, it does not *have* to involve teamwork. We could design a collaborative learning system in which students would cooperate in the learning process but only in their own unenlightened self-interest. In teamwork, there is an innate, burning desire for the *team* to succeed; it's an attitude as much as a skill. As our colleagues in industry continue to tell us that the solitary engineer is as outmoded as the slide rule—and as much mourned—we need to respond in the kind of education we provide for our students.

Probably the best place to develop teamwork is in the design courses that are increasingly scattered throughout the curriculum. At Arizona State University, Donovan Evans is directing a project entitled "Student Teaming and Design" to develop a set of exercises that can be used at all levels to develop and maintain team skills. Thomas Regan, at the University of Maryland, has developed a course, "Introduction to Engineering Design," as part of the ECSEL Coalition. This course features team-based activities as well as various other skills and again couples into the design process.

A good, solid project that demands such varied skills will probably also provide a lot of motivation as the students are involved in some quasi-real engineering. I think, however, there is a lot of room for creative ideas concerning how to develop teamwork in other venues as well.

(3) **Career-long education.** Of course, we have long been concerned about career-long or life-long education and have always said that we teach our students to learn. I believe, however, that we are experiencing a fundamental shift in the way engineers will manage their careers in the future and that one of those shifts is an increasing emphasis on the individual's responsibility to maintain his or her personal knowledge base. As educators, we will have to devote more attention to preparing students to do that, efficiently and effectively. At least one of the coalitions,

the Foundation Coalition directed by Carl Erdman at Texas A&M University, has as its central theme the creation of a foundation for life-long learning.

One aspect of teaching students to learn is what has come to be called self-directed learning, and I would probably identify this as an emerging subtheme. There is a fair amount of recent thought on the subject, and it could well serve as the basis for some new approaches to teaching our students how to manage their own career-long education.

Waning Trends

It is fairly safe to say that no educational movement ever really disappears completely. It is possible, however, to detect decreasing emphasis, and I believe I have seen this in a couple of areas.

(1) **Manufacturing engineering.** Please do not think that I am suggesting that manufacturing is not important or that engineering educators should ignore it. On the contrary, we are still moving toward according it the importance that it deserves. I believe, though, that we are moving away from the fervor that was prevalent in the first few years of the manufacturing renaissance and are no longer trying to develop programs to produce engineers who know only manufacturing. For many years, we educated design engineers with no concern for manufacturing. Then, for a while, we tried to educate manufacturing engineers with no concern for design. Now we seem to be moving toward educating engineers who are versed in concurrent or, as I prefer to call it, seamless engineering where design, development, and manufacturing are seen as one continuous, integrated process.

While I consider manufacturing engineering to be a waning trend, I would expect to see some increased activity in developing programs that produce graduates educated in the process of seamless engineering. The project being conducted by the Southern California Coalition for Education in Manufacturing Engineering, under the direction of Richard Williams at California State University—Long Beach, appears to be developing such an integrated and broad program.

(2) **Engineering generalists.** During the 30 odd years of my engineering education career, I think I have seen about three cycles of the call for engineering generalists—someone who knows a little bit about every engineering discipline but is not weighted down with too much knowledge about any one field. Fortunately, in my opinion, this call is diminishing right now. I hope we do not hear it again. With the ever-increasing amount of knowledge available in every field, it is unrealistic to expect anyone to practice without an extensive knowledge base in some area of specialization.

On the other hand, we have to recognize that our graduates will be practicing in a wide variety of venues and that many will find themselves in rather small companies without the benefit of a large engineering staff. We must prepare them to work in such a situation by giving them tools to gather knowledge from others and integrate that knowledge into the product or process for which they are responsible. Can this be done in 4 years of education? Probably not.

In these last paragraphs I have tried to identify some trends in engineering education that I gleaned from studying the projects and talking to the conference participants. As always, this analysis has rather soft edges, and there are exceptions to every trend. In general, however, I am reasonably confident that this is a good representation of where engineering education is headed in the next few years.

Dissemination of Products and Ideas

In addition to analyzing the educational trends, I was asked to take a careful look at how the results of this educational research might best be disseminated. To do this, I spent a lot of time talking to individual educators and also just listening to their conversations in informal or workshop settings. At first, I was bent on simply finding and recording specific ideas on dissemination. As the conference progressed, however, I was struck by the emergence of common themes. Specifically, people were giving me not only information on *how* to disseminate; they were also helping to define conditions of the dissemination problem. It occurred to me that the most useful approach might be to synthesize as much information as I could into an analysis of dissemination. This information would lead to a catalog and an assessment of evaluation methods. I hope that you will agree.

The Stakeholders

One of the interesting things I gained from the Project Impact conference was a better understanding of the broad range of people and entities who have a stake in successful adoption of NSF-sponsored educational research. It might be useful to look at those stakeholders and see where they might better fit into the process.

(1) **The principal investigator.** Why should the PI care? I think there are two reasons. First, NSF has defined a successful project as one that has a broad impact, i.e., is adopted by other universities. If the PI is to be successful, his or her ideas must be adopted by others. If the PI is to get more funding, he or she must be successful. Second, there is the phenomenon of ego or professional pride. Most peo-

ple want to have their ideas recognized and appreciated by others, and adoption of those ideas is the ultimate recognition. Imitation is the sincerest form of flattery. Given these two reasons, it was somewhat of a surprise for me to talk with a few PIs who really did not have much interest in dissemination. Perhaps NSF would do well to clarify what a successful project entails.

(2) **The National Science Foundation.** It is a truism to say that NSF wants to see the ideas it has funded find broad adoption. If the benefit–cost ratio is high, those at NSF have done their jobs well, and they will be rewarded with both professional satisfaction and continued funding. Both are important. On the other hand, program directors must be careful not to place too much importance on concrete evidence of immediate adoption. Some ideas will take longer to germinate than others, and some will never take root. It would be unwise, however, to crucify risky innovation on the cross of widespread adoption.

(3) **Professional societies.** In engineering, we are particularly fortunate to have professional societies that are intimately interested in the education of engineers. Clearly, the better their education, the more they can contribute to the success of the profession. With few exceptions, engineering faculty have not made good use of the societies in their efforts to have innovations more widely adopted. This connection might be mentioned by NSF in future solicitations. Indeed, joint proposals involving university faculty for development, a professional society for dissemination, and a partnership of both to encourage adoption might prove quite fruitful.

(4) **Receiving faculty.** A faculty member who is considering adopting a new idea is engaged in a very complex process. I think it would be useful to consider what might motivate faculty to adopt the new idea and what might prevent them from doing so.

Earlier, we noted that a professor's ego would motivate him to try to get other faculty to adopt his ideas. That same ego tends to keep him from adopting the ideas of others. Understanding that, it would seem that a good tactic is to make sure that any innovative materials or processes are sufficiently flexible so that the receiving faculty member can personalize them. This suggests that flexibility needs to be built into the transferable portion of the project from the very beginning. The result is an interesting conflict of egos.

Virtually all faculty possess a number of motivators, though. First, most faculty (I hope) want to be more effective in teaching. Dissemination activities must make it very clear that adoption of the innovation will result in an improvement in the educational process for students. Second, faculty are very busy and are reluctant to take on the added effort of making a change in their course material or in their way of teaching. They would probably do so, however, if it were clear that they would not be working harder or if, indeed, they were spared some effort. Dissemination activities must convince the adopter that if an increase in effort is required, it will be only temporary and the effort needed to maintain the new methods will be no more than needed in teaching, in the old way. Third, there is an increasing tendency in universities to look for and reward good teaching and, in many cases, this includes educational innovation. It should be made clear that the adoption of a proven innovation is as useful as generating more innovations and that such adoption can result in the commendation of one's colleagues and administration.

(5) **Receiving administrators.** Throughout the country, academic administrators are being asked what they are doing to improve teaching at their institutions. It is important that they provide a good answer, because it promises to have an impact on enrollments, appropriations, graduate placement, alumni gifts, and other things dear to the hearts of chairs, deans, and presidents. It would seem that documented adoption of the latest in teaching techniques and materials would be a very effective response. Most dissemination activities concentrate on faculty. Future activities might be directed toward academic administrators. Such efforts would show how adoption of educational innovations can improve teaching at their institution and impact how their performance is judged.

(6) **Sending administrators.** Administrators at the institutions where the innovation was developed have the same need to show that teaching is improving at their college. Given this, it might be possible to enlist administrators in disseminating, or at least publicizing, their faculty's educational innovations. Indeed, if we could somehow get presidents involved in a competition over whose faculty was the most innovative in their teaching, the pedagogical era will have arrived. In the current climate, an attempt to do just that would have a fair chance of success.

(7) **Students.** Obviously, students have a stake in educational innovation just from the standpoint that it should make their education better, or at least make the educational process more interesting and even fun. I have a suspicion, however, that their interest goes beyond their concern over their own education. Consider the following:

First, many, if not most, students have a greater altruistic tendency than do many of their more seasoned and cynical elders. They will participate in the work of educational development and, if invited, the follow-up activities as well, simply because it seems like the right thing to do.

Second, they are beginning to realize that they will soon be looking for employment and that any experience in a creative and responsible position is an asset in the job market. Working on an innovative education project could be just such an experience.

How might students be employed in the dissemination process? One possibility, suggested by John Lindenlaub of Purdue University, is to conduct summer workshops in which undergraduate or graduate students participate in the preparation of educational materials. At the end of the workshop, the students take the produced materials back to their own campuses where they would help their own faculty integrate the new materials into their coursework. If the students were teaching assistants, this could be particularly effective.

In another scenario, students who receive a baccalaureate degree from one institution could take materials with them when they go elsewhere for graduate school. For instance, some kinds of computer software would be useful to the student and would soon be recognized by other students and eventually the faculty. There are sure to be other possibilities.

I hope this analysis of the stakeholders in the dissemination process proves useful. Recognizing who is (or should be) interested in the process, and understanding how adoption of innovations affects their success, can perhaps trigger ideas of how to employ them in meeting our dissemination goals.

In talking with the conference participants, I developed the opinion that the most effective method of dissemination is probably the workshop. A 2- or 3-week faculty workshop has several appealing features. Workshops are usually held at a remote location, so the faculty member is taken away from regular campus activities that compete for attention. Workshops have depth, so the participant comes away well-versed in the innovation and probably convinced that it will indeed work. Finally, the participant is far enough along in the learning curve that effort required for implementation is minimal. A well-structured workshop, with a provision for follow-up by the leader, will also create a sense of obligation in the participant to indeed implement whatever is being disseminated.

Another kind of workshop that a few people mentioned is what I call the road show. In this format, the innovator travels to host campuses and presents workshops for faculty from that campus or from a small group of nearby campuses. Most likely, they would be 1-day programs, so the fraction of faculty who become converts would be smaller than in an extended summer workshop. The cost, however, would be significantly lower, and the benefit–cost ratio could be high. Of course, not all innovations lend themselves to this dissemination format, but, for those that do, a good return on investment could be realized.

There must be other ways to reach faculty who are interested in improving education but are not inclined to devote a great deal of their own effort to doing so. These faculty need to be made aware of innovations, need to be convinced that innovations will increase their effectiveness, and need to believe that the innovations will not add significantly to their workload. With the addition of other characteristics that have been identified, a top-down design of a system could achieve some conversions.

The Internet

Throughout the conference, there was a background hum that, if you listened carefully, could be described as cyberspace crystallizing. Many participants were looking to the Internet to either advertise their innovative products and/or to distribute them. Without a doubt, this is a wonderful new tool that we have, and it has a great deal of potential. I would expect a lot of the more innovative, progressive educators to be "surfing the net," and, if our wares are displayed, they will pick up some ideas as well as some software and other materials.

There are some clever ideas out there. The National Engineering Education Delivery System (NEEDS) is a distributed repository of media-based educational modules indexed at Iowa State University. The group is now addressing the challenge of advertising its availability. Among other things, they are listed in library systems and made available through the gopher-type access systems. Once a user is tied into the system, she may download the material and use it as needed.

Clearly, the Internet has a lot to offer, and its use is certain to expand. I suspect, however, that a great many of the faculty mentioned above will not be doing a lot of "surfing," so we will have to get creative in order to reach them. Perhaps we can do something to induce Professor Cyberwalker to ftp some stuff for Professor Cyberphobe even though the latter does not know a gopher from a gateway.

Of course, the use of Internet to disseminate innovations is not new. Some people, however, are starting to flirt with ways to involve the Internet in the educational process itself. This is an innovation which is, in a way, self disseminating.

Conclusion

The Project Impact conference was, in a probably outdated idiom, an upper. The people who came to describe their projects were enthusiastic about their own projects and supportive of others. They joined discussions in workshops, in hallways, and in eating and drinking establishments. If there was a problem, it was not with the preaching; it was with the congregation. No one attended but the choir. What is needed is a way to get the message to a wider audience. It is hoped that this chapter and this publication will at least contribute to the achievement of that goal.

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Keep on Moving—Energizers in Mathematics Education Reform

Brian Winkel

Introduction

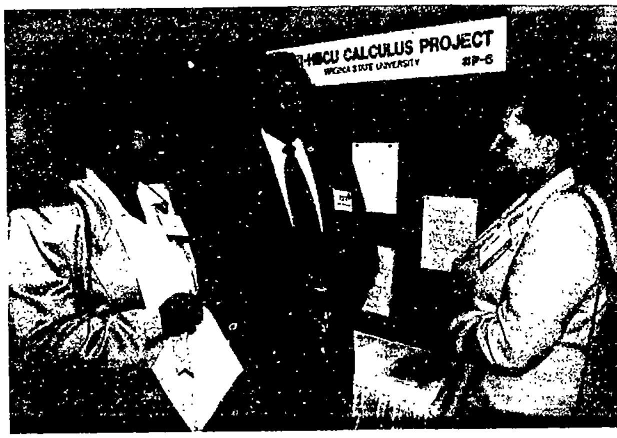
"Thank you for those words of wisdom you offered at graduation years ago. I have used them often," said the returning engineer to the dean at her class reunion. Puzzled as to what he might have said, the Dean asked for clarification. She replied, "When I came across the stage you shook my hand, gave me my degree, and said 'Keep on moving.'" Science, engineering, and mathematics faculty sponsored by the National Science Foundation (NSF) and the good folks at NSF do just that—keep on moving!

With curriculum reform spurred by NSF support of the calculus movement, mathematics PIs were the largest group at the 1994 Project Impact conference. Addressing change, action–reaction, and dialogue, the meeting featured PIs and publishers grappling with issues of disseminating, evaluating, piloting, and upscaling projects. However, there was never an insular atmosphere as exhibit booths and many discussion groups cut across disciplines.

In leading the mathematics discussion groups, Division of Undergraduate Education (DUE) Program Director Bill Haver reported that nearly two-thirds of the nation's colleges and universities are undertaking some type of calculus reform involving at least some of their students. Yet the reform effort is definitely not complete. Only an approximate 15–20 percent of students are enrolled in courses making heavy use of reform approaches. Despite this, I believe an inner clock ticks toward progress in undergraduate curriculum reform. The best programs effectively use cooperative learning; graphical, analytical, and numerical approaches; oral and written communication; and technology. Faculty are responding to these reform efforts.

Reform is being spurred in two major ways: (1) professional meetings devoting large portions of their programs to change and improvements in teaching and (2) local administrators encouraging experimentation—doing something to improve retention. Evidence of reform includes the following:

- Standards produced by the National Council of Teachers of Mathematics (NCTM) making an impact in textbook publishing for K–12 mathematics,
- Technology engaging teachers,



- Cooperative learning becoming an alternative to lecturing,
- Journal literature featuring new approaches to mathematics education.

Published results of reform and peer interaction spread curricular change, for as Haver said, "Some mathematics faculty are feeling pressure to change, hopefully to improve." Stimuli for change abound!

I believe we could do no worse than to continue to lecture on the same topics with the same emphases on analysis and symbol manipulation. We now see before us an expanding menu of options from emerging approaches, such as graphical, numerical, symbolic, analytic, and communicative aspects of mathematics, coupled with significant use of technology and small-group, cooperative learning in which teachers act as coaches and mentors rather than knowledge dispensers. A growing number of faculty believe that their courses should concentrate on a smaller set of materials through which students can "learn how to learn" and use mathematics with confidence. Less is more! Leaner is better! The emphasis shifts from content to process—an appropriate change—for mathematics offers process, not just facts.

The Project Impact conference brought publishers and faculty together to facilitate commercial publication and sustainable dissemination of NSF-funded activities. The commercial market offers the exposure and push to enable faculty to examine, adopt, and deliver new materials. Commercial dollars support continued reform by sustaining the innovators in the process of developing, testing, evaluating, and improving materials. Moreover, in the eyes of some faculty the "proven" value of commercial texts may be just the edge to convince them to change. There are, however, others who believe that placing materials on the Internet permits fast sharing of materials and significant "localization" and customization. This approach can produce dialogue and feedback, but not extensive and sustained reform. Only the commercial market, coupled with a good pedagogical approach and a ready audience of faculty, can ensure real dissemination and systemic change.

Those who are working in mathematics education reform need to be more aware of one another's efforts and should incorporate developed ideas rather than reinvent them. In interviewing PI exhibitors, I heard a number of common themes and approaches, although the PIs were unaware of what the other was doing. PI meetings such as the Project Impact conference help, but the PIs themselves need to spend time and funds publishing materials about their projects, examining other programs, and visiting or hosting colleagues. They all need to read the reports of abstracts of NSF-funded projects published by NSF and other sources, e.g., *UME Trends*, and to establish contact with colleagues doing similar projects. Four years ago the Rose–Hulman Institute of Technology founded a journal, *PRIMUS—Problems, Resources, and Issues in Mathematics Undergraduate Studies*, for the specific purpose of supporting a wider dialogue.

Finally, a renewed emphasis on the value of teaching needs to accompany mathematics teaching reform, and institutions must encourage, support, and reward innovative teaching. We need "at home" recognition of such efforts in the recruitment, mentoring, tenure, and promotion processes.

One way to realize the forces necessary for reform is to examine specific efforts. Within the main framework of mathematics innovation are lab approaches, resource materials, and totally structured curricula. One finds a broad spectrum of efforts, from the community college level, where projects build on the NCTM Standards approach and make use of appropriate technology, to efforts at large state universities, such as the University of Michigan's efforts to upscale reform calculus instruction, coupled with cooperative learning. Let us look at sample innovations in precalculus, calculus, upscaling of a calculus effort, cognate courses, statistics, linear algebra, upper-level specialty and mainline courses, and integrated courses involving science, engineering, and mathematics.

Precalculus

- "Functioning in the Real World," a project of Sheldon Gordon (Suffolk Community College) demonstrates that a good time to change precalculus occurs when you change the calculus to deemphasize manipulations. The precalculus course can develop more useful skills, e.g., fitting functions to data using linear regression and nonlinear regression by recognizing a pattern, linearizing, fitting a line, and converting back to the nonlinear model.
- "Redesign of College Algebra," by Linda Kime (University of Massachusetts—Boston), fulfills a general university quantitative reasoning requirement. The course, taught in a computer lab, includes linear and nonlinear fits of data collected in the physics lab, e.g., inverse square law using light meter. The course stresses group work, writing, reading, and reporting with more work for students. Performance, however, correlates well with effort and amount of work rather than with innate ability.

Calculus

- At CUNY—Borough Manhattan Community College, Patricia Wilkinson, Chair, added a 2-hour lab to calculus for commuting students. Students meet in small groups and submit portfolios of work using Uri Treisman's model of challenging problems. Students learn word processing on their own and use Mathematica. Exams look the same, but professors include lab grades for as much as they want and influence lab activities, permitting reluctant faculty to join in at their comfort level.
- With regard to Duke University's "Project CALC," Lang Moore says they have a revised pedagogical approach driven by real-world lab problems. Jack Bookman, also involved in the project, just finished a longitudinal study concluding that "Project CALC" students become better problem-solvers, possess better attitudes, and, on average, tend to take one more mathematics course than students who took traditional calculus. It was also revealed that weaker students succeed at a higher rate because f group work. Faculty who have taught this approach will no longer teach the regular approach even though this new approach takes more resources and increases the intellectual load for teachers. D C Heath is publishing the first draft of "Project CALC" material.
- Wiley publishes thorough material for the widely used reform effort of Sheldon Gordon (Suffolk Community College) and Deborah Hughes Hallet's (University of Arizona) "Harvard Calculus Project." Students who learn by algorithm and pattern matching find this approach scary. "You have to be gentle with them at the start and then firm with them else they will hold on to your hand forever," says Hughes Hallett. Gordon says they get a deeper level of questions back, and community college students find a release in thinking, not just grinding (algorithmic approach). Implicit plots are hard to get, but after doing derivatives and slope of tangent line to an

implicit plot, students said why not use the tangent line "envelope" to outline the function, thus discovering an algorithm to construct the implicit plot. Faculty do not present solutions in class. It is tough to make up exams. The key here is the interplay of ideas—students think, faculty think.

- Greg Foley (Sam Houston State University) works with "Calculus for Comprehensive Universities and 2-Year Colleges," a project in which two faculty from each of four local schools meet biweekly to discuss approaches to a calculator-driven calculus course in which students work in groups in lab projects. Write-ups ask students leading questions and expect written responses. Labs lead to healthy discussions, and each group member rates the others in terms of contribution. In addition to the use of labs and technology, there are more extensive, long-range projects. There is one "gateway" exam on skills in differentiation, but major exams are not based on skill, focusing instead on problem-solving and concepts. A higher percentage of students go on to more mathematics courses from this program than from the traditional approach.
- Kenneth Hoffman (Hampshire College) states that Five Colleges, Inc.'s, "Calculus in Context" seeks to show how calculus grew out of attempts to deal with science—starting with a science problem and doing mathematics to address that problem. This technology-based course opens with nonlinear differential equations. Students enter program codes for 1 1/2 semesters, then use Mathematica. Downstream faculty are happy with student strengths in modeling and interpretation, but they say the students' skills in manipulation are weak. The course philosophy is to get a method that works first, in all situations, then show students the few examples in which they may get a closed-form solution, e.g., integration is taught with numerical methods first, then a few special methods. Grading homework becomes more intense because faculty need to read it very carefully.

Upscaling of a Calculus Reform Effort

- In 1990–91, Morton Brown (University of Michigan) taught one section of Calculus I using graphing calculators with standard text. In 1991–92, several sections used graphing calculators with supportive texts, while others used calculators with traditional texts. In 1992–93, the first year of Michigan's NSF support, cooperative learning and reform materials, such as "Harvard Calculus," were used in 10 pilot sections. Brown thought they were doing cooperative learning, but in the second week of the term he found the excellent book, *Active Learning: Cooperation in the College Classroom*, by David Johnson, Roger Johnson, and Karl Smith (Interaction Book Company, 7208 Cornelia Drive, Edina, MN 55435 USA). Brown read the book, modified the teaching style, and began to assign roles to students and do true cooperative learning. In 1993–94, Michigan used calculators and the "Harvard Calculus" materials in all Calculus I and II classes. Some classes were still in traditional rooms with 35 students in each class; however, a number of sections were in smaller rooms (24 per class) using full cooperative learning.

The goal is to limit class size to 24 students with groups of 4 executing cooperative classwork and group homework. All faculty and teaching assistants in this program attend a summer workshop on sensitivity training, cooperative learning, technology utilization, and the "Harvard Calculus" materials.

Cognate Courses

- An example of this genre is the "Quantitative Science Curriculum for Life Science Students" developed by Louis Gross (University of Tennessee, Knoxville). Few biology departments require statistics or linear algebra. Gross put together a 1-year course driven by data and hypothesis testing to teach necessary calculus, statistics, probability, and linear algebra (with some dynamical systems). Gross conducts workshops to encourage educators to offer this approach.

Statistics

- Two examples of enrichment in statistics are Richard Schaeffer's efforts to create an "Activity-Based Introductory Statistics Course" at the University of Florida and an electronic encyclopedia of examples and exercises at the University of Ohio. Elizabeth Stasny explains that the Florida project adds a lab component to the "Introductory Statistics" course. Students see statistical principles unfold with materials they use in small demonstration groups. Faculty are working toward a lab manual of modules. This approach changed the tests from "plug and chug" to "what would happen if . . . " There is more work such as thinking about how to use materials and grading assignments. The Ohio State project produces HyperCard materials based on interesting activities found in the media: "Are baseball players worth their salary?" and "What is the real story on doctor-to-patient HIV spread issue?" Projects, indexed by topic and by statistical concepts, are on-line, and a user can specify the level.

Linear Algebra

- Steven Leon (University of Massachusetts, Dartmouth) heads up "Project ATLAST" to encourage and facilitate the use of software in teaching linear algebra. Summer workshops using MATLAB are offered for faculty to develop projects. Participants develop modules, try them in courses, and return the finished product.

Examples of Upper-Level Courses

- Through "Geometry at Cornell," David Henderson (Cornell University), as a member of a geometry group, offers a sequence of geometry courses particularly for prospective high school teachers. Efforts stress writing, relate geometry to the real world, and offer classical geometry concepts.
- By implementing an "Upper-Division Mathematics Computer Classroom/Laboratory," Gary Sherman (Rose–Hulman Institute of Technology) offers students discovery-based algebra and discrete mathematics in a Magma/Cayley software environment where algebraic structures are real, substructures and relationships are computed, and theorems are founded on tactile sense and experience. Sherman has motivated undergraduates at Rose–Hulman, and his Research Experience for Undergraduates summer efforts have produced published research results based on this approach.

Integrated Approaches

Integrated approaches in which mathematics is taught as a part of, and in relation to, elements of a larger picture do exist and are increasing in number. During the summer of 1994 at a conference sponsored by NSF, GE Foundations, and Rose–Hulman Institute of Technology, faculty from 30 schools gathered to discuss the merits of an integrated approach in first-year science, engineering, and mathematics curricula. A number of schools will pilot such an approach in the fall of 1994, among them Texas A&M University, University of Alabama, and Arizona State University.

- Robert Quinn's (Drexel University) "Enhanced Learning Experience for Engineering Students" (E4) attempts to integrate calculus with physics in the first-year engineering curriculum. Robin Carr has developed an excellent text of applications-driven calculus using Maple technology. E4 is now the standard curriculum in engineering at Drexel.
- "Integrated, First-Year Curriculum in Science, Engineering, and Mathematics" (IFYCSEM) by Brian Winkel *et al.* (Rose–Hulman Institute of Technology) is in its fifth year of teaching one-quarter of entering students in a 3-term, 12-credit/term, one-grade, team-taught (8 faculty members from science, engineering, and mathematics) course. All technical material in the first-year curriculum is included in this one course and is available for mathematics integration on the spot! Mesa Community College, as a part of the NSF-funded Foundation Coalition, is teaching an IFYCSEM project modeled after the one at Rose–Hulman.
- Dennis DeTurck (University of Pennsylvania) team teaches an integrated course with physics and chemistry colleagues. They found it very exciting and dared to be different—students can only ask questions of faculty not from the field in question.

Learning from and with Colleagues Outside Mathematics

There is a rich collection of experiences, ideas, and successes outside mathematics. David Hestenes (Arizona State University), a leader in the physics community, has discovered misconceptions that students bring to physics courses (and they leave with these same misconceptions). Physics teachers are examining what they do and are introducing many active, tactile learning opportunities. The new NSF initiative in chemistry education will produce an effort comparable with calculus reform. Mathematics educators do not have a monopoly on major reform efforts. Ask around your campus community to find others interested in reform. Perhaps you can form a team interested in integrated curriculum efforts, or you might learn something from these reformers that works for them and could work for you.

The NSF initiative, Mathematical Sciences and Their Applications Throughout the Curriculum, will stimulate dialogue among reformers across the disciplines and provide excellent opportunities to work with colleagues outside the mathematics community. In addition to the support of upper-division course development, this initiative will enable dialogue across disciplines concerning introductory courses.

Examples of Sources

- "Calculus Reform in Liberal Arts College," represented by Wayne Roberts (Macalester College), delivered modules and readings from five books from the Mathematical Association of America and Roberts' book *Resources for*

Calculus. These books serve faculty who do not want to invest in an entire reform program or who wish to supplement a reform program with other projects.

- "Snapshots of Applications in Mathematics" by Dennis Callas (SUNY College of Technology, Delhi) is creating *Real World, Contrived, and Charming Applications*. The material comes from faculty, popular press, and scientific journals. Two mathematics journals have agreed to feature these snapshots in regular columns: *The AMATYC Review* and *NY State Mathematics Teacher Journal*.

General Observations

Commitment and involvement, both individual as well as institutional and consortial, are essential. Consider the efforts of Lang Moore and David Smith (Duke University) on "Project CALC," who speak at conferences; visit projects; host visitors; write, publicize, work and rework materials; and provide source materials for review and scrutiny in the development stage. The same applies to the team involved with the "Harvard Calculus" project. They field tested many versions of their material before approaching a publisher.

Evaluation of materials is generally not done in small projects, but often there is at least one other site at which the material is being developed and tested. Some of the bigger projects have extensive evaluation. Formal evaluation is scarce.

Students learn better when they have to formulate their ideas and communicate them. People talk about cooperative learning and small groups, and some do it in labs that accompany lectures. There is a movement to do more small-group work in class and use writing, e.g., logs, journals, papers, homework write-ups, and portfolios, both for internal assessment and external evaluation.

Students also benefit when they are given more attention. It may well be economical to do so, for attrition rates are reduced, the need for repeat courses is lowered, and students are more likely to pursue a subject area that makes them happy.

Final Words

Several years ago, at a national engineering education meeting, Richard Boyce (Rensselaer Polytechnic Institute) said, "It is the most exciting time to be teaching calculus." Indeed, it is the most exciting time to be teaching mathematics! More and more faculty are willing to do what it takes to bring about positive changes in their professional lives, in the learning activities of their students, and in the broader mathematics education community. Calculus reform, sponsored by NSF, has been a jump start for mathematics education improvement, and those in the field just "keep on moving!"

Brian Winkel, Professor of Mathematics at Rose–Hulman Institute of Technology, having taught mathematics in liberal arts settings (Albion College) and now engineering settings (Rose–Hulman), is committed to teaching with cooperative learning, to using technology, and to teaching using an integrated approach. He has been a team member in innovating science, engineering, and mathematics education in Rose–Hulman's "Integrated First-Year Curriculum in Science, Engineering, and Mathematics" (a nationally recognized curriculum originally funded by NSF); is part of a larger team of educators who form the Foundation Curriculum, funded by NSF to effect systemic change in engineering education; heads an NSF-funded project to create a development site for complex, technology-based problems in calculus with applications in science and engineering at Rose-Hulman; and edits two journals, PRIMUS *and* Cryptologia.

Bridging the Gap: Disseminating Physics Innovations

Robert H. Romer

Introduction

The 1994 Project Impact conference focused on how to get innovative teaching materials and ideas out into the college and university communities. Curiously, the conference itself was perhaps one of the best methods of dissemination.

There are two major obstacles to effective dissemination, one posed by the innovators (the disseminators) and one by the intended audience. First, the principal investigators (PIs) on these projects are, for the most part, much more interested in the creative work of developing new methods, texts, software, laboratory apparatuses, etc., than in the often slow and difficult work of making their efforts known to others. PIs say, in effect "I'll develop some good materials and try them out on my students. When they're done, I'll create more materials, for some other topic." The subconscious thought is that, if the materials are as good as the PI thinks, then they will somehow catch on. Dissemination is someone else's department. Surely every textbook author (myself included) has had the illusion: "I'll write a great book, and everyone will use it." However, as every published author can testify, distribution is the key problem that must be solved if the book is actually going to be used.

The second major obstacle is most easily characterized by the power of Newton's First Law. When considering all the well-known manifestations of inertia exhibited by college and university professors, it is amazing that anything ever changes. This problem is illustrated by the nearly identical tables of contents appearing in several widely used, introductory physics texts. We often blame this particular inertial effect on the publishers, but I am afraid we cannot so easily evade responsibility. It is professors who choose textbooks for courses, and, for many understandable reasons, we are extremely reluctant to change. We are in charge of very large courses. We seem to spend all of our energy supervising teaching assistants. We have problem sets and assignments ready for use again. We come up for tenure review, and jobs are scarce, and research funding is tight, etc. Why should we adopt someone else's innovation? Anything that gives us an excuse—lack of statistical significance in data that supposedly show improved student performance—will lead us not to use your innovation but to stick with what is supposedly tried and true (*tried*, surely, but not necessarily *true*).

Modes of Dissemination—Examples

The only generalization that one can make about current methods of disseminating physics and astronomy curricular materials is that they are diverse. There are no clear trends in methods of dissemination except for the obvious one that electronic means are much more prevalent than they were only a few years ago. Materials often disseminated include conventional textbooks, printed newsletters, software of various kinds, videodiscs, and CD-ROMs. Information is disseminated through commercial book publishers, postings on electronic bulletin boards, talks and workshops at regional and national American Physical Society (APS) and American Association of Physics Teachers (AAPT) meetings, papers submitted to journals (*The American Journal of Physics*, *The Physics Teacher*, *Physics Today*, and others), and various software "publishers" such as Vernier Software and Physics Academic Software (PAS) of the American Institute of Physics.

My participation as an observer at this conference reinforced my impression that PIs are fascinated with the materials they develop and plans for dissemination tend to get overlooked. Although the abstracts for this conference asked PIs to describe "Published Instructional Materials," display booths at the conference were focused (understandably) on content rather than dissemination. Even though the purpose of the conference was to discuss dissemination, PIs seemed puzzled when I asked about their past, present, and future plans for distribution. Nevertheless, it is clear that most investigators do want to see their efforts used elsewhere even though dissemination is not the top item on their agenda.

Listed below are examples of projects and various dissemination methods. It should be understood that this is not an exhaustive list, but rather an illustration of various modes of dissemination. Moreover, some PIs are distributing their materials through methods not mentioned here.

- Richard Hake, Indiana University, produced a set of Socratic Dialog Inducing lab manuals, which he supplies on request. He also puts material up on the Phys-L electronic bulletin board, a group coordinated by Richard Smith of University of West Florida.
- Larry Coleman, Donald Holcomb, and John Rigden, as well as many collaborators around the country, are testing various new models for the introductory course of their well-known "Introductory University Physics Project" (IUPP). In addition, they distribute a newsletter, have published proceedings of IUPP conferences, and have described their work in a *Physics Today* article (April 1993).
- Robert Fuller, University of Nebraska, and colleagues Dean Zollman, Kansas State, and Evelyn Patterson, U.S. Air Force Academy, and others, have developed a variety of new materials using new media, including videodiscs and CD-ROMs.
- Zaven Karian and Ronald Winters, Denison University, have given talks at AAPT meetings and at regional meetings of APS sections, on their project to incorporate the use of symbolic computation in a variety of undergraduate science curricula.
- Patricia Heller, University of Minnesota, has published papers in *The American Journal of Physics* about her introductory physics program. She recommends obtaining opportunities to use new materials locally by "offering to teach the physics courses no one else in your department wants to teach."
- Lillian McDermott and her group at the University of Washington have had remarkable success at getting new methods and materials for the introductory course into use. She has published a number of papers in *The American Journal of Physics* and elsewhere. More significantly though, her research in education follows a conventional physics pattern within a physics department. Her graduate students take the same qualifying exams as students doing more conventional physics research theses. She trains teaching assistants for the entire department. Part of the introductory course, no matter which professor is in charge during a particular year, is based on her materials and methods. Much careful and diplomatic effort is required to become accepted in this way by a large department at a major research university.
- Jerome Pine, California Institute of Technology, and his colleagues John King, Philip Morrison, and Phylis Morrison at Massachusetts Institute of Technology, have published an article in *The American Journal of Physics* (November 1992) on their "ZAP" freshman electricity and magnetism course, offering free sets of their experiment notes.
- Ronald Thornton, Tufts University, publishes his Microcomputer-Based Laboratory (MBL) through Vernier Software. He has published various articles on MBL and has presented this work in talks at various places, including regular physics department colloquia.
- Priscilla Laws, Dickinson College, has described her Workshop Physics in talks at university colloquia, at the "Unity Day" session of the APS/AAPT meeting in April 1994, and in a *Physics Today* article (December 1991).
- Joseph Amato and others at Colgate University are undertaking a major revision of their introductory course. A new lab manual has been produced, and a lengthy article has been written for submission to a physics journal.
- Laurence Marschall, Gettysburg College, with his Contemporary Laboratory Experiences in Astronomy project, publishes a newsletter, maintains an electronic bulletin board, and distributes free copies of his software. In one of the highlights of the conference, Marschall presented the rationale for this policy by entertaining us with a musical rendition of a verse from Tom Lehrer's "The Old Dope Peddler":

  He gives the kids free samples,
  Because he knows full well,
  That today's young innocent faces
  Will be tomorrow's clientele.

- Jan Tobochnik, Kalamazoo College, and Harvey Gould, Clark University, produce computer simulations of physical phenomena that cannot be readily observed directly. They edit a regular column in *Computers in Physics* and have published a text through a commercial publisher.
- Jack Wilson, Rensselaer Polytechnic Institute, and many co-workers at other institutions use a wide variety of media in their Comprehensive Unified Physics Learning Environment. They plan to distribute some of their software through the American Institute of Physics' Physics Academic Software.
- Curtis Hieggelke, Joliet Junior College, and co-workers hold workshops and distribute a newsletter specifically for teachers at 2-year colleges. Their program provides curriculum development workshops for community college physics teachers in all parts of the country.
- Robert Beck Clark, Texas A&M University, and co-workers have a faculty enhancement program for teach-

ers at 2-year colleges. They have held workshops all over the country and presented numerous talks at professional meetings.

Because of their specific nature, some very valuable projects are not readily transferable to other locations. One such project, and one of the most impressive projects I learned about at this conference, is that of Elisabeth Charron, Gregory Francis, and others at Montana State University. They have begun an ambitious outreach program to improve the preparation of science teachers in rural areas with large minority populations, a largely ignored problem. By reaching Montana's tribal community colleges, they hope to increase the level of science teaching for Montana's large Native American population To a New England observer like myself, the distances that must be covered are in themselves daunting.

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From Idea To Impact: Realizing Educational Innovation in the Social Sciences

Kenneth E. Foote

Avenues of Innovation

An upsurge in educational innovation in the social sciences has occurred during the past several years. A tremendous number of projects that have the potential to reshape traditional methods of classroom and laboratory instruction are underway. These projects respond to a number of forces, not the least of which is the sense that the conventional wisdom of good research leading inevitably to good teaching is not always true in practice. Effective teaching often requires careful thought and special skills—and a substantial investment of time and energy. Research advances do not always filter down to the classroom as quickly as they should. Scholars are often faced with too many demands to meet the challenge of continually rethinking and redesigning the undergraduate curriculum—particularly when the existing curriculum is sufficient to serve the basic needs of undergraduate education. Yet scholars are increasingly asking whether it may be possible to improve existing models of education and to do a better job of preparing students for the challenges they will face in professional life. In higher education, the adage that "if it's not broke, don't fix it" is being supplanted by the view that "if it's not broke, improve it."

The innovations that are underway revolve around four interrelated issues. First, more attention is being placed on developing analytical and problem-solving skills through "active-learning" strategies. At the moment, many curricula seem to stress mastery of content over comprehension of the processes of scientific inquiry. New projects are based on the idea that the cultivation of analytical reasoning skills needs to be more assertively pursued at the undergraduate level. Second, many scholars are attempting to span disciplinary boundaries to challenge students to consider concepts and issues from interdisciplinary perspectives. The sense here is that conventional disciplinary boundaries are increasingly blurred in both theory and practice, and students must learn to apply conceptual and analytical skills from many disciplines, rather than those of a single field. Third, a good deal of attention is focusing on issues and student populations that are underrepresented in the social sciences. A number of curriculum initiatives underway weave issues of race, gender, and ethnicity into

the basic fabric of undergraduate education and also draw an increasingly diverse student population into the social sciences, reflecting national trends in the workforce. Finally, a great amount of thought and energy is being invested in facing the challenge of employing information technologies in higher education. The debate over effective use of information technologies has changed radically in the past several years. It was possible, even quite recently, to equate information technology with computer use in the quantitative branches of the social sciences, but new technologies—distance learning, Internet resources, hypermedia—have spilled over into all disciplines and subfields. Some of the most exciting experiments underway involve attempts to harness the potential of "electronic" classrooms and textbooks. Numerous examples can be cited of successful projects in all four categories.

Cultivating Reasoning Skills through Active-Learning Strategies

The cultivation of student problem-solving and critical-reasoning skills is an important part of many initiatives, as one would expect of effective educational projects. More than ever, emphasis is being placed on developing these skills through "active-learning" strategies. Gary Hanson's 2-semester psychology course at Francis Marion University is a good example of this approach. He has developed 20 laboratory exercises that facilitate the development of scientific thinking and demonstrate the process of science in the context of demonstrable psychological phenomena both to improve scientific literacy among non-science-majors and to attract students to careers in science. Richard Larson of the Linguistics Department at the State University of New York (SUNY)—Stony Brook uses his courses to accomplish similar goals in so far as syntax and semantics serve as vehicles to engage students in scientific reasoning and method. At the University of Colorado—Boulder, Herbert Covert and a team of his colleagues have created a 2-semester laboratory sequence in biological anthropology that emphasizes student observation and measurement, the organization and quantification of results, and the development and evaluation of hypotheses. Andrew Beveridge, of the City University of New York (CUNY)—Queens College, has adopted the same aim in his introductory sociology course, which attempts to bridge the gap between introductory-level training and research experience. Finally, Michael Flower has implemented an honors course at Portland State University that uses small-group learning techniques and collaborative problem-solving to engage students in active debate and investigation of pressing scientific, political, and social issues. In almost all of these initiatives, computers and information technology play a key role. Although these technologies will be discussed below, they are intrinsic to these projects both to capture student interest and to promote problem-solving skills.

Some natural science projects provide other good examples of this approach to introducing the principles of scientific investigation and reasoning to non-science-majors. These projects take two forms. The first is organized around core courses that seek to integrate the teaching of fundamental concepts and methods. Examples include Frederick Greenleaf's 3-semester math and science sequence at New York University, Daniel Friedman's project in introductory science at Howard Community College, and Len Troncale's project at California State Polytechnic University at Pomona. A second set of projects has been developed around interesting topics selected to pique student interest in science. One of the most original of these is Michael Henchman's course at Brandeis University on the "Chemistry of Art." Henchman uses this interesting topic to draw non-science-majors into careful study of the chemistry of materials used in the creation, conservation, and authentication of works of art. Other examples of this sort are Lawrence Kaplan's course "Chemistry and Crime: From Sherlock Holmes to Modern Forensic Science" at Williams College, Zafra Lerman's course "From Ozone to Oil Spills: Chemistry, the Environment, and You" at Columbia College of Chicago, and Stephen Weininger's junior–senior seminar "Light, Vision, and Understanding" at Worcester Polytechnic Institute. Weininger's project is notable for its success in incorporating into one course insight drawn from physics, biology, art history, philosophy, mathematics, computer science, and the history of science. All of these courses derive from the natural sciences, but the strategies could be applied to the social sciences to highlight fundamental concepts and commonalities of method across many disciplines.

Highlighting Interdisciplinary Research Methodologies

Some projects in the social sciences are already highlighting interdisciplinary commonalities of method and stressing the importance of cross-disciplinary research. These interdisciplinary projects often use a team of faculty to address a single important and interesting topic, such as sustainable development or environmental quality, from a variety of perspectives. An excellent example is Guru Khalsa's project at Thiel College entitled "Global Heritage: A Multidisciplinary Focus on Sustainable Development." In this project, faculty from the natural and social sciences and humanities, along with guest lecturers, use the concept of sustainable development to guide their investigations of the cultures of Nigeria, India, China, and Brazil and to explore the close interrelationship between culture and environment in a year-long, sophomore-level course. At Thiel College, the success of the Global Heritage project has suggested the possibility of additional integrative courses—at both the lower and upper divisions—that may help to break down traditional disciplinary boundaries. At Occidental College, Elizabeth Braker's project, "The Border: A Multidisciplinary Approach to Critical Issues," has a similar thrust but focuses on the border between Mexico and the United States. By concentrating on this "edge" or "seam," Braker's team of faculty and students can explore the environmental, demographic, economic, and cultural influences each country has upon the other and, in addition, how these relate to important domestic and foreign policy issues. Among the issues addressed in the classroom and in field projects are immigration, agriculture, industry, and public health. Patricia Cunniff, of Prince George's Community College, is pursuing similar goals, but with respect to a different geographical unit—the Chesapeake Bay watershed. Her faculty development workshop compiled field projects, laboratory exercises, and teaching resources for students to explore the complex ecological relationships of one of the major watersheds of the eastern seaboard (Cunniff, 1993). Although the disciplines of biology, chemistry, and geography are featured in this project, the other social and natural sciences play a part in understanding the processes that have shaped the watershed.

Other topics sometimes serve as the focus of promising interdisciplinary projects. The "Connections: A Model for Integrated Freshman Year Studies" project of Barbara

Olds and Ronald Miller, at the Colorado School of Mines, seeks to get freshmen to appreciate the connections among their courses in engineering, humanities, and the natural and social sciences. By highlighting such connections from the very start of the freshman year, Olds and Miller can demonstrate how all courses in the students' programs bear on their future professional work and lives. At CUNY, John Wahlert focuses on Darwin and Darwinism to explore theory construction as well as its social context and cultural ramifications. Michael Gorman, of the University of Virginia, has his students study key inventions, such as the telephone, to demystify the complex forces involved in design innovation as both a social and a scientific process. Finally, Jack Bristol, at the University of Texas at El Paso, has developed a year-long freshman course that focuses on critical milestones in the history of science as a way of exploring the philosophical, cultural, and social dimensions of science. All of these projects take a fresh look at the curriculum and attempt to move away from compartmentalizing knowledge within time-worn disciplinary categories. Such projects are likely to increase in number and scope in coming years as a means of reintegrating specialized undergraduate curricula.

Diversifying the Curriculum and the Scientific Workforce

Diversification of education to serve populations underrepresented in the professional social sciences is an important avenue of development. Efforts are being made on two fronts: (1) developing curricula that seek to serve—and perhaps recruit—such populations directly and (2) weaving issues of gender, race, and ethnicity into the basic fabric of undergraduate education. Examples of the former include Akbar Aghajanian's project at Fayetteville State University, a summer institute in social demography and population studies for undergraduate faculty at Historically Black Colleges and Universities. The idea is to bolster demographic training at such institutions by providing faculty with the training and materials needed to implement effective curriculum initiatives. Mary Ann Medlin's project at Barber Scotia College pursues a similar goal, but in anthropology. The project involves a year-long lower-division course in cultural anthropology followed by a summer field school in ethnography and a second year of study in language and culture. Emphasis is placed on the scientific analysis and cultural phenomenon of race as well as the scientific vocabulary, anthropological theories, and technical skills that students can use to understand their own experiences within a pl. ral society. Interactive multimedia materials have been prepared to improve laboratories for these courses and to promote critical thinking and problem-solving skills among students. Claire Bailey's project "Improving Science and Mathematics Education through Integrated Content and Interactive Discovery Learning" at Florida Community College—Jacksonville has similar aims, both to improve introductory training and to draw minorities and women into scientific careers.

Susan Feiner's project at Hampton University, "Improving Introductory Economics Education by Integrating the Latest Scholarship on the Economics of Women and Minorities," takes a very different but promising approach. Her work involves collaborative faculty workshops that seek to rework existing curricula in microeconomics to reflect a realistic appreciation of the role of gender and racial difference in economic processes. Rather than developing a completely new curriculum, Feiner's workshops seek to make incremental changes in a large number of courses at a wide range of institutions. Feiner has found that colleagues are receptive to such improvements if they are provided with guidance about the best materials to use and strategies for integrating them into their courses. An important part of this project has been the compilation of these materials (Feiner, 1994). This reshaping of existing curricula is also part of Susan Feigenbaum's project "Introductory Microeconomics: The Way We Live" at the University of Missouri at St. Louis. In this project, the concepts and analytical tools of microeconomics are introduced to students in the context of the decisions they will make over the course of their lives. The goal is to draw students of all backgrounds into critical reasoning about economic decision making.

Experimenting with Information Technology: Electronic Textbooks, Electronic Classrooms, and Virtual Departments

Some of the most exciting curriculum development projects involve creative applications of information technology. Indeed, virtually all of the projects discussed above make use of information technology in one form or another. Even as recently as a few years ago, information technology was equated solely with the use of microcomputers in traditional quantitative subfields such as econometrics, demography, experimental psychology, or geographic information systems. This is no longer the case. Scholars from all disciplines are experimenting extensively with multimedia, hypertext, Internet resources, distance learning, and many other techniques that fall under the broad heading of information technology. At the moment, the instructional materials being developed seem to fall into two categories: (1) supplementary materials, such as laboratory exercises, and (2) more extensive sets of materials that qualify as "electronic textbooks." At the University of Northern Arizona, Kathryn Cruz-Uribe has developed materials of the first type for her courses in archeology. To date, she has developed three modules: faunal analysis from an African archeological site; ceramic analysis from the American Southwest; and spatial analysis of house structures in a Mayan area of Central America. These modules can be used independently in a variety of contexts as a complement to conventional course materials. Another example of this approach is the software tools developed by Richard Larson of SUNY—Stony Brook for teaching linguistics. Syntactica and Semantica allow students to explore the principles of scientific reasoning and method that lie behind the analysis of syntax and semantics. Both tools are distributed with a laboratory manual that can be adapted to meet the needs of different instructors and students.

Clearly, however, scholars are attempting to create software prototypes that go far beyond exercises and laboratory materials and into the realm of the electronic textbook. At the moment, the electronic textbook is more a concept than a fact, but a number of projects are moving in the direction of demonstrating the feasibility of such materials. The extensive suite of materials developed by Andrew Beveridge (CUNY—Queens College), Susan Feigenbaum (University of Missouri at St. Louis), Gary Hanson (Francis Marion University), and Mary Ann Medlin (Barber Scotia College) come very close to suggesting the form such texts may take in the near future. Currently, these projects are composed of interlocking laboratory exercises, but it is easy to imagine how they could be expanded into comprehensive hypermedia-based texts. Hypermedia "books" may come to supplant conventional textbooks in some courses, but other models for hypermedia development are being explored in disciplines outside the social sciences. At California State University—Los Angeles, Robert Desharnais and Gary Novak are experimenting with an "electronic desktop" for use in the natural science curriculum. Their idea is to use information technology to unify access to electronic mail, locally developed software, commercial software, reference materials, and Internet resources all from a single workstation. Rather than envisioning a discrete electronic textbook, Desharnais and Novak are using computers to link whatever resources are available with a common graphic interface, an idea closer to what might be termed an "electronic library" or "electronic laboratory." A related idea has been demonstrated by Len Troncale at California State Polytechnic University in a project to support integrated general education in science. Rather than attempting to teach scientific method from the perspective of a single discipline, Troncale employs hypermedia materials to demonstrate features common to all disciplines.

It is difficult to predict what form such electronic media will assume. The momentum being gained by hypermedia-based laboratory materials may carry through into the development of full-scale hypermedia texts. At the same time, there is no reason for hypermedia materials to imitate the form of conventionally printed texts. The idea that students will trade in textbooks for CD-ROMs misses an important point. Information technology is not solely a means of delivering course materials, but rather a point of interconnection, communication, and access. Students can become far more active participants in their education as they search for information interactively and debate competing theories on-line. In this view, the "scientific desktop" or "scholarly workstation" may become the model of choice. It would allow access to a wide range of resources—including those hypermedia materials developed locally—as well as on-line discussion and interaction.

Some of the most interesting experiments may be just over the horizon. Hypermedia authoring techniques have just recently become accessible to large numbers of scholars, and it is only in the past year or two that Internet browsers like Mosaic have made it possible to envision the development of on-line course materials. As the academic community gains facility with these resources, experiments may go far beyond the creation of individual electronic textbooks. It may be possible to develop "virtual" departments, disciplines, or universities in which ready access to educational resources of all sorts is available through an easy-to-use graphical interface. The idea of using the Internet and hypermedia resources to link faculty and students from many departments and universities is, in some respects, just around the corner. Such cooperative endeavors would not only expose students to a richer educational environment but also help to average out the high development costs of hypermedia resources.

Dissemination: Different Projects, Different Paths

Dissemination is usually the last thing on the mind of most principal investigators (PIs) as they begin a project. Their primary concern is the project innovation—the idea—and the problems of mobilizing the resources needed to reach their goal. Yet, in the long term, an effective plan of dissemination is perhaps more important than the innovation itself. A superb idea will eventually count for very little if it fails to reach a larger audience either within the home institution or among other educators at other colleges and universities. The only way to make sure this happens is to consider dissemination from the very start of a project—even if plans are a bit sketchy at first—and continue to focus on these issues throughout the project. The truth is that dissemination should come first, rather than last, in a PI's plan of work, and some excellent guidelines (Ely and Huberman, 1994) are already available from the National Science Foundation (NSF).

Dissemination, of course, means much more than publication. It entails promoting a project in ways that lead to adoption and change within a department, at a university, or at other institutions. Within the academic world, we think first of publication as a means of dissemination because it is the model to which we are accustomed in research. Educational innovations are different, in so far as we must persuade our colleagues not only to rethink their methods but to do something differently in the classroom. Effective adoption of an educational innovation requires changing behavior—and more effort is usually required to convince colleagues to do something differently than to accept new research findings. Dissemination must be viewed as persuasion, in a very broad sense. Publication is important, but other strategies must also be considered—workshops, training, discussion groups, Internet communication, and other forms of person-to-person and face-to-face interaction. A plan of dissemination will necessarily entail considering all possible strategies for persuading colleagues to accept and adopt change—and these strategies may vary radically from project to project and from audience to audience. In deciding which strategy to use for a given project, PIs must keep in mind two points. First, all possible methods of persuasion must be considered, not just publication. Second, information technologies such as the Internet and "electronic" texts offer new, unexplored resources for facilitating curricular change.

Publication will, for obvious reasons, continue to play an important role in virtually all curriculum projects. Journal articles, laboratory manuals, and textbooks remain excellent ways of promoting or marketing both the ideas and the concepts that lie behind an innovation and the curriculum materials that need to go into the hands of faculty and students. Yet with increasing use of electronic media and software, simply publishing new materials sometimes is not enough. Effective use of electronic media requires adopters to devote much more time to retooling and redesigning courses, learning new software, and even creating new classrooms and laboratories. The learning curve is much steeper for electronic than for print media. Dissemination plans should take this difference into account in several possible ways. First, potential adopters should be brought into the development cycle as early as possible so that they can learn as the project evolves and even contribute to its development. Second, interaction with potential adopters should be promoted actively through Internet communication, regular gatherings at professional meetings, newsletters, and discussion lists. Third, workshops and training can be built into a dissemination plan, either at professional meetings or perhaps in summer institutes. Training with new software and face-to-face discussion is critical when adopters are faced with retooling their skills. This last point is underscored by the fact that NSF is bolstering its Undergraduate Faculty Enhancement program to support precisely these sorts of workshops and institutes. Finally, for investigators envisioning hypermedia courseware, it seems important to make contact with potential publishers early in the development cycle—earlier than would be the case for print media. Hypermedia is still in its infancy, and authors can occasionally find themselves in deadends. Time spent working with professional producers from the start can pay off in the long run.

As important is the question of how the Internet can serve as a tool for curricular change. Electronic mail, list servers, and the World Wide Web have all had tremendous impact on the academic world and should all be factored into dissemination plans. Perhaps the best is yet to come. The Internet seems to offer a new forum for collaborative development, for testing materials, and for "publishing" materials that serve too small a market for commercial publication. Collaborative development across the Internet is already underway, but testing and publication have not yet attracted as much attention. Many software developers are hesitant to test materials on the Internet for fear of losing proprietary rights to future publication. Until copyright issues are clarified this will remain a problem. One alternative is to put demonstration versions of software on-line or at least to place course outlines on the Internet, possibly through World Wide Web file servers and the Mosaic browser. Publication on the Internet will offer new opportunities for some projects that may not attract ready interest among commercial publishers. Many excellent projects emerge from relatively small disciplines, serve very specialized courses, or produce software and exercises that must be constantly revised. These sorts of projects have always had a difficult time making their way into the mainstream through commercial sources. The Internet now makes it possible to issue these sorts of ephemeral and "fugitive" materials to an international audience so as to add to cumulative experience and knowledge. This is an important issue. In the realm of curriculum development, too many scholars inadvertently reinvent the wheel because they simply are not aware of related projects at other universities. Education is not quite like research, in which a cumulative body of scholarship sets the terms of debate. In education, hundreds of instructors are teaching similar courses in slightly different ways without ever really comparing notes. Internet publication of course materials and outlines could reduce this duplication of effort.

Expanding the Bounds of Innovation

The cultivation of innovation requires more than a good idea and an effective plan of dissemination. Seed projects require nurture and support to effect change. The basic problem is that, in the current context of higher education, the cultivation of educational initiatives cuts against the grain of institutional rewards and incentives. Although tenure, promotion, salaries, and reputations are said to be based both on research and teaching, at many institutions little weight is, in fact, placed on the latter. Although this problem has long been faced by scholars interested in educational innovation, the advent of informational technologies has added additional pressures. Many of the most interesting innovations now underway in the social sciences involve the creative use of information technologies. These technologies make tremendous demands upon educators willing to put them to use in the classroom and laboratory. Software requires extra time for training. Hypermedia materials are time-consuming to write. Laboratory resources require substantial time to establish and maintain. Not too many years ago, the major complaints of innovators revolved around finding funds for hardware and software and issues such as the compatibility of hardware and software. These are not mentioned nearly as often any more; rather, the major complaints revolve around balancing the demands of curricular innovation against other academic responsibilities.

Change is likely to come slowly and must occur at several levels simultaneously: within individual colleges and universities, within professional societies, and within funding agencies such as NSF. Bottom-up and top-down change will play a role at each of these levels. PIs are already becoming a force of bottom-up change at all three levels. As conferences such as the Project Impact conference attest, the enthusiasm of innovators can go far to influence the reward system of higher education. Top-down changes may be more problematic. Two things must happen. First, innovators must be recognized for their investments of time and energy by either being released periodically from other responsibilities or being acknowledged and rewarded explicitly. Second, methods must be found within universities and professional societies to bring innovators together to work toward common goals. Within universities, the creation of media centers and institutes and release time for faculty to use these resources can have a positive effect. Within professional associations, the creation of specialty groups and working committees is important.

Funding agencies such as NSF are already making a positive impact on educational innovation, and it may be possible to increase this still further. For many innovators, NSF is already an important source of rewards, such as release time and equipment for seed projects, that are not as readily available through universities or professional societies. Furthermore, NSF awards are often instrumental in persuading university administrators to support innovations. Existing NSF programs can be used to build upon this trend. The Undergraduate Faculty Enhancement program, in particular, can support the creation of institutes and working groups to promote innovation among consortia of universities and within professional associations. Organizational changes that provide for closer coordination of the Foundation's research and educational units—for example, through the creation of permanent educational program officers for some disciplines—could help to nurture innovation even further. The fact remains that NSF does have a powerful influence on the reward system of higher education. New programs that set an agenda for curricular innovation, such as the Advanced Technological Education program, will continue to be an important means of wielding this power. The idea of creating a national teaching college or institute in collaboration with public and private universities may be another way to expand the bounds of innovation in American higher education.

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Project Impact Conference: Participant Feedback

Principal investigators (PIs) who attended NSF's 1994 Project Impact conference were asked to complete a brief questionnaire to elicit feedback. Responses were received from 127 PIs. The findings are highlighted below.

Conference Usefulness. As to overall usefulness, 83 percent of the respondents said the conference was very useful while 13 percent said it was somewhat useful. The exhibits were especially well-received, with 80 percent of the PIs describing them as very useful and most of the rest finding the exhibits somewhat useful. Disciplinary workshops were also quite popular, with 75 percent describing them as very useful.

Conference Activities and Impacts. Ninety-four percent of respondents said they talked with other PIs or staff members about possible future cooperation and 78 percent said they are likely to continue their associations with these PIs after the conference. Most respondents—87 percent—said they talked with commercial publishers at the conference, and 46 percent said they are likely to pursue commercial publication as a resu ' of these discussions.

Many PIs reported that they expect to find concrete applications for ideas and information obtained at the conference: 76 percent said they obtained new course and curriculum/lab ideas that they are likely to try; 61 percent said they obtained new dissemination or implementation ideas that they are likely to try; and 78 percent said they are likely to make m .re dissemination and/or implementation efforts with their project products as a result of the conference.

Recommendations. Some of the more common recommendations were to: increase the emphasis on exhibits and on unstructured time for networking; broaden participation to include more publishers, institution administrators, deans, etc.; consider making a videotape or compact disc of the exhibits to disseminate to institutions and faculty who cannot attend the conference; and add a how-it's-done, getting-started session for PIs who have never published materials.

SECTION IV

Resource Guide

Abstracts and further information about the projects referenced in this document are found in Project Impact: Disseminating Innovation in Undergraduate Education, Abstracts of Projects: Things That Work, *NSF 95-70.*

National Science Foundation 1994 Project Impact Conference Participants List

For the reader's convenience, projects with available instructional materials are marked with an asterisk (*). Further, the project's discipline is indicated through the following symbols: **A**-astronomy, **B**-biology, **C**-chemistry, **CS**-commputer science, **E**-engineering, **G**-geological sciences, **I**-interdisciplinary, **M**-mathematics, **P**-physics, and **S**-social sciences.

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"Summer Seminar in Social Demography and Population Studies for Undergraduate Faculty at Historically Black Colleges and Universities"

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"Implementation of Calculus Reform at a Comprehensive State University with Project CALC"

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"A Preparatory Course for Computer Science"

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"Computer Laboratory for Quantitative Economic Analysis"

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"CIM Summer Workshops for Undergraduate Engineering Faculty"

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"Modern Introductory Physics: The Second Semester"

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"Integrating Computer Technology into the Introductory Chemistry Laboratory"

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"Development of Steel Design Educational Module (SteelDEM)"

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"A New Approach to Undergraduate Engineering Education: Integration of Solid Modeling and Finite Element Analysis"

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"Finite Elements for the Instruction of Electromagnetic Fields"

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"A Dynamic, Interactive, Electronic Textbook in Plant Pathology USDA/CSRS/HEP"

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"Freshman Engineering Experience"

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"Improving Science and Mathematic Education Through Integrated Content and Interactive Discovery Learning"

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"Development of Science of Computing Courses 1 and 2 at SUNY Geneseo"

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"A Laboratory Approach to Introductory Differential Geometry"

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"Improving Science Education: An Integrated Approach Project"

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"Workshops Which Provide Instruction in the Implementation of an Innovative Model for Introductory Chemistry Laboratory Manuals"

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"ANEX/RIED: Analysis, Experiment, and Engineering Drawings in a Portable Structural Model Laboratory"

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"Strengthening Enrollment Using Shared Resources and Distance Delivery"

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"Improving Scientific Literacy of Undergraduate Students through Hands-On Multidisciplinary Science Courses"

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"Enhancing Undergraduate Learning in Natural Science: A New Curriculum for Laboratory Classes in Biological Anthropology"

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"Computer-Based Laboratory Exercises for Introductory Archaeology Courses. A Pilot Project for a Minority Approach to Archaeology"

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"A Redesign of the College Algebra Course"

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To get an electronic copy of the "STIS USERS GUIDE," NSF 94-10, send an e-mail request to: ***stisserve@nsf.gov***. Your message should read:
get NSF9410.txt. For a printed copy of the "STIS USERS GUIDE," see instructions "How To Request Printed NSF Publications."

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