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ABSTRACT

This conference, cosponsored by the NSF and the National Research Council (NRC), focused on developing and implementing strategies for improving undergraduate education in science, math, engineering and technology (SMET). Represented at the conference were various types of 2-year and 4-year institutions, private industry, professional societies, federal agencies and other organizations. The major session topics covered were: (1) The Challenge to Undergraduate Education; (2) Perspectives on Revitalizing Undergraduate Education; (3) The NSF Review of Undergraduate Education and the NRC "Year of Dialogue"; and (4) Institution-Wide Reform: Towards a Coherent Plan. Roundtable discussions and forums included the following: a Legislators Roundtable, an Industry Roundtable, a Corporate and Foundation Partners Forum, and an Academic Presidents Forum. Contains 4 appendices: excerpts from the 1996 report to the NSF "Shaping the Future: New Expectations for Undergraduate Education in Science, Math, Engineering and Technology" (NSF 96-139) and the companion NRC study "From Analysis to Action: Undergraduate Education in Science, Mathematics, Engineering and Technology"; abstracts of institutional plans from various undergraduate institutions, including 6 community colleges; directory of exhibitors; and conference participants. (RDG)

Shaping the Future:

Strategies for Revitalizing Undergraduate Education

Proceedings from the National Working Conference
Held July 11-13,1996
Washington, DC

National Science Foundation
Directorate for Education and Human Resources
NSF 98-73

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PREFACE

The National Science Foundation (NSF) and the National Research Council (NRC) cosponsored this major working conference, July 11-13, 1996. It was attended by over 500 representatives from academic institutions, industry, professional societies, Federal agencies, and other organizations. Academic participants came from all types of colleges and universities, and included students, faculty, deans, presidents, and other high-level administrators. Twenty-three of the teams were drawn from institutions receiving NSF awards for outstanding progress and plans to nurture institution-wide reform.

The focus of the conference was developing and implementing strategies for improving undergraduate education in science, mathematics, engineering and technology. Several documents were used effectively to focus attention on the key components of this vital task. Participants received copies of the 1996 report to the NSF: *Shaping the Future: New Expectations for Undergraduate Education in Science, Mathematics, Engineering, and Technology* (NSF 96-139), and the companion study of the NRC: *From Analysis to Action: Undergraduate Education in Science, Mathematics, Engineering, and Technology* (Washington, DC, National Academy of Sciences, 1996). See Appendix A for a review of these reports. In addition, conferees received Abstracts of action plans submitted by the nearly 50 participating institutions, which are included in these proceedings as Appendix B.

Participants reviewed the recommendations, plans, and initiatives designed to speed progress toward the goal of revitalizing undergraduate education. Discussions were held on the value of designing and supporting an environment and supporting a process for learning that is suited to educating *all* students in science, mathematics, engineering, and technology. This revitalized quality of education is necessary in order to meet the needs and challenges of the real world, and to improve the preparation of the next generation of teachers in grades K through 12. The diverse group of participants discussed systemic strategies for improving undergraduate education, reviewed institutions' initial implementation plans for achieving institution-wide reform, and examined exemplary achievements in improving undergraduate education. Conferees agreed that a key step toward reform is the formation of strong partnerships among academic institutions and their stakeholders in industry, local school systems, professional societies, and Federal agencies. Such were only some of the issues discussed by attendees as they sought to identify strategies for achieving the vision urged in both the NSF and NRC reports that:

> *All students have access to supportive, excellent undergraduate education in science, mathematics, engineering, and technology, and all students learn these subjects by direct experience with the methods and processes of inquiry.*

Fostering increased public understanding of the social benefits that could be gained by achieving significant improvement in undergraduate education was deemed to be very important to maintaining and increasing the overall rate of change.

It is impossible to convey in these Proceedings the excitement and energy that pervaded virtually all of the planned and spontaneous discussions that occurred during this conference. We hope that the ideas and recommendations recorded herein will serve well all those who are determined to improve undergraduate education in the sciences, mathematics, engineering, and technology.

BACKGROUND

The impetus for this conference grew from the pair of reviews conducted by NSF's Advisory Committee for Education and Human Resources and the National Research Council (NRC), and from the interest in reform stimulated by the announcement of the Institution-wide Reform initiative by the NSF's Directorate for Education and Human Resources and its Division of Undergraduate Education.

Shaping the Future: New Expectations for Undergraduate Education in Science, Mathematics, Engineering, and Technology (NSF 96-139) was officially released at this conference. During most of 1995 and into 1996, NSF supported a national review of practices, problems, pressures, and the promise of undergraduate education in science, mathematics, engineering, and technology (SME&T), undertaken by NSF's Advisory Committee for Education and Human Resources, in parallel with a related effort sponsored by the National Research Council. Broad in scope, the review considered the conclusions of numerous prior studies and reports published over the preceding decade. It examined the findings of special focus groups of parents, students, recent graduates, and employers conducted in support of the study. It held a series of formal hearings designed to solicit input from faculty in the SME&T disciplines; college and university presidents, provosts, and chancellors; and employers. And it gave serious and detailed attention to nearly 200 letters received in response to an invitation from Dr. Luther S. Williams, NSF Assistant Director for Education and Human Resources, to comment on the strengths and weaknesses of U.S. undergraduate SME&T education. Letters were received from several federal agencies, many disciplinary societies, numerous faculty and administrators employed in a wide variety of academic institutions, and employers in private industry.

In parallel with the NSF Advisory Committee for Education and Human Resources, the National Research Council conducted a study, initiated in April 1995 with a national convocation jointly sponsored by NRC and NSF, and continuing during academic year 1995-96, subsequently designated as a "year of national dialogue." During this year, input was obtained from four regional symposia hosted, respectively, by the University of Michigan in Ann Arbor, the GTE Corporation in Boston, The Johnson Space Center in Houston, and Pomona College in California. These activities culminated in the publication of a national blueprint for achieving substantial improvement in undergraduate SME&T education: *From Analysis to Action: Undergraduate Education in Science, Mathematics, Engineering, and Technology* (Washington, DC: National Academy of Sciences, 1996). See Appendix A for details.

Both of these national activities compared the needs of undergraduate students today—as defined by the skills that employers define as crucial—with the opportunities for improved undergraduate learning experiences. These opportunities have been bolstered by a better understanding of effective pedagogical practices in undergraduate instruction, numerous improvements in course and curriculum design across American campuses, and major advances in information technology—advances that we are beginning to explore to their fullest potential. At the same time, it was also noted that increased employee skills are in demand by many employers, placing more pressure on undergraduate programs to raise the effectiveness of introductory courses in SME&T for students majoring in the fields, students majoring in non SME&T fields, and students preparing for teaching careers.

It was widely agreed by participants in these reviews that the most effective teaching methods emphasize student learning in active, collaborative settings. Students today frequently want to know *why* they are being asked to master difficult concepts. Approaches that introduce concepts and knowledge in a focused pursuit of solutions to familiar and important problems have a higher frequency of success. Frequently, this approach is strengthened by collaboration among faculty from different academic disciplines because socially and technically important problems are often multidisciplinary. Students are also responding enthusiastically to opportunities to learn science and engineering through direct experience with the practice and process of inquiry. Information technology promises to speed the development and use of these approaches to learning.

Comprehensive improvement will require that faculty in SME&T departments and schools of education collaborate to demonstrate the connections among their disciplines, promote the integration of research and education, and strengthen the pedagogical quality of introductory courses for all undergraduates. Major improvements will require partnerships among elementary and secondary schools, two- and four-year colleges and universities, and strengthened connections with industry and other employers of college graduates.

Both reviews concluded that as these more collaborative, student-centered approaches to learning increasingly displace traditional instructional approaches, that internal organization and reward systems of institutions will also change. Moreover, these changes will support institutional efforts to shift to active learning environments.

The reviews set forth a national agenda for improving undergraduate education. They have provided a set of comprehensive recommendations for consideration by individuals and organizations within business, industry, and the professional community; higher education; Federal and State government agencies and committees, and the National Science Foundation itself. The recommendations are inherently interrelated, with an emphasis on the need for all of us to work *in concert* to the benefit of student learning and, thereby, to the benefit of society.

PLENARY SESSION I:
The Challenge to Undergraduate Education

Introductory Remarks

Robert F. Watson

NSF Division Director for Undergraduate Education

Good evening! It is my great honor to call to order this first formal session of our conference, "Shaping the Future: Strategies for Revitalizing Undergraduate Education." We are proud to sponsor this conference in collaboration with our colleagues from the National Research Council. Indeed, the twin driving forces for this conference are the related year-long emphases—by the NSF and NRC and with the participation of probably most everyone here tonight—on undergraduate science, mathematics, engineering, and technology education. Our meeting also coincides, though not coincidentally, with two additional important events. Tomorrow we will announce NSF's first undergraduate institution-wide reform awards. We are especially hopeful that those institutions and all the other institutions represented here will both gain and give significant insights on how to succeed in institution-wide reform. Also, tomorrow we will recognize the inaugural group of corporations and foundations committed to partnering with the NSF for revitalizing undergraduate education.

DUE Division Director Robert Watson welcomes the Shaping the Future conferees

The meeting has been planned for all of us to *participate*, beginning with the interactive exhibits which demonstrate successful initiatives in undergraduate education, and receptions promoting one-on-one and small group conversations, as well as the more organized group discussions interwoven with expository sessions featuring individuals who have valuable insights to share with all of us. Finally, reminders that we got into science because it is fun and interesting: a celebration at the Air and Space Museum tomorrow night, and a presentation by TV personality Bill Kurtis on Saturday.

Each plenary session has a theme. Tonight's is "The Challenge to Undergraduate Education." That challenge, briefly stated, is to help ALL students at ALL U.S. two- and four-year colleges and universities learn the necessary science and technology to be successful, each in his or her own way in our complex, changing civilization. Easy to say, truly a challenge. That challenge, in my judgment, is greatest for the college and university faculties. Fortunately, as it always has been, it is the faculty upon whose intellect and imagination the rest of us will ultimately depend.

We have tried to include in the conference representatives from most sectors important to undergraduate education: administrators of academe itself, faculty and students, employers, societies and associations, schools, and government at all levels.

The format of the conference, through plenary and breakout sessions, was planned to forge partnerships between and among all those stakeholders. Approximately 50 institutions, represented by teams of up to five people each, are among us. They include, but are not limited to, those receiving the first NSF reform awards. They are definitely committed to, and working toward, institutional reform.

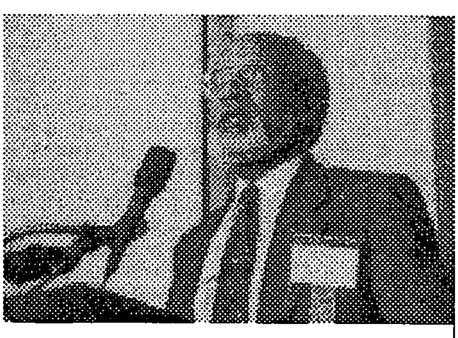
It is now my great pleasure to introduce the leader of NSF's efforts in education at all levels and our first speaker. As NSF's Assistant Director for Education and Human Resources, Luther S. Williams, is the Foundation's chief education officer. The shortness of time prevents my detailing his many accomplishments—suffice to say that his has been a distinguished career as academic scientist, educator, and executive, and as Senior Science Advisor to the NSF Director before assuming his current position in 1990. But, NSF is, as you know, a funding agency, and so let me note two more things in particular. First, since 1990, the NSF education budget has increased threefold, from less than $200 million to over $600 million in the current budget request. Secondly, the undergraduate portion of that budget has increased from about $25 million to over $100 million. These are indeed credentials also worth noting.

Welcoming Address

Luther S. Williams

NSF Assistant Director for Education and Human Resources

As we started the budget process for Fiscal Year 1997, I quoted the following statement to a member of Congress: "At no time in history has the possession of knowledge been so strong an indicator of economic wealth," presuming it would be appropriately motivational. The House reduced our request by $7 million, but the Senate restored the reductions and actually made a modest increase. The result is the largest budget in the directorate's history. If properly configured, the centrality of undergraduate science, mathematics, engineering, and technology (SME&T) education is integral to the country's welfare. I am not talking about the traditional focus of undergraduate SME&T education—to prepare the next generation of scientists and engineers. The undergraduate sector is inseparable from the quality of the technological work force, whose knowledge and skills grow from an understanding of those disciplines. It is also inseparable from any effort to improve K-12 math and science education because the undergraduate sector prepares a work force that is increasingly critical to broad sectors of industry, education, and government.



Luther Williams, NSF Assistant Director for Education and Human Resources

In the 21st century, SME&T education must assume a place in undergraduate and K-12 education that for students is equal to knowing one's predominant language. *Competency*, not literacy, is the undergraduate sector's responsibility. Improving the value of introductory SME&T courses is a total university enterprise, connecting colleges and universities to broad societal challenges and issues. We have little choice but to improve introductory courses by modifying pedagogical methods to take advantage of the fast-growing knowledge base that feeds science learning. We must purposely use educational technologies and acknowledge the science enterprise in its current state, not its historical one. And it is important to emphasize the connections between organized bodies of knowledge. To do that in all institutions—from research universities to doctorate level to comprehensive to liberal arts colleges to two-year institutions—faculties must emphasize this connectedness to integrate education and research, use research products to inform education, and raise the appreciation socially and institutionally for the value of instruction compared with other faculty efforts.

Another reason it is important to examine the enterprise is that the visibility of undergraduate SME&T education has grown. After years of innovation, there are models of how to make a difference in discrete activities. We must compile the best practices, position them as new knowledge bases for science learning, and find out if it is possible to simultaneously improve the quality and productivity of undergraduate activities. It is the latter issue I refer to if you believe the role of the undergraduate intellectual experience is to give graduates the basic knowledge and skills they need to engage in lifelong learning. That means we must improve the enterprise—its impact, its focus, its relevance. The undergraduate enterprise confronts these aspects of science learning while dealing with an increasingly diverse student body. To prepare *all* students, we must acknowledge diversity as a fundamental element, not a theoretical variable. Success demands it. Technology is another reason this conference is important. Educational technologies will eliminate academic institutions as unique repositories of knowledge. Some of the most interesting research at NSF involves knowledge networks. Increased reliance on technology to custom tailor instruction gives us reason to commit to progress, not recite what we already know.

For deliberations during the conference, we have two excellent products—NSF's Review of Undergraduate Science, Mathematics, Engineering and Technology Education, and NRC's Year of Dialogue. This "Shaping the Future" conference will catalyze the revitalization of undergraduate SME&T education. I say revitalize, but some aspects of the enterprise are being transformed, particularly in the sense of serving all students and definitively measuring whether one is running a successful enterprise. It is certainly transforming in terms of the many new opportunities and the choice of technologies for enhancing SME&T education.

By way of a charge, I suggest four areas are important:

- We must continue strategizing to improve undergraduate education, including institution-wide reform.
- We need to better understand exemplary achievements, practices, models and variables that mean success so we can transfer innovation from one sector to another, one institution to another.
- Intellectual and fiscal economies make it vital to forge partnerships among academic institutions and other stakeholders in the undergraduate enterprise—industry, professional societies, NSF and other Federal agencies.
- SME&T education has a fundamental place in undergraduate experience. It is important to identify effective, sustainable ways to inform, stimulate and challenge the public to understand how critical this enterprise is to their welfare.

The EHR directorate has an advisory committee of national leaders. As an extraordinary effort within NSF, the Advisory Committee for Education and Human Resources dared to take responsibility outside the Foundation to organize a year-long examination of the undergraduate enterprise and prepare its report. Melvin George led that effort. Other committee members are: Sadie Bragg from the Borough of Manhattan Community College; Denice Denton from the University of Wisconsin at Madison; Peter Gerber from the MacArthur Foundation and the State of Florida; Mary Lindquist from Columbus College; James Rosser, president of California State University-Los Angeles and Chair of NSF's Advisory Committee for Education and Human Resources; David Sanchez from Texas A&M University; Alfredo G. de los Santos, Jr., from the Maricopa Community Colleges in Arizona; and Carolyn Meyers from the North Carolina A&T State University.

Donald Kennedy from Stanford University and Chair of the NRC Center for Science, Mathematics and Engineering Education, led the second group. Melvin George was a co-chair. Members included Karl Pister from the National Academy of Sciences Board of Engineering; Bradley Moore of the Committee on Undergraduate Science Education; and Hyman Bass of Columbia University and the Mathematical Sciences Education Board. At-large members were Dudley Herschbach from Harvard University; Angelica Stacy from the University of California-Berkeley; Denice Denton from the University of Wisconsin-Madison; Sharon Long from Stanford University; Sylvia Bozeman from Spelman College; Gerald Holton from Harvard; and Marilyn Suiter from the American Geological Institute.

I hope you take the charge seriously. There is no reason to gather over 500 talented, experienced individuals, then go home having done nothing but examine two reports. If you believe the undergraduate enterprise is critical, we desperately need to turn the information from reports into feasible deliverables we can use to get the job done.

Industry Roundtable

Moderator:
Denice D. Denton
Dean of Engineering Designate
University of Washington

Panelists:
Jimmie Haines
Director, Technical Resource Management
The Boeing Company

Alfred Moyé
Director, University Affairs
Hewlett-Packard Company

Pamela Peters
Science Education Manager, Access Excellence Program
Genentech

John Saurer
General Manager and Vice President, Kodak Colorado Division
Eastman Kodak Company

The theme of this session was the fundamental importance of the undergraduate education sector to the quality of the workforce in a global technological society. Four representatives from a diverse group of corporations discussed their views on the partnership between industry and academe in preparing graduates to meet the challenges of the future. Their comments were remarkably consistent and provide guidance on effective strategies for revitalizing undergraduate education.

The Industry Roundtable portion of Plenary Session I

Dr. Denise Denton moderated the roundtable discussion. After each panelist gave opening comments, discussion within the roundtable was followed by a question and answer session with the audience. In their recommendations to colleges and universities, industry representatives uniformly encouraged the formation of working partnerships, increased communication between stakeholders in quality education, departmental accountability for graduates they produce, and the dissemination of best practices in the teaching of undergraduates. The following highlights provide an overview of the issues presented and discussed.

Jimmie Haines

Director, Technical Resource Management, The Boeing Company

Mr. Haines discussed the skills that were desirable in graduates and the need to instill a culture of lifelong learning. He stated that we need to continue the emphasis on mathematics and science. The world we live in is going to be a challenge for most of the young graduates and we need to prepare them to be productive to do the kinds of things that society really needs to have done. He emphasized the need to enhance the relationship between academe and industry. "We need to be able to figure out how to share resources. We need to have a true partnership—and what I mean by that is we need to be able to share one another's strengths and shore up each others weaknesses." One example of an effective partnership activity that he cited was to have industry assist in bringing laboratory experiences closer to real-world problems that are encountered in the workplace.

The Boeing Company has prepared a profile of a "work-ready" graduate. Such an individual:

- Can effectively manage knowledge, information, and systems as well as multiple tasks, resources and people.
- Is technologically savvy both in general and in specific technological areas.
- Can work, problem solve, and communicate (orally and in writing) in a team setting.
- Is flexible, and a continuous, lifelong learner who can participate and accommodate rapidly changing global work environments.

Alfred Moyé

Director, University Affairs, Hewlett-Packard Company

Dr. Moyé reinforced the themes set forth by Jimmie Haines. He described several ways to enhance the partnerships between industry and academe. Serving on advisory committees and councils was cited as an excellent avenue for industry representatives to bring the real-world experience, or "where theory meets application," to the curriculum. He pointed to the shrinking budgets for higher education as a reality. Industry has already dealt with many of these issues and can share their experiences with finding more efficient ways to operate. He stressed that Hewlett-Packard, when making hiring decisions, looks for individuals who are prepared to continue to learn. "In getting to the work ready product, we do not wish to subvert the academic process. We still need to have people that can come into our institutions, our workplaces that is, and contribute today, but be contributing members for 10-20 years. And the only way that one can continue to contribute for the long haul and be productive as changes occur rapidly, would be to have very good, strong fundamentals." He stated that almost every industry is willing to chip in and do its part to make sure our educational institutions are strong so that we can remain competitive.

Pamela Peters

Science Education Manager, Access Excellence Program, Genentech

Dr. Peters stressed the need for self motivation and critical thinking skills. A strong knowledge base was cited as a key, with hands-on learning in the laboratory being a major factor in getting students to learn to identify facts and issues for themselves to build on their knowledge. A firm foundation in ethics is important in graduates. "We see students coming in without the kind of ethical background we like. It is not to say that we make the ethical decisions for people, but it is important that the people in the labs have some sense of what's happening. You fudge a data point in a mouse and eventually it is going to affect a patient, and [that] is a problem." She also pointed out the need to be able to work independently, while on a team, and in collaboration with other teams, since this is "the way science is going to take place." Finally, she commented that Genentech, is interested in *balance*, a very important aspect that is often over looked. In addition to the "apply what you know" sorts of situations in interviews, they also ask "do you go rock climbing and have you ever been to Tibet" since they find that the people who are most productive are those who actually have *lives*.

John Saurer

General Manager and Vice President, Kodak Colorado Division, Eastman Kodak Company

Mr. Saurer talked of the need for the industry-academic partnership to look strategically at how we are going to meet the demand for technically trained individuals from both a quality and a quantity standpoint. He also stressed the need for fundamentals in the engineering sciences as well as the natural sciences. "We find that students who are grounded in the fundamentals... can ask these stupid questions more comfortably and have more confidence... A "stupid" question is one that puts us to the next plateau of excellence." On the issue of how industry could be involved in revitalizing undergraduate education he used the analogy of the efforts that have been placed on improving supplies of "materials" through vendor/vendee teams. "We need to put the energy into this collaboration with the people that supply us with technical young folks as we have with our traditional suppliers."

An eloquent summary of the panel discussion was provided in the closing comments of Mr. Moyé:

> "Significant change is required. And I think the NSF is uniquely positioned to take the leadership in encouraging this change. Changes in our world have had a major impact on our sense of what students need to learn, and how the learning should be delivered to them. Increasingly, we are recognizing that mastering a body of knowledge is simply not enough. Students must acquire lifetime skills such as critical thinking, quantitative reasoning, effective communication, along with such abilities as finding needed information and interacting well with others. We want graduates who have the capacity to learn, not who know everything. Some institutions are rethinking and redesigning their curricula to reflect the shift from teaching content to enabling students to developing lifelong learning skills. Some faculty understand the implication of the information explosion, and have reengineered their courses accordingly. But we really are talking about major changes in what we expect, and what we need. There is a shift from lifelong job security, to a more realistic hope for *career* security. We have to be aware of global interdependence in our world and an emphasis on teamwork over isolated individual activities."

Focus on Exhibits

With revitalizing undergraduate education as the theme of the conference, the opening session appropriately focused on the exciting reform efforts happening on campuses across the nation. Each of the institutional teams demonstrated their institution-wide strategies in progress. These were a true reflection of team efforts involving many stakeholders—faculty, administrators, students, business and industry, professional societies, publishers, and government. There were models of reform efforts at all types of institutions: two-year and four-year colleges and universities, private and public, large and small. In addition, several companies, private foundations, and publishers exhibited their initiatives in undergraduate education reform.

Three Focus on Exhibits sessions were held during the conference. The first such session served as the opening to the conference to set the tone of change in action. The reception held in conjunction with this session fostered an environment to promote the exchange of ideas. After the first plenary session, conference participants returned to the exhibit area to focus on institutional plans for change in preparation for the breakout sessions the next morning. Jamey Turner provided entertainment and education with his acoustics demonstration. During lunch the next day, focus was again placed on revitalization efforts in progress. The participants had spent the morning discussing the key elements of institution-wide reform and the subsequent exhibit showcase afforded another opportunity to discuss reform strategies on a one-on-one basis.

The abstracts of their projects reflect a diversity of approaches to reform. More detailed descriptions of the institutional plans is given in Appendix B. A list of exhibitors is provided in Appendix C.

Conference delegates experience more than 50 exhibits from academic institutions and industry employers

PLENARY SESSION II:
Perspectives On Revitalizing Undergraduate Education

Institution-Wide Reform: Time to Turn Up the Heat

Neal F. Lane

Director
National Science Foundation

Good morning. As someone who has devoted many years to teaching undergraduates—sometimes successfully, other times not so successfully—it is an immense pleasure for me to join all of you this morning and lend my support to your efforts to revitalize undergraduate education. I want to thank Luther Williams, Bob Watson and the staff of NSF's Division of Undergraduate Education for effectively moving mountains to produce a conference of this magnitude. And, I especially want to thank Mel George and the members of the review committee for their leadership and hard work over the past year. We also owe a special thanks to Don Kennedy for spearheading the NRC's role in this process, and to the Exxon Education Foundation for its generous support of the NRC's activities in this area.

I also feel I owe each of you a word of thanks—and perhaps an apology as well—for consenting to come to Washington in the middle of July. You have gotten something of a break from our normal weather pattern. The high today is expected to be *only* 85 degrees. Notice that I said *only 85* degrees. The average daily temperature approaches 90 degrees this time of year, and the 100's are never out of the question. Combine that with high levels of humidity and the searing summer sun and you will know why some here think the city should erect one more monument on the mall—one in honor of the physicist Jean Peltier. In case you do not know, he discovered the process we now call air conditioning. I am sorry that NSF cannot take credit for that important work.

But there is a method in our madness of bringing you to Washington in July. You may have heard the old saying, some people change when they feel the heat, others when they see the light. Since you are all here as agents of change for the institution-wide reform of undergraduate education, we thought large doses of heat and light might help you strengthen your resolve. For this reason, my talk this morning is entitled "Institution-Wide Reform: Time to Turn Up The Heat."

NSF Director Neal Lane

It is no exaggeration to say that institution-wide reform is a challenge so monumental that it will severely test our collective resolve. Institution-wide reform means just that, across the entire institution. It requires that we break down barriers of all kinds and work together—across departments and disciplines, across bureaucracies and institutions, and most importantly, across the entire student body.

This last point sums up what is perhaps our greatest challenge. The review committee captured this challenge when it adopted the goal of reaching all students and promoting inquiry-based, hands on learning experiences in science, mathematics, and engineering. Achieving this goal is vitally important to all of NSF. Education and learning are at the core of our mission. I often tell people that the NSF is involved in everything from elementary schools to elementary particles—and it is not clear which is more complicated or more challenging. I know from my own experience that teaching science is just as hard, in some ways harder, than doing science.

I've always enjoyed teaching undergraduates, and learned early on that good teaching requires immense amounts of time and energy. For example, in those rare instances when my lecture for a given class was already prepared, perhaps from a previous year, then I could get ready for a 50 minute lecture with three hours of preparation. The time and energy required increased exponentially from there. There were instances when I could not put the time required into preparation and I was often disappointed with the outcome.

Just over a month ago, we received some startling news that may require us to devote even more time and energy to our efforts. You may have seen or read about the results of NSF's latest survey on public science literacy. Dave Barry took a lighthearted look at the results in a column that ran in the *Washington Post* last Sunday. Other journalists took a more serious look at the results. The *New York Times* article ran under the headline, "Americans Flunk Science." The *Los Angeles Times* was inspired to draft an editorial entitled, "America's Failing Grade in Science." When we examine the survey results, it is not clear whether we should laugh or cry. Over 2,000 adults were surveyed, and on average they could correctly answer only 5 out of 10 questions about scientific knowledge. Fifty percent correct usually does not yield a passing grade, and this is no time for grading on the curve.

Some of the specific results were even more disturbing. I got an acute case of heartburn from one question in particular. My own research has focused on atomic, molecular, and optical physics. One of the questions on the survey was, what is a molecule? Only 10% of the respondents provided an acceptable answer. This could explain why at family reunions a number of eyes glaze over whenever I am asked to describe my research. Such discussions, if carried on for any length of time, can cool the festive nature of the occasion.

Similarly, despite substantial media attention to deep space probes, comets, and astronomy in general, less than half, only 49 percent, of Americans know that the Earth orbits the Sun once each year. We do not know if the problem was with "once per year" or "orbits the sun" or possibly "what is the sun?" Of course, this could help explain why some people are inclined to lie about their ages. We just use an alternative measure of the Earth's orbit. That's how I justify telling people I am a 39 year old grandfather.

Some even more disturbing news, and news more relevant to this gathering, was related to a part of the survey that has generated few headlines. The survey for the first time asked people to describe in their own words what it means to study something *scientifically*. It is not a trivial question, and the surveyors were flexible in their interpretations of the responses—giving lots of partial credit, so to speak.

Even with this flexibility, however, the results made me sit up and take notice.

- Only 2 percent of the respondents—one person in 50—appreciated what is truly the essence of science: that it is a process of developing and testing theories and hypotheses.

- Another 21 percent, barely more than one in five adults, understood that science is based on experimentation and observation.

- An additional 13 percent of the respondents could view science in general comparative terms—as a process involving many measurements and precise comparisons.

- But the overwhelming majority of those surveyed, 64 percent—nearly two-third of U.S. adults—could not describe the scientific process even in broad comparative terms.

What does this mean? Consider that nearly every day, newspapers run articles about new drug therapies, medical procedures, and about the risks associated with everything from pesticides to power lines. Based on this survey, it appears that only a small fraction of American adults understand scientific inquiry well enough to assess whether the findings presented in the media have any basis in science.

In his book, *The Demon Haunted World*, the eminent astronomer and author Carl Sagan suggests that this lack of understanding portends a disturbing future. He writes:

> "Finding the occasional straw of truth awash in a great ocean of confusion and bamboozle requires vigilance, dedication, and courage. But if we don't practice these tough habits of thought ... we risk becoming a nation of suckers, a world of suckers, up for grabs by the next charlatan who saunters along."

In my view, there is only one way to keep us from becoming the gullible nation Sagan describes, and it begins with your work and your leadership.

We know that only a small portion of undergraduates—fewer than 20% in fact—take a mathematics or science course after their freshman or sophomore year of college. The undergraduate years are perhaps our last chance, certainly our best chance, to reach all those future teachers, lawyers, executives, neighbors, voters, members of Congress and taxpayers—people for whom science and technology are at best remote curiosities and at worst impenetrable mysteries.

Of course, getting students to sign up for more courses is only part of the challenge. I would argue a small part. This is one situation where *quality* matters substantially more than quantity, and our focus should be on how we teach rather than how much we teach.

My own love of science has lasted a lifetime and is due as much to hobbies as to formal schooling. I grew up in Oklahoma, in the middle of tornado alley, where just watching the weather sparks your curiosity about science and the natural world. I was the classic curious kid, with microscopes, chemistry sets, rock collections—and all kinds of other scientific toys and curiosities that indulged my intellect and taxed my parent's patience. Throughout my childhood, my father would take me out to limestone outcroppings along the Texas-Oklahoma border to look for fossils. These were great spots for brachiopods, trilobites and huge cephalopods known as ammonites, which my dad lugged back to the car. I still have some of the fossils I collected on those trips.

I often reflect back on my own experiences when I think about the National Science Foundation's contribution to mathematics and science education. That same spirit of exploration and discovery that I received outside of school is now being brought into our schools, colleges, and universities. That is happening because of the hard work and leadership all of you here today are providing.

You probably already know that NSF is committed to inquiry-based learning in mathematics and science at all levels—from kindergarten through graduate school. The NSF Strategic Plan includes this under the rubric of the integration of research and education. In simple terms, this means learning by doing, getting your hands dirty, experiencing the excitement of the discovery process, and bringing something of the culture and practice of research into the classroom.

We have already established a number of programs that promote the integration of research and education. The CAREER program is aimed at young faculty. We support a number of programs at the disciplinary and departmental level. We have also established a new activity, Recognition Awards for the Integration of Research and Education, that focuses specifically on research universities. The Division of Undergraduate Education's Institution-Wide Reform program has also emerged as a vital part of our overall efforts.

As we look to the future, we expect that employers will seek people who not only are well versed in science and technology concepts, but also are adept at learning through experimentation, inquiry, critical examination, and discovery—all characteristics of research. Harold Raveche, the President of Stevens Institute of Technology in New Jersey, summed this up in an op-ed that ran in *The New York Times* a few months ago. He wrote, "employers today are seeking a highly *trainable* work force, rather than just a highly trained work force."

In his recent bestseller, the famous economist, Lester Thurow put this another way, writing that: "Americans are not used to a world where ordinary production workers have to have mathematical skills." I would add that we are also not used to a world where nurses, auto mechanics, farmers, and other front-line employees need the kind of critical thinking skills that one best acquires through research.

Because of this, NSF is committed to seeing that all students gain the skills and tools they need to deal with the complex and the unpredictable, regardless of where their careers eventually take them. We know it can be done, and in the decade since the Neal report, we have seen it done. Calculus has been perhaps the biggest success story, but it is far from the only one. I am sure you will share countless others here this week.

To conclude, I would just like to say once again that now is the time for all of us—and by that I include NSF, our partners in government and industry, and all the institutions we support ... now is the time for all of us to raise our sights and commit ourselves to institution-wide reform. As I said earlier in my talk, this is a monumental challenge, but it also presents us with a monumental opportunity.

Many of us have waited years to pursue a vision like the one presented in the review committee's report. It is a vision that reaches all students and taps their natural sense of wonder and curiosity. You should know that NSF is committed to working with you to help fulfill this vision.

I realize it may have been somewhat cruel and unusual of us to call you to Washington in the middle of July. But I, for one, can think of no better time for us to turn up the heat and shed new light on how best to revitalize undergraduate education.

PLENARY SESSION III:
The NSF Review of Undergraduate Education and the NRC "Year of Dialogue"

Moderator:

Luther S. Williams

NSF Assistant Director for Education and Human Resources

Dialogue:

Melvin George

Chair, NSF EHR Advisory Subcommittee for Review of Undergraduate Education

Donald Kennedy

Chair, NRC Center for Science, Mathematics and Engineering Education

During Plenary Session III, conferees listened to two distinguished educators discuss the essential conclusions of the respective reports by NSF and NRC that provided the intellectual underpinnings for this conference. (See Appendix A for more details about the conduct of these reports.) Melvin George was the principal author of *Shaping the Future: New Expectations for Undergraduate Education in Science, Mathematics, Engineering and Technology* (NSF 96-139). Donald Kennedy chaired the Steering Committee that hosted the Convocation at the National Research Council that produced *From Analysis to Action: Undergraduate Education in Science, Mathematics, Engineering, and Technology* (National Academy Press, 1996). During 1995-1996, Melvin George and Donald Kennedy worked closely together in order to solicit opinion and information from diverse institutions across the nation.

Donald Kennedy. I think undergraduate education, particularly in the sciences, is being revolutionized in the research universities. Why pay particular attention to that? It never left the center in many other places represented here. But it is important that new and exciting things are happening with science education in the research universities. That's where the culture is germinated. Unless we can change that part of the system, the rest will be slower to change than we would like. That's why the National Academy of Sciences is involved. To change that piece of the culture, we are going to engage the national leadership of science in a new way.

Melvin George. Luther's charge to our committee was to look at the needs of all students in all institutions. I want to stress that, because people, no matter how many times a year they may say, "All students in all institutions"—most tend to think about their majors in their institutions. That's a very small part of the audience we are trying to reach, the public we are trying to deal with. I mean *all* institutions—research institutions, community colleges, big city campuses, rural four-year liberal arts institutions—and all students in all institutions. That was our charge—to consider their needs and the needs of the society they will be part of in the next century.

Kennedy. You should not have to miss a good science experience just because you are not majoring in science. If broadly educating a citizenry is important to us, we must be as concerned about what we do for students who will not go on in science as we are about those who will.

Mel George, Chair of the committee for the Shaping the Future report

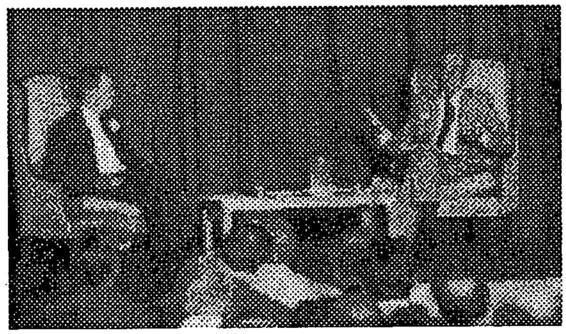
George. As Don said, this has been very much a collaborative effort. There has been a wonderful convergence of views of many disparate people. And they have come to basically the same kinds of conclusions about what ought to be done. That, in itself, is remarkable and reassuring. We tried hard to listen, to find out what was happening in our institutions, with our students and faculty, in business and industry, what our partners outside institutions said about us, and to make sense of it so we could move forward. We had a wonderful session with employers who told us what they look for in our graduates and do not always find. And what they hoped we might do cooperatively with them to address the need for a different kind of workforce than existed even 10 years ago. We asked student focus groups on four campuses about their experiences in science education. What did they think about the science courses they had? What was their experience in mathematics? A workshop of social scientists helped us understand what is known about human learning. Finally, we have read reports that have come out over the last few years about the status of U.S. science education.

My report has a lot devoted to faculty—it is by individual faculty in individual classrooms or laboratories that things happen. The first recommendation the committee makes is that faculty should believe that every student should learn. That's an important attitudinal shift. I believe expectations have a lot to do with performance. The truest piece of educational research ever done indicates that what you believe, and help students believe they can do, powerfully influences how much they learn. Departments are the fundamental unit in universities. They ought to become places where people talk about learning and have expectations for students. How many of you have been in a department meeting where what the department expected its undergraduates to learn was seriously discussed?

Kennedy. One thing not being done in many places is to evaluate the performance of departments or programs "in the round." What is the total output to department teaching effort? What attention is given to balancing the whole curriculum? Does the curriculum attend to non-majors *and* majors? What does the whole thing look like? What is the reward system for department or program units? There is a shortage of the education venture's collective accountability. Until that problem is solved, we will continue to have trouble getting where we want to go. One of the strongest foci of the Academy Convocation and regional follow-ups was attention to the question of balance between teaching and research in terms of how institutions attend to and reward faculty activities. That there is a problem in higher education with respect to that balance is not exactly hot news. But we think there is a wonderful opportunity now to address it in new and creative ways—to expand the definition of legitimate scholarship and to think about new ways to enliven the educational venture with opportunities for investigative work.

George. This recommendation, that SME&T is important for all students and should be provided in supportive, excellent programs that include direct experience with inquiry, is really a framework for both reports. I am reminded of one of my favorite stories, about the grasshopper and the cockroach who met on the Iowa lawn one October. The grasshopper said to the cockroach, "It is about to be winter and you're going inside the kitchen of that house to live. I, on the other hand, am going to die and that's not fair." The cockroach agreed it was not fair. The grasshopper said, "What can I do about it?" The cockroach thought and said, "I have an idea. Why don't you turn yourself into a cockroach?" The grasshopper said, "That's a wonderful idea," and hopped off, stopped, turned, hopped back and said, "Wait. How do I do that?" The cockroach said, "I don't have the foggiest idea. I just make policy." One might say about this recommendation that it sounds wonderful but how do you do that? So the substance of both reports is to make specific recommendations to specific groups of people, agencies, organizations and individuals about how to make progress.

Kennedy. I came away with was a much deeper sense than I had going in of what I would call the democracy—or demography—of innovation. There are extraordinary ideas everywhere. One of the amazing things about innovation in science education is how poor the contagion is compared to the quality of innovation and invention. Terrific ideas are made to happen. But compared to the speed with which results travel from one lab to another halfway around the world in the research domain, transmitting good ideas about science education is much slower. One reason for being engaged in this effort is to try to improve the contagion and make it possible for a good idea to move from Point A to Point B a little faster.



Mel George (left) and Don Kennedy summarize the year of dialogue on undergraduate education

George. We hope people will understand that an investment is needed to move us from the plateau we have reached after many years of hard work. We need to improve dissemination. There are few things the community said more strongly—that we need ways to spread ideas, to help people know and get excited about what is happening. Finally, we need ways to direct assistance to faculty and departments that struggle with these issues. When we talk about collaborative learning, some people say, "I lecture in a room with fixed chairs seating 500 people. I don't know how to do collaborative learning in that setting." There *are* people who know how to do collaborative learning in that setting and we need to find ways, Don, using NSF and NRC, to help those who seek answers.

Kennedy. I think it is a lot harder to teach introductory biology to non-majors than it is to teach it to students that have the calling, or are hellbent for medical school. You really have to make it interesting and challenging, and think hard about what you want to leave with them.

George. One memorable quote from a hearing at NSF came from a geoscientist who said, "My attitude about teaching introductory geoscience changed dramatically the day that I recognized that, for 90 percent of students in that course, it is not an introductory course, it is a *terminal* course. It is the last experience they will ever have of science ." She added, "I've thought about that course in a fundamentally different way since that moment of revelation." We've focused a lot of attention on changing K-12 education. But those teachers are prepared at the undergraduate level. We certify people to go out and teach K-12 at the undergraduate level. In most cases, on most campuses, there is very little dialogue between science departments and people in colleges of education. There is not much joint thinking about what it takes to produce a teacher who can energize students with the joy, excitement and fun of science.

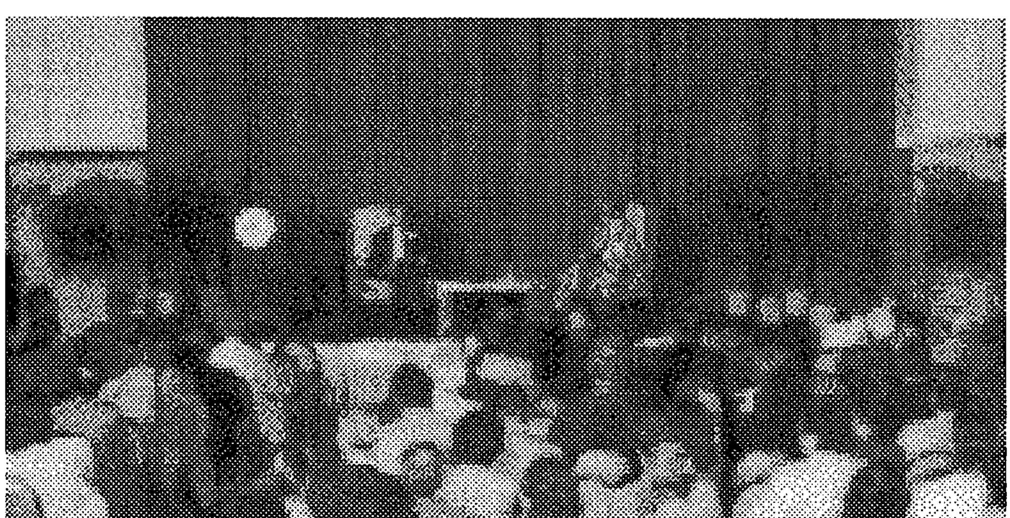
One thing I learned doing this study is how much good has happened over 10 years. I hope no one reads our reports as doom and gloom statements about the present situation. So much good has happened that I think our vision of what we could do has expanded. That's part of our problem and it was reflected in the responses to Luther's letter. It was fascinating to see how many times the same things were mentioned as improvements *and* barriers. People would write, "One of the great improvements in the last 10 years is the increased availability of technology in the classroom." A page later the person would say, "One of the greatest barriers is that we don't adequately use the full range of available technology." We've made enough progress to see what can be done, and that's whetted the community's appetite to do it better and, for all students in all institutions, more effectively. It is a point that's been very interesting—the glass is half empty and half full.

We expect things to happen as a result of these recommendations, which have much in common. We regard this conference as part of the implementation of our reports. There are teams here from 50 different institutions around the country. One thing we very much hope is that—as they go back with institutional plans, informed by the recommendations of our reports—we will find seeds scattered around the country that will become models for other institutions. That's one way this "disease" will spread.

Kennedy. Making changes in academic institutions isn't easy. The process of getting agreements then moving ahead must be thought through. We think bringing people from each sector together and giving them a chance to create a template for undergraduate science education reform was essential. I've found it very rewarding.

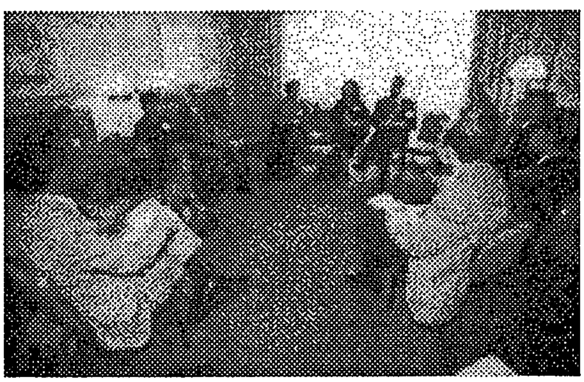
George. We have to look to a locus of responsibility, and it seems the Academy and NSF in partnership are the ones who can keep the heat on and turn the light up so students and, ultimately, society will benefit.

Luther Williams. [To follow up on Mel George's comment], we are in the early stages of creating a structure for math, science, engineering and technology education by which the academy, NSF and other Federal agencies will do what you describe. The intent is to make sure we deliver on this.



BREAKOUT SESSIONS
Introduction

This working conference was designed to meet several goals, which might generically fall into three categories. One objective was to share information and recommendations that had grown out of the NSF and NRC review processes, both of which were very inclusive of the academic, scientific and technical community. The plenary conference sessions were designed with this objective in mind. A second objective was to allow participants to exchange information. Collectively, the participants were drawn from institutions and programs that were engaged in a large number of exciting new developments. This conference was an opportunity to connect them, and afford them opportunities to describe reform efforts underway on their campuses. A third objective was to continue the dialogue about reform that we had initiated as part of the review processes, and to solicit further ideas, opinions, experiences and beliefs about valuable next steps. The four breakout sessions were designed in pursuit of these latter two objectives.



Conference participants discuss the revitalization of undergraduate education

These breakout sessions were designed after considerable discussion among members of the NSF and NRC staffs, and with input from representatives from 50 institutions engaged in reform efforts, who experimentally engaged in breakout discussions in early May to test the potential of various approaches, and to ensure the completeness of topics covered. A major design consideration was achieving a balance between "vision" and the details necessary for successful implementation. The variety of institutions participating in this conference made it imperative to allow room for a range of reform models to be described, examined, and discussed.

BREAKOUT SESSION I:
Basic Premises: The Needs and Goals for Institution-Wide Reform

On the vision side, it was clearly important to discuss the need for institution-wide reform. This was a natural lead-off issue. Participants were assigned to breakout groups according to their type of institution, in the belief that differences in need across different types of institutions might be quite high.

In this breakout session, participants collectively considered several "model" institutional strategies for comprehensive reform—with a focus on the reasons why institution-wide reform is needed and the goals for reform. Breakout session activities were based on seminal background material consisting of two-page descriptions of institutional plans provided in advance by approximately 50 institutions (See Appendix B). The strategies were be considered with a view towards prompting critical self-examination of the needs and goals for institution-wide reform at participants' own institutions. For each breakout group, one such strategy was used as a case study to initiate discussion. The results from this breakout provided informed consideration for the subsequent breakout session (effective practices that can serve as common themes or practices in institution-wide reform).

Questions for this Session:

1. From your perspective, why is institution-wide reform needed?
2. What are the goals of institution-wide reform?
3. How will we know when institution-wide reform efforts or activities are leading in the right direction?

BREAKOUT SESSION Ia:
Perspectives from Industry/Employers

At the same time as Breakout Session I, above, a second session was convened to address the particular perspectives of industry representatives and employers.

Questions for this Session:

1. Dealing with Change

How can industry and other employers—such as school districts and government agencies—better communicate to academe the rapidly changing nature of the workplace, where most undergraduates will become employed?

2. Collaboration Issues

2a. How can industry leverage its ongoing investment in undergraduate education with other companies, foundations, other government agencies, and the NSF?

2b. How can industry make their expertise, knowledge, equipment, and tool-rich environments more accessible to academe?

2c. Is the issue of company proprietary knowledge of products and processes important? If so, what methods can be used to protect these?

3. Student Demographics

What are the implications of the changing demographics of the U.S. undergraduate student population (for example, increased numbers of mature students and students from underrepresented groups)?

4. Faculty Reward System

How can the faculty reward system be improved to encourage/promote stronger faculty involvement in education (K-16) and in industry interactions?

BREAKOUT SESSION II:

Effective Practices and Collaborations: A Base for Institution-Wide Reform

As part of its ongoing effort to improve undergraduate education, and enlightened by the NSF and NRC reports from which this conference arose, NSF staff believed that it was important to give participants a chance to discuss the promising building blocks of institution-wide reform. The result was "Effective Practices and Collaborations: A Base for Institution-Wide Reform." The primary objective in the assignment of participants to this second breakout was to ensure wide coverage of improvements in order to connect participants with new ideas.

In this session, participants met in 30 small groups to identify and discuss effective practices and collaborations that are principal reasons for engaging in reform. Conference participants were distributed broadly by type within each of these groups in order to maximize opportunities for cross-fertilization of ideas among institutions and participant types. Participants became acquainted with effective practices being nurtured in other institutions represented in their respective breakout groups, and established the contexts in which these effective practices will take place.

Effective teaching practices in SME&T are frequently defined as "student-centered" and "inquiry-based." They *actively* engage students in learning, build on contexts that are familiar to students, provide a sense of the importance of the knowledge being developed by connecting it to societal issues and fascinating problems, and provide students with ready access to feedback from faculty, graduate students, and other experienced people. In addition, some effective practices provide students opportunities to experience directly the methods and processes of inquiry, employ methods of collaborative learning, and develop interdisciplinary connections that strengthen students' grasp of the knowledge.

Effective practices also meet the needs of employers and society by educating graduates who—in addition to specialized knowledge—have developed strong cognitive skills (ability to solve problems, make decisions and continue to learn), social skills (ability to work in teams and communicate effectively), and positive personal traits (e.g., adaptability and flexibility).

The ultimate judgment of "effectiveness," however, was made on the basis of hard assessments of gains in: *student learning*, particularly long-term gains; *skills and knowledge* of value to society, employers, and robust lifelong learning abilities; and *broad measures* of academic productivity, taking into account total learning and costs.

Questions for this Session:

1. Discuss effective teaching practices with which you are familiar that exhibit some of these features. What is their current extent of use?

2. What is the role of information technology and education technology in improving the quality of learning on your campus (and on other campuses)?

3. Do you consider it possible to conduct large lecture courses in ways that allow them to be effective, exhibiting some of the features listed above?

4. What are some barriers to fuller use of effective practices? At the faculty level? At the departmental level? At the college or institution-wide level? What are the critical roles of sponsors of education innovation, such as federal funding agencies and private foundations?

5. Are there effective teaching practices in SME&T education available to all students; including those traditionally underrepresented in SME&T and those who historically may not have been a priority in SME&T education, such as future teachers, non-SME&T majors and future technologists?

6. Should academic institutions and their faculties be responsive to the putative needs of employers and "society" as long as these needs are defined in general cognitive and social terms, as above? In what ways?

7. What kinds of processes inform faculty about the needs of employers and society?

8. What constitutes strong or indisputable evidence of improved learning by undergraduates?

BREAKOUT SESSION III:

Facing Challenges: Strategies for Institution-Wide Reform

At this point in the conference, the focus was shifted to designing strategies for effective institution-wide reform in the participating institutions. The third breakout session examined *strategies* for institution-wide reform. True reform requires an array of changes in an institution's internal organization and processes, and in its reward system. Because change is never easy, the focus of this breakout was to consider the range of strategies employed in actual cases of reform, by building these sessions around the participating institutional teams. However, brainstorming was definitely encouraged.

The purpose of this session was to identify strategies to meet the challenges facing institution-wide reform, building on insights gained during previous sessions. The format of the session was for each team to give a brief overview of their plan. Each group consisted of one or two institutional teams and additional participants not representing teams, with the types of institutions represented. The participants focused on each team plan in turn, serving as consultants to make suggestions and comment regarding the challenges and strategies. This initial discussion provided a foundation for a broader discussion of guiding principles and effective strategies for institution-wide reform. Perspectives of individuals outside of academia, such as employers and public policy makers, were important to consider in this discussion.

Some principles which guide institution-wide reform might include, for example: 1) all students can learn; 2) all faculty should be effective educators; 3) institutional structures should support development of a coherent curriculum and undergraduate experience, encouraging cross-disciplinary and departmental interactions; 4) perspectives of all stakeholders, including students and prospective employers, should be well represented.

Questions for this Session:

For the institutional plans discussed—

1. What are the guiding principles for the institution-wide reform?

2. What are the effective strategies for the institution-wide reform, and what additional strategies are suggested?

For institution-wide reform more generally—

3. What are other guiding principles for institution-wide reform?

4. What other strategies for institution-wide reform will be most effective ?

BREAKOUT SESSION IV: *Institution-Wide Reform: Towards a Coherent Plan*

Achieving a coherent plan of reform is known to be difficult. In order to focus the idea of *coherence*, and to continue the discussion of the spectrum of changes that are needed to support reform, these breakout sessions were built around actual reform plans being undertaken by participating teams. The institutional teams present outlined their plans, which became the focus of discussions in these breakout groups. The prime focus was on strengthening these current reform efforts and initiatives.

The fourth breakout session focused on institutional teams gathering in groups from similar institution types. Two or three teams were assigned to each group to maximize the opportunities for discussion, along with other participants from the public and private sector). Each group presented brief overviews of their institutional plans, based on their preparatory work and informed by the activities of the previous sessions (e.g., surveys of "effective practices," institutional strategies discussed by a random mix of participants, or institutional teams interacting with teams from different types of institutions).

Breakout groups from similar institution types were expected to have similar needs and opportunities. The intent of this session was to help these groups identify common themes among their institutions, to present institutional plans for consideration by groups from similar situations, and to develop communication networks that would continue beyond the conference. Participants from the public and private sector served as consultants to these predominately academic groups to provide insights into the needs and concerns of potential employers and of the society at large.

The institutional plans were distilled and reported at the final plenary session of the conferences, and the revised institutional plans were submitted for the final workshop report.

The questions presented below derive from input by numerous sources about important aspects of institution-wide reform. These questions address common concerns and were meant to guide and inform the discussions in the breakout session. To ensure that the full range of questions were addressed, each breakout session was assigned a specific question to initiate the discussion. Participants were not expected to cover all of these questions, and during the course of the breakout session they were free to explore any of these or issues of related interest to the group.

Questions for this Session:

1. How are these plans consistent with the institutional mission(s)? Is there a coherent implementation plan to meet the needs of all students, faculty, and the community that this institution will serve? Is there a shared institutional vision regarding reform on your campus? What communication mechanisms have been established between the numerous stakeholders who will be affected by this plan? How will you measure the success of the reform effort?

2. What institutional human, physical and fiscal resources will be needed for the planned institution-wide reform? How will your institution reallocate resources to implement this plan? What is the long-range planning process in operation at your institution? Is your plan flexible enough to meet the changing needs of students, industry, and other stakeholders?

3. Are all of the stakeholders involved in the reform process? What plans are in place to a) deliver administrative support; b) recruit, train and, reward present and future faculty; c) best meet the needs of students; and d) involve the community in this reform effort? How will this plan improve learning by students at your institution?

4. What are the potential impacts of this plan at your institution (e.g. on the culture, resources, etc.)? How do these plans meet the needs of the public (national, state, and local) and private (industry and business) sectors? How will you resolve conflicts between priorities of these groups?

5. What impact will your institution's plan for reform have beyond your campus (e.g., K-12 schools, industry)? Is the plan adaptable, or can it be adopted at other institutions, and how will you help transfer your experience to other institutions?

6. What are the barriers for implementation of these plans? (e.g., political issues and cultural barriers, how to handle resistance and suggested techniques for inducing active participation from all stakeholders, financing, building flexibility into the plans, the introduction and use of information technology in the plan, etc.). What concrete advice can you offer to help facilitate implementation of these plans?

PLENARY SESSION IV:
Institution-Wide Reform: Towards a Coherent Plan

Moderator:
Donald Kennedy

Chair, NRC Center for Science, Mathematics and Engineering Education

Introduction of Bruce Alberts

It is my happy duty to introduce the boss of this place, Bruce Alberts. He needs very little introduction to you, but I want to say a couple of things about him whether you need it or not. What I want to tell you is that he has caused a real revolution in the concerns of the Academy and matters that bring us here today. Bruce was educated at Harvard. He was a faculty member at Princeton before he was lured away to the Bay area, as people have a way of being. He became a professor at the University of California - San Francisco. There he not only participated in the building of a basic science research center at the University, but he led the establishment of a firm relationship with that faculty and the schools of San Francisco. There he not only developed an interest in primary and secondary science education but as a consequence it has affected his work at the Academy. He did it in the trenches before he ever got here and he did it as a faculty volunteer. So, his concern comes very much from the heart and it has produced a real impact in this town and on the science establishment of this country. I'm very proud to introduce him this afternoon, NAS President Bruce Alberts.

Bruce M. Alberts

President, National Academy of Sciences

Thank you, it is a pleasure to welcome you to our home. I always take these special occasions to explain briefly who we are. The National Academy of Sciences is an unusual organization among all the academies of sciences in the world. Although there are approximately eighty such Academies now, we received a unique charter from Abraham Lincoln in 1863. This charter gave us the right to be a privately incorporated entity. But it also says that we shall advise the government at no compensation whatsoever.

This mandate launched a volunteer tradition of which we are very proud. Today more than 6,000 volunteers are involved in a large variety of different committees. We publish over 200 reports a year, covering everything from global warming to what we should do with plutonium from the nuclear weapons that are being dismantled. Under our charter, the National Academy of Engineering and the Institute of Medicine were subsequently established. Together we run an institution called the National Research Council, which is our "operating arm."

As Don Kennedy implied earlier, education has been a major concern of the National Research Council. We now have a Center for Science, Mathematics, and Engineering Education. Don chairs the Center as a volunteer. Rodger Bybee is the Center's Executive Director. The Center has several different divisions. One of these is the National Science Resources Center, shared with the Smithsonian Institution, and headed by Doug Lapp. The Division on Educational Policy, Research, Assessment, and Evaluation is headed by Sandy Wigdor; it brings the research

National Academy of Sciences President Bruce Alberts

community into this enterprise—in particular, educational research. The two remaining divisions are the Division on K-12 Policy and Practice and the Division on Postsecondary Policy and Practice involving mathematics, science, and engineering.

This morning you heard Don Kennedy and Melvin George discuss two reports—the NRC's Convocation report on undergraduate science education and the subsequent Year of Dialogue, and the National Science Foundation's review of undergraduate education. Rather than discuss those activities further, I would like to describe some other activities and, while doing so, emphasize how they are related to the focus of this meeting—undergraduate science, mathematics, engineering, and technology education.

As many of you may know, the National Research Council undertook a massive effort in 1991 to produce the *National Science Education Standards*. The *Standards* were completed in December 1995, the result of a project that involved thousands of people. It is a book of 250 pages. You can buy it, of course, but it is also available free at the Academy's Web site. The *Standards* were produced in response to the governors of our fifty states, who in 1989 asked for national standards in major curriculum areas. The *National Science Education Standards* outline what students need to know, understand, and do in order to be scientifically literate. They do so at three different grade levels: kindergarten through 4th grade, 5th through 8th grade, and 9th through 12th grade. Incidentally, the question of whether we should also develop similar standards for what all college graduates should know needs some serious thought.

The *Standards* are really a revolutionary document. For me, they present three bottom lines:

- Science should not be viewed as an optional, add-on activity. I can remember a year when my children had a choice between shop, band, or science. Science must become a core subject in every year of school starting in kindergarten. This is already true in Great Britain. It needs to be true in the United States as well.

- Science is a subject to be learned by all and understood by all. The abilities and understandings of science have great power for many different areas of everyone's life, as this audience will certainly understand.

- And, finally, the reason the *Standards* are so revolutionary is that we are not talking about science as science words, the kind of science that we test for on most of our standardized exams. Instead, we are talking about science as inquiry-based learning.

To understand more about the *Standards*, let me explain how they are organized. There are eight different Content Standards, beginning with a science inquiry standard. In addition to the major divisions of science—life science, physical science, and earth and space science—there are connections to all the things that kids worry about: Science and Technology, and Science and Societal Challenges standards.

The inquiry issue is crucial. Included as scientific inquiry is the ability to:

- identify questions and concepts that guide scientific investigation;

- design and conduct scientific investigations;
- use technology and mathematics to improve investigations and communications;
- formulate and revise scientific explanations and models using logic and evidence;
- recognize and analyze alternative explanations and models; and last, but not least,
- communicate and defend a scientific argument.

This ability to inquire is what we want for all students by the time they reach 12th grade. Today, even at the end of college we are far from this goal.

The *Standards* are best understood by looking at some of the outstanding curricula that are available. Many such materials exist for our elementary schools. For example, the National Science Resources Center has developed 24 eight-week units for use for 1st through 6th grade on various science topics. These are not textbooks. Although they include a brief pamphlet for the students, these are primarily exercises involving inquiry that center around a box of materials for the teacher to use with a class of 30 students. This is the type of well-researched, teacher-tested science curricula that we need at all levels. It also represents the type of investigation that we need to offer everyone in college.

I often tell a personal story about how, after three years as a science major at Harvard, I could not tolerate my science laboratories anymore. I never liked cooking and that was all I was doing in labs—following a recipe as if I was cooking. When I successfully petitioned out of physical chemistry laboratory, they told me that there was no way to understand the course without it. In fact, as far as I could tell, the laboratory had nothing to do with the course and I did quite well without it. Not until I got a chance to work in a research laboratory for the summer did I end up wanting to be a scientist rather than a doctor.

In my opinion, we need to give all college students the opportunity to solve problems in their laboratories through scientific inquiry. I would like to convince Doug Lapp, who directs the National Science Resources Center, to try to make a few boxes of materials like the ones he produced for elementary school science for college. I bet we could do it much more efficiently and at much lower cost, while leaving students much more excited about science. What is needed are laboratory exercises that are relatively modest with regard to materials needed, but which involve much more active problem solving and independence on the part of the students than do our usual college labs.

I have talked so far about only one chapter of the *Standards*—the Science Content chapter. This is really what the governors wanted, what students should know at the end of 4th, 8th, and 12th grade in all kinds of science. The hundreds of people who developed the *Standards* were science teachers and scientists, including 40 members of the Academy. They realized that we were calling for a radical change by stressing science as inquiry, and that we need to change all other parts of the system as well. They therefore developed standards for those other parts: teaching, professional development, assessment, and so on. For example, if we do not change the way we test students for science accomplishment, we cannot expect teachers to teach differently. Today, we mainly test for associations between science words when we test students in biology, for instance—on the SAT II exams for college entrance. There is no way that a teacher can teach biology well according to the *Standards*, with time for exploring subjects in depth, especially if they teach in a district where the parents are mainly focusing on getting their kids into good colleges and high exam scores are a major goal.

What are the challenges of the *Standards* for our colleges and universities? How are we going to change college science education to remove the striking inconsistency between the new standards for K-12 science education and the present messages about K-12 education emanating from our schools of higher education? There are many challenges, because a great deal of change is needed in my opinion.

1. We need to align university admission policies with the *Standards*. I already mentioned the biology SAT II exam. If you looked at the study guides for that exam, you would be horrified by all of the detail we expect students to know about biology after one year. There is no way that a student can understand anything meaningful about biology if they get all that material thrown at them. As long as universities do not change what they require in the way of science skills for entry, we are not going to have substantial change at the pre-college level, and we are going to continue to alienate huge numbers of students from science.

2. Our first-year college courses also need to be aligned with the *Standards*. Students who come from a good high school science program emphasizing science as inquiry will be shocked by a typical Biology I class in which they experience cookbook laboratories, and are expected to memorize the Krebs cycle, glycolysis, and so on. What are they going to do? Many of them are going to drop out of science again. If inquiry-based learning is best for pre-college by everyone's admission, why should it suddenly change when you enter college? We must introduce institutional rewards for those college faculty who initiate and support innovative new science courses based on inquiry and recognize this as a scholarly contribution.

3. As a nation, we need to recruit a large number of scientifically trained young people into the pre-college teaching profession. We have a great shortage of such people now and we will desperately need many more if we are going to make science a core subject in every year in school, as called for in the *Standards*. We must provide support for those science majors who are considering a career as a science teacher. Every campus has a pre-medical advisor and puts major resources into helping premeds; we must do the same for aspiring teachers. As part of this support, outstanding local K-12 science teachers should be visibly respected on the campus.

4. We need to provide programs that allow science students to become certified as science teachers as part of their normal curriculum. Both MIT and Harvard now have such programs. If they can do it, why can't every other college or university?

I would like to extend this point more broadly by talking about something that concerns the Academy a great deal—the "oversupply" of scientists. We only have an oversupply of scientists if you expect that there is only one thing for scientists to do—research. We badly need scientists in many other places—journalism, government, law, and of course, pre-college science teaching. It is incumbent upon our college science departments and faculty to change our expectations and our rewards for our students. Too often we give our students the impression that they will have failed if they do anything else except research. That is no longer a tenable position, even for the good students. There are not enough research positions for them all, and their scientific training will serve them and their communities very well in many different professions.

Because it is in all our interests to help young scientists use their talents most productively, the Academies have recently produced a little booklet called "Careers In Science and Engineering" (which is available at www.nap.edu/readingroom/books/careers). It provides advice on how students should plan their careers, making the point that there are many vocations where they can employ their science talents.

We also try to help them find those careers. On our Internet site, we have established a career planning center for beginning scientists (www2.nas.edu/cpc/index.html) that is aimed at both research and non-research careers. We provide information about different careers, and also try to connect students and other people seeking science and engineering advice with real people who have those careers, so they can have an electronic dialogue that will help them make wise choices.

Let me finish with this photograph of the front page of "The Scientist" from several years ago. According to the first headline: "Job market for researchers will remain sluggish in both academia and industry, observers predict." Just below this article, by chance, starts a second article with the headline, "NSF study finds many teachers unprepared for instructing children in the sciences." This is the situation we are in today. So, we have a very big task ahead. The people in this room have a major part to play and the Academy plans to be there to help in any way we can. I hope you will keep in touch with us and let us know how we can help you. Thank you.

Introduction of Clarence Eidt

The National Science Foundation and the National Academy of Sciences have been partners in this venture for some time, but another important partner illustrates the value of getting the private and public sectors and independent organizations working together on this difficult problem—the Exxon Corporation and the Exxon Education Foundation. We are fortunate today to have Clarence Eidt, president of Exxon Research and Engineering Company, the research-intensive subsidiary of Exxon Corp. Clarence and his division headquarters are in Florham Park, New Jersey, where they develop, process and produce engineering technology and conduct research to expand Exxon's science base. His division employs 250,000 scientists in New Jersey and at Exxon research sites around the world. He received bachelor of science and master's degrees in chemical engineering and a distinguished alumnus award from Louisiana State University. He's a research administrator and has several patents of his own.

Institution-Wide Reform: Toward a Coherent Plan

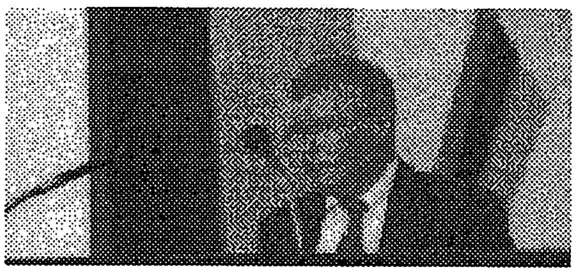
Clarence M. Eidt, Jr.

President, Exxon Research and Engineering Company

Thank you, Don. It is certainly a pleasure for me to be here today. On behalf of Exxon Corporation and the Exxon Education Foundation, I would like to welcome all of you to this important conference. Much of the momentum for reform in undergraduate science, engineering, and mathematics education has been and will continue to be provided by those gathered in this room, and that makes you a very important group of people, indeed.

Why does Exxon care about science and engineering education? The obvious answer is that scientists and engineers and other technically trained personnel form the cornerstone of the Exxon workforce. At Exxon Research and Engineering Company, the organization where I work, fully two-thirds of all of our employees have degrees. It is critical to the future of our business that there be an adequate supply of appropriately prepared science and engineering graduates from which to draw our employees.

"Appropriately prepared" Exxon employees have, of course, mastered the fundamentals of their chosen disciplines. But, they must have other qualities as well. We place a premium on employees who can communicate with those outside their disciplines, including non-scientists and non-engineers, who have the interpersonal skills for teamwork as well as leadership, who have the flexibility to grow and change as needs and demands change, and who will be able to serve the company in many different capacities over the years.



Exxon's Clarence Eidt, Jr.

The more interdisciplinary the content and conduct of science becomes and the faster new technologies evolve, the more important this list of attributes becomes. It is likewise increasingly important that a sound technical education be supplemented by exposure to other fields of study such as history, liberal arts, and the fine arts which help one to understand how technology relates to all aspects of the world in which we live. This is a demanding task, but the kinds of changes being advocated by the National Research Council, the National Science Foundation, and others give us reassurance that American higher education will continue to be able to meet the growing requirements of American industry.

I spoke a moment ago about employees who can serve in a number of different capacities. At Exxon, we have literally thousands of people with science or engineering backgrounds who work in areas outside their fields of academic training—as managers, marketers, business analysts, public affairs specialists—and even philanthropists. It is also not unusual to find new B.S. degree-holders in such departments as the Treasurer, the Controller, Human Resources, and Land Management. Our own experience has taught us that the educational base and habits of mind instilled by the study of science and engineering can be effective general preparation for many areas of endeavor. We are glad that a growing number of voices are pointing this out, and we agree, too, with related recommendations that courses in science and technology become part of the regular curriculum in fields like economics, political science, journalism, and so forth.

This brings me to the other reason Exxon cares deeply about science and engineering education: The monumental importance of public understanding of science and technology—usually referred to as science literacy—to the future of our country and the well-being of its citizens, which includes its corporate citizens. Sound public policy decisions are based on an understanding of the issues and objective analysis of the likely consequences of alternative options. Unfortunately, many Americans' ability to come to reasoned conclusions about issues involving science and technology is not keeping pace with the growing complexity of such issues. One reason—the one that brings us here—is that colleges and universities have been graduating students who do not understand the fundamentals of science and the nature of the scientific process. This lack of scientific literacy makes them susceptible to hype and hyperbole. I think we have all seen examples of public policies that have been implemented not because they were the wisest option, but because they were being championed by the loudest voices. The costs associated with this approach can be enormous.

Our concern for the science literacy of liberal arts students, as well as the liberal learning of scientists and engineers I mentioned earlier, dates back many years. It is documented historically in the programs of the Exxon Education Foundation, which has been the vehicle for Exxon's educational philanthropy for more than 40 years. As many of you know, the Foundation is continuing that tradition with a new grant program dedicated to facilitating undergraduate science, mathematics, and engineering education reform. Among other activities, this program funded the 1995 NRC Convocation and the subsequent Year of National Dialogue.

We are here to recognize and release the final document from the Convocation. I would like to call your attention to some of the highlights of this document. First, I think it is significant that such a diverse group of 250 Convocation participants quickly came to the consensus that a good science education can be sound preparation for a wide variety of societal roles and that the nation will depend increasingly on a citizenry with a solid base of scientific and technical understanding. As such, the fundamental recommendation of the assembled group is as follows: All students should have access to supportive, excellent programs in science, mathematics, engineering, and technology, and all students should acquire literacy in these subjects by direct experience with the methods and processes of inquiry. Let me emphasize the word "all" in this recommendation. All students means both science and non-science majors.

The participants also addressed how faculty and institutions can work both separately and together for effective change. The need for interaction between departments and institutions received considerable attention, as did the critical need for institutions to promote a new balance and linkage between teaching and research.

The final conclusion from the Convocation expands on the need to enliven teaching by investigation and to reward faculty for educational scholarship by noting that: Institutions and departments should promote educational innovation both through broad cultural change and through providing the resources and support needed for effective teaching. Change requires ongoing discussion between individuals and institutions that will reinforce and drive reform. Toward that end, the Exxon Education Foundation has sponsored the dissemination of this report to every college and university in the country. In addition, the dialogue will continue over the course of the next year with a series of topical forums at meetings of professional societies and higher education organizations. In this connection, the National Research Council has been an effective and active participant in promoting national discussion about the need for reform.

I thank all of you for your contributions to this process and the effort you have invested thus far. We still have a long way to go, but with each of you as active partners, we are confident that tomorrow's students will be better equipped to deal with increasingly complex societal issues—science and technology oriented and otherwise. I would especially like to thank the members of the steering committee who are with us today and the staff at the National Research Council and the National Science Foundation who work behind the scenes. I would also like to point out that under the presidency of Dr. Bruce Alberts, the National Research Council established the Center for Science, Mathematics, and Engineering Education, which will be a strong force in guiding the desired reform in undergraduate science education.

We at Exxon are proud to have sponsored the Convocation and the Year of National Dialogue. I know you will have a productive conference and I wish you the best of luck as you continue these discussions over the next two days.

A well-known scientist recently defined science literacy as the ability to ask the right question and know whether you have gotten a real answer. In addition to achieving that goal, he and I—and I am sure many of you—sincerely hope that future generations of Americans will come to appreciate the sheer pleasure of scientific inquiry and learning.

LEGISLATORS ROUNDTABLE

Moderator:

Alfredo G. de los Santos, Jr.

Vice Chancellor for Educational Development, Maricopa Community Colleges.

Panelists:

Andrew W. Nichols

State Representative (Arizona)

Mignon R. Waterman

State Senator (Montana)

David J. Goldston

Legislative Director to Representative Sherwood Boehlert (New York)

Andrew W. Nichols

State Representative (Arizona)

Representative Nichols observed that education, and in particular higher education, is perceived by public policy makers to be increasingly disconnected from the needs of society; in fact, almost irrelevant to social needs. He asked rhetorically: Is education relevant? Is it as good as it could be? Can you have good education that is irrelevant to social needs? Challenging the effectiveness of current practices in education, he paraphrased a Chinese proverb in a revised context: "Go to a lecture and forget; go to a laboratory and remember; go to the community and understand."

Andrew Nichols

He emphasized that "*community* is the word to remember." Employers want graduates educated for the real world and policy makers want educational institutions which can serve societal needs. As a teaching and learning tool, a community-based curriculum serves both these needs and holds the potential for "saving the educational ship of state."

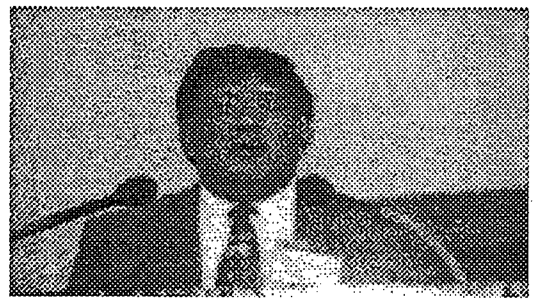
Mignon R. Waterman

State Senator (Montana)

Senator Waterman saw severe conflicts between the "noble efforts" being proposed at the conference and budget realities. In particular, she questioned how institutions can really provide all students access to the quality science, mathematics and technology education being proposed, including direct inquiry experiences. She noted that the infrastructure needs are great, commenting that the "average gas station has more technology than the average K-12 classroom." She also noted that a recent study in Montana showed that if tuition in the state institutions increases at the current rate, by 2010 it will take 20 percent of the average family annual income to pay tuition and fees, and 43 percent if room and board are added.

In terms of increasing resources, she said that, although funding from other sources is critically important, the state legislatures provide the "bulk of your funding." Observing that she does not receive many letters urging her to fund higher education, she challenged the participants to "tell the people what you are doing." This would include engaging media, legislators, and business people and bringing them into the classrooms to build public support. Her final advice was to "talk to us often and in English" because "if legislators do not understand it, they will not fund it."

Mignon Waterman and David Goldston



Moderator Alfredo de los Santos, Jr.

David J. Goldston

Legislative Director to Representative Sherwood Boehlert (New York)

Mr. Goldston stated that the main concern of Congress about undergraduate education is that undergraduate education not be slighted by a federal emphasis on research. Although he does not see an inherent conflict between education and research, there is a general feeling that over the past 40 years attention has been skewed toward research and away from undergraduate education. The concern is how to correct that possible skewing without limiting the country's research capability or disconnecting research and education.

In this context, he observed that it is in a university's interest to be seen as an effective educational institution, as most members of Congress assume colleges and universities are primarily there to educate. Furthermore, "universities communicate through their students." He noted that most Hill staff are 23 and 24 year-old recent college graduates who have an opportunity for immediate impact on Congressional members. In general, it will be today's undergraduate students who will be the citizens influencing future legislation. For the health of the academic enterprise, it is critical that these students have a positive experience. Mr. Goldston concluded that it is in the political interests of colleges and universities to improve undergraduate education "because everything else flows through that."

Question and Answer Period

Q. Jo Yader of the University of Wisconsin, stating that universities have long horizons and legislators have short horizons, asked what can be done to improve understanding between the two groups.

A. Senator Waterman agreed that legislators seem to live from election to election and two year budget cycles discourage long term commitments. However, she advised higher education to build community support, so that the constituency support remains even though a particular legislator may not remain in office.

A. Representative Nichols agreed that the legislative agenda tend to be short term, but "legislators are not the only culprits." He believes that higher education suffers from "mural dyslexia"—it cannot read the handwriting on the wall. He emphasized again the need for education to become a part of the community. He observed that economic development is the long term concern of legislators, and short changing the educational system has a negative impact on economic development.

A. Mr. Goldston suggested that the disconnect motivating the question may be exaggerated. However, he did advise closing the communication gap by inviting members of Congress to campus and having them meet students and visit labs. By forging links when there are no specific issues at stake, a relationship will exist when a particular concern needs to be discussed. Nevertheless, he stated that it is more than just a communication problem, since there are real financial constraints. Institutions should anticipate these financial crises coming and make changes which provide better education with fewer resources. He advised that taking this initiative will strengthen an institution's position with policy makers.

Q. John Vontee of Clinton Community College asked the panel if, given the ascendancy of certain radical political groups, they see legislators and Congress meddling in the educational enterprise to promote a certain political or religious agenda.

A. Representative Nichols expressed concern regarding this issue, commenting that education is in danger of losing policy makers' support by probing intellectually into society's social problems. He gave an example in which the existence of a college course about transvestitism was used as a reason to cut the budget. Noting the "near universal acceptance that tenure is bad," he also expressed concern that the purpose of tenure has been forgotten and we may have to learn it over again. He further warned that we have to be eternally vigilant: "The American Civil Liberties Union said eternal vigilance is the price of liberty; it is also the price of academic freedom."

A. Senator Waterman expressed the need to balance the influence of extreme groups by the general public becoming more involved in government and expressing their opinions on these issues.

A. Mr. Goldston noted that the Air and Space Museum is still "under attack" because of its controversial Hiroshima exhibit. He concurs with the need for 'eternal vigilance' and said that the case for free inquiry must be made before crises occur.

Q. Karl Pister, University of California at Santa Cruz, asked who speaks for the community. He also expressed concern that a large segment of the population—the homeless, the poor, the unemployed—have no voice or political weight.

A. Representative Nichols stated that the "true silent majority" support education, but are not mobilized. However, because "we worship at the altar of economic development," it is important that business and industry speak on behalf of education. He said that legislatures are to serve the homeless, the poor, and the disenfranchised, but they do not participate in the political process.

A. Senator Waterman stressed the importance of education addressing real issues to help the community understand the importance of education and its relevance.

A. Mr. Goldston emphasized the need for the educational community to make the case why its expertise should be respected.

RECEPTION AND RECOGNITION CEREMONY
National Air & Space Museum, Smithsonian Institution

A reception was held at the National Air and Space Museum on the last evening of the conference, providing a festive occasion in celebration of the past achievements and future promise of revitalized undergraduate education. At this event, conference participants had the opportunity for informal discussions in the surroundings afforded by this national tribute to advances in science and technology.

In a plenary session conducted in the Air and Space Museum theater, a recognition ceremony was hosted by Dr. Luther Williams to honor:

- Institutional awardees in the inaugural year of the NSF Initiative: *Institution-wide Reform of Undergraduate Education in Science, Mathematics, Engineering, and Technology Education*
- Corporate and foundation partners for the revitalization of undergraduate education

Institution-Wide Reform of Undergraduate SME&T Education

Twenty three institutions were awarded grants in the inaugural year of the NSF Initiative: *Institution-wide Reform of Undergraduate Education in Science, Mathematics, Engineering, and Technology Education.* According to Dr. Williams, applicants to this Initiative were asked to "present visionary plans for the revitalization of undergraduate education based on significant past institutional achievements." These awards are intended to stimulate changes in institutional culture and infrastructure, and to provide national models of excellence in undergraduate SME&T education.

The awardees are public and private institutions, including two- and four- year colleges and comprehensive and research universities. The twenty three awardees were:

- California Institute of Technology
- California State University-Fullerton
- Clark Atlanta University
- Community College of Philadelphia
- Grinnell College
- Miami University
- Middlesex County College
- New York University
- Northeastern University
- Oakton Community College
- Panola College
- Rensselaer Polytechnic Institute
- Richard Stockton College of New Jersey
- Salish Kootenai College
- St. Andrews Presbyterian College
- Stanford University
- State University of New York - Binghamton
- University of California-Berkeley
- University of Hartford
- University of Michigan-Ann Arbor
- University of Michigan-Dearborn
- University of Rochester
- Wake Technical Community College

"The institution-wide reforms envisioned uphold high academic standards while promoting development of a diversity of individual students to their maximum potential," said NSF Division of Undergraduate Education Director Robert Watson. "A major objective is to help two- and four-year colleges and universities align their curricula with the employment opportunities that await their students as graduates."

"Impressive and broadly representative" is how NSF reviewers described the proposals submitted to the initiative in its first year. For Fiscal Year 1996, NSF made 23 awards of up to $200,000 each to colleges and universities that have demonstrated success in revitalizing undergraduate education on a relatively modest scale and now wish to infuse their entire institution with similar gains. More than 130 institutions submitted applications, including 63 doctorate-granting institutions, 26 comprehensive (masters degree-granting) universities, 24 baccalaureate institutions, and 19 community colleges.

NSF has maintained a broad perspective about what plans for "comprehensive reform" might be submitted by the variety of institution types involved in undergraduate education. All awarded proposals are expected to demonstrate:

- *excellence* in science and technology education
- *national leadership*, by providing an exemplar for sweeping change at institutions of a similar type and education mission
- *visionary thinking* about broad-based change in curriculum and infrastructure that will significantly improve learning and teaching campus-wide
- *balance* in the resources devoted to excellence in both teaching and research that is appropriate for the type of institution; and
- *active involvement* of administrators, faculty, and students from many backgrounds, disciplines, and areas of interest

The awards highlight tangible examples for state legislators, governors, boards of trustees, parents and students that several institutions are responding to the changing needs of their students and of society for their graduates. The ultimate goal of the awards is to benefit all students at institutions undertaking campus-wide reform, preparing graduates who can make valuable, responsible and informed contributions to society, and who can flourish in the increasingly technology-based society of the next century. These inaugural awards have the potential to serve as national exemplars, leading the way in meeting the needs of their own students while providing models for the nation's higher education system, now and for the decades to come.

Corporate and Foundation Partners

Recognizing the need for business and industry partners to achieve excellence in undergraduate education, Dr. Williams reiterated NSF's commitment to forging these partnerships. Through the Memorandum of Understanding, the partners "committed to nurturing the evolution of the highest quality undergraduate science, mathematics, engineering and technology education, and to catalyze working relationships between all parties involved in its delivery and its support." The signers are pledging to pursue a continued partnership, with all participants working to expand the circle of cooperation. Sharing of information on funded projects and exploration of ways to leverage support is already occurring.

Memorandum of Understanding

COMMITMENT TO COOPERATION FOR REVITALIZATION OF THE NATION'S UNDERGRADUATE EDUCATION

In these rapidly changing times, the demands placed on the educational infrastructure of the nation, at all levels, are enormous and growing. This pace of change will continue to encourage cooperative relationships between all of those involved in, and all those who provide support for, the undergraduate education enterprise in the nation.

We, the undersigned, are committed to nurturing the evolution of the highest quality undergraduate science, mathematics, engineering and technology (SME&T) education, and to catalyzing working relationships between all parties involved in its delivery, and its support. Towards this goal we intend to cooperate with our colleagues in other private, government or industry oriented funding organizations that support undergraduate education in the nation. We intend to share information about our funding plans and funding profiles, to work towards common and complete assessment of our funded projects, to encourage the widest possible dissemination of project results, and, when appropriate, to support these projects through cost sharing partnerships. We intend to meet as a group periodically to share successes and to cooperate in developing national strategies in education. Through cooperation, we intend to amplify the impact of our individual efforts.

The National Science Foundation

The Boeing Company
DuPont Company
Exxon Education Foundation
Hewlett-Packard Company
Howard Hughes Medical Institute
Lucent Technologies
Pew Science Program
Shodor Education Foundation

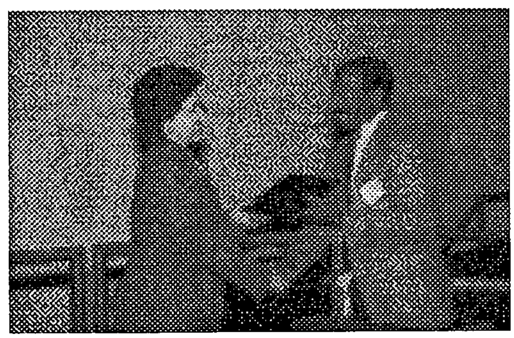
Dated this 12th Day of July, 1996

CORPORATE AND FOUNDATION PARTNERS FORUM

Building on the excitement and momentum from the evening at the Smithsonian Institution's National Air and Space Museum, there was a meeting of corporate and foundation representatives interested in partnering with the National Science Foundation for revitalizing undergraduate education. The meeting included both signatories to the Memorandum of Understanding (MOU) and those who were interested in learning more about the partnership activities.

The session focused on strategies for fostering the partnership between government, corporations and private foundations which support reform efforts across the nation. The MOU and this meeting built on the NSF Foundation Roundtable, convened April 18, 1996. Participating in that event were representatives from DuPont, the Exxon Education Foundation, the General Electric Foundation, the Hewlett-Packard Company, the Howard Hughes Medical Institute, the MacArthur Foundation, the Pew Science Program, Shell Oil Foundation, and the Shodor Education Foundation. The goals of both meetings were threefold:

- to share NSF's goals in undergraduate education with foundation representatives;
- to explore common goals in the outcomes expected from quality undergraduate education; and
- to explore next steps, including sharing information and the possibility of collaborative funding ventures.



NSF's Janet Rutledge recognizes Alfred Moyé and Hewlett Packard as an inaugural signatory to the Memorandum of Understanding for revitalized undergraduate education

Included in the areas of mutual interest was the development of a common set of metrics for evaluating and assessing funded projects, sharing of Web site information and encouraging the electronic dissemination of information, and continued exploration of collaborative funding opportunities.

The following areas were seen as particularly important:

- K-16 education;
- teacher preparation;
- the impact of information technology on education and graduate preparedness;
- the need for advocacy role of foundations and industry in revitalizing undergraduate education; and
- the need for continuing roundtable discussions.

Specific activities for the group to undertake were discussed. The group will continue to meet about twice a year, with all participants working to expand the circle of cooperation. Sharing of information on funded projects and exploration of ways to leverage support is already occurring.

ACADEMIC PRESIDENTS FORUM

The purpose of this session was to provide presidents, chancellors, provosts, and vice presidents or vice provosts attending the "Shaping the Future" conference the opportunity to discuss issues related to their unique perspectives and responsibilities.

Luther S. Williams, Assistant Director for Education and Human Resources, convened the first plenary session. Robert Watson, Director of NSF's Division of Undergraduate Education, convened the second session. Participants identified at least four major themes in free-wheeling discussion. These were:

- key faculty issues retarding the reform of undergraduate education;
- other resource issues, constraints, and emerging educational technology;
- institutional missions and organizational barriers; and
- preparing K-12 mathematics and science teachers

Faculty Issues

Many high-level college and university administrators, particularly in the public sector, see the existing faculty, collectively regarded, as a retardant to true reform in undergraduate education in science, mathematics, engineering, and technology (SME&T). This perspective derived from a widespread belief that it will be increasingly important to reach virtually all of the faculty and convince them to support new approaches to undergraduate education. Most believed that true reform was beginning to occur on their campus, led by some key faculty, but that this process was far from becoming widespread. The faculty issues they identified included the following:

- The average faculty member does not believe that there is a crisis in undergraduate SME&T education, and sees reform as antagonistic to the faculty's best interests.

- Many faculty don't want to teach in new ways, and are not comfortable with inquiry-based approaches. Some participants saw this as a problem of inertia and faculty "burn-out."

- Some faculty are not willing to be flexible in serving the needs of an increasingly diverse student body.

- Many senior faculty— and some new faculty—are not prepared for education reforms. New faculty teach as they were taught in graduate school, and graduate school teaching practices have not changed much.

- Most faculty must *enjoy* working with undergraduate students and being facilitators of learning, rather than considering students (particularly introductory level students) to be a burden. This is essential in order for the new approaches to take root.

- Faculty governance can be a barrier. In some places there is a tendency for faculty to "think like a union," such as debating the conditions of work, which can impede progress.

- In community colleges and small four-year colleges, a significant number of the faculty, including some of the science faculty, ostensibly express an animosity toward scientific research because they see themselves as excluded from the research community.

Removing Faculty Barriers

Most of the participants in the forum agreed that overcoming these faculty issues is vital in successfully carrying out reforms in undergraduate education in a comprehensive way. One strategy identified as helpful was to look for (and support) innovative faculty who institute initial improvements in courses and curricula. Successful starts could be bolstered subsequently by growing reliance on faculty leaders to spread (or institute) desirable changes to the rest of the faculty. A number of institution leaders believed that a strong focus by senior faculty leaders on improving undergraduate education is needed to successfully implement institution-wide reform. There was widespread agreement that faculty leaders are crucial to supporting change.

A strategy being employed by the administration of a growing community technical college is to hire faculty who are "ready and able" to employ reform methods in the classroom. However, this path to reform will be too slow for most institutions of higher education, many of which are not growing. One community college president remarked that it is crucial to make certain the faculty know how to teach, because we cannot expect them to turn out able K-12 teachers until they demonstrate good facility with quality teaching and learning.

Some high level administrators believe that faculty must have an internal commitment to institutional expectations, i.e., they must be "mission driven," rather than autonomous independent agents whose first priority is their disciplines.

Other methods that were identified for improving faculty participation in reform efforts were:

- Provide monetary rewards to faculty who are willing to engage in collaborative projects,

- Institute a program of special recognition for reform faculty.

- Teach leadership skills to reform faculty.

- Support faculty development workshops to aid the faculty in learning new methods and materials for improved undergraduate instruction. It will be necessary to support faculty enhancement opportunities in order to promote change. Some presidents identified Project Kaleidoscope workshops as useful opportunities. Several participants indicated that they were already doing this in a number of ways on their campus.

- Support programs that connect faculty to the constituents of higher education. There was considerable support for the idea of strengthening formal channels for obtaining input from employers, and for widening the practice of faculty sabbaticals in employer organizations.

The Use of Educational Technology

Four major issues were identified:

- New "up-to-date" laboratories and classrooms are needed to support reform. But these are expensive.
- There are a number of unresolved concerns about how to implement new technology into the classroom in support of reform objectives.
- It is important to develop educational technology expertise at the departmental level, so that faculty are making full and effective use of technology in their disciplines.
- Distance learning is a potentially powerful but also a destabilizing force.

Organizational Issues and Strategies

Many of those participating in the forum identified the central issues of organization, strategy, mission, and priorities as keys to reform in their institutions. The discussion revolved around the principle that it takes a whole campus to institute change. Resources (faculty time and funds) in most institutions are not expected to rise, meaning that they need to be reallocated in high priority directions. This suggests the need for mission (or goal) statements. Mission statements should be used as a basis for establishing an ideal set of plans to implement change, and should be adhered to as much as possible. Human resources—especially faculty—are the most costly and the most important aspect of successful change, because they define the learning experience for students.

Leadership is very important to creating desired institutional change. To achieve comprehensive reform in undergraduate education, a good strategy is to spotlight faculty committed to reform, otherwise the reforms they institute will not stick. It is particularly helpful if the NSF sets a sort of gold-standard set of reform objectives and methods for SME&T courses and majors, to help guide high level administrators in supporting faculty-led reforms.

Many participants agreed that they had a role in lowering institutional barriers to allow the change process to take root more readily. Many had also reached the realization that it takes time to incorporate changes in curriculum and pedagogy, and did not expect a lot of progress in a short period of time.

Some of the discussants identified academic departments as key units of change—vitally important to reform. One reason for this is process related. It is easier and more effective to institute change in small groups (e.g. departments), then attempt to use that change to encourage further change (e.g. in other departments) and, eventually, achieve true institutional change. One provost invited us to consider the calculus reform movement at his institution, which had been carefully nurtured over a period of five years to a position of widespread use. Calculus reform has not spread to other departments in his university and he concluded from this experience that change is very difficult to promote across the board.

Broad Issues of Organization and Mission

There was general agreement that we do not yet have a clear set of procedures in hand to instill nation-wide reform of undergraduate education. Most of the participants believed that it should have as its chief objective making science learning fundamental to K-12 and undergraduate education. They believed that learning in the SME&T disciplines should be imbedded into the educational system beginning in early grades, and that SME&T should be taught in an *inquiry* mode. They also realized that teaching in an inquiry mode requires a procedural shift that is going to be tough for many faculty who do not know how to teach this way.

These beliefs were identified as a response to a growing awareness that (in general) improved knowledge of science, mathematics, engineering, and technology would be needed increasingly by productive members of society. The tendency of new jobs to arise in relatively small firms was noted. These employers tend to need graduates who are adaptable and flexible, and can successfully engage in continuing education when that is needed. Some participants believe that it is increasingly going to be an employee's responsibility to identify situations when the need for continuing education arises, but that it will be the institution's responsibility to ensure that appropriate opportunities existed.

There was broad agreement that colleges and university administrations need to support faculty who are able or willing to teach students in this more effective mode. Several participants stated that this issue was also important to address among graduate students, and also more efficient to address at that stage. Others pointed out that if we could solve the problem of educating K-12 teachers to be effective facilitators of learning in science and mathematics, that this would obviate the need for special efforts in graduate programs. One participant offered the notion that we need to teach classes that reflect the dynamic nature of the phenomenon being studied, and that we need to build in research on teaching and learning into our courses. There was considerable agreement that building into courses ways to examine learning effectiveness was an important objective of undergraduate reform.

Another observation was that *motivation* is key in reaching the majority of undergraduate (or K-12) students. One observer believed that science ought to be studied from the perspective of technology, which has been a very important force in recent times, leading to social change. This is a natural starting point to maintain student interest in learning about science and technology. Science has enabled this fast pace of technological advance, and studies of this process should be added to basic undergraduate curricula. Studying science from this point of view is inherently interesting for many students.

Some participants stated that it was important to get undergraduate students more involved in the learning process. A number of ideas surfaced. One was using juniors and seniors to mentor and work with freshmen and sophomores. Another was to ensure that all important curriculum committees and promotion and tenure committees had strong student input. Several recommended involving students in community-based projects as a way of introducing them to organizations and forces that shape their lives after graduation.

Considerations for K-12

There was some discussion of the idea that college and university mission statements should state that they are learning institutions where teachers are being taught. Also discussed was the importance of achieving better collaboration between the mathematics and the science faculty, and the importance of building a nexus of enhanced communication between these faculty and the education faculty to produce K-12 teachers who routinely develop expertise in both educational technology and content areas of math and science.

Many agreed that one attainable goal is to simply stop the faculty practice of discouraging students (particularly the best students) from selecting careers in K-12 teaching. Following this theme, another participant argued that we need to raise our standards for teacher certification. Some believe that this has to be done before serious reform of K-12 teacher preparation can be initiated.

LUNCHEON

Invited Speaker:

Bill Kurtis

Chicago News Anchor
Executive Producer, "The New Explorers"

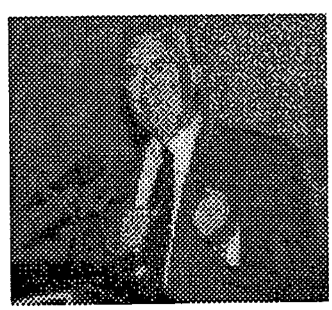
The following account was synthesized from a lunch time presentation Bill Kurtis made to conference attendees.

The New Explorers is supported by the Department of Energy, and more recently by the U.S. Postal Service. It employs an adventure story format which follows scientists into the field. *Newsweek* called it "*Nova* with an adrenaline rush." If *Nova* is high school, *The New Explorers* is junior high, but teachers at both the K-12 and undergraduate levels use its material because it is science-oriented, and it is capable of contributing to learning at each of these levels. Let us explore how this came about.

Over the years educational television has learned and changed. This change has been driven by the realization that television isn't "magic." In the 1950s, educational television was seen as the universal answer to improved teaching. The usual technique was to record a master teacher and then broadcast the teacher in action to large numbers of students to raise aggregate learning benefits. But student test scores didn't go up, leading increasing numbers of educators to conclude that TV wasn't necessarily more effective in producing results than a good teacher-student relationship. For example, my image on the screen doesn't enhance what I'm saying by itself. Success with educational television is determined by the marriage between people who know the creative aspect of producing television shows and those who know how to tell scientific stories.

Television has been moving into the academic classroom for a long time. In the process there have been studies of its effectiveness. Vanderbilt University showed that a video tape is far more comprehensible by students than reading a printed story. If you combine video tapes and interactive multimedia, student test scores can double those achieved by passive learning through video alone. The electronic classroom of the future may be long distance learning with satellites, the Internet, CD-ROMs, and personal computers, but the use of television video is still a positive force, adding to the effectiveness of these other media.

Today, the effective use of video tapes requires that we tell a story. In telling the story you have the perfect organizational device to deliver information. You must have a beginning, a middle, and an end so you can logically follow what happens. A scriptwriter would call it a heroic journey; the new explorer armed with a sword goes to cut the Gordian knot and resolves it as the hero in the end. Following that model, the scientific process would be to observe a problem, hypothesize, try and solve it by experimentation, and resolve it. These approaches match each other.



Bill Kurtis

The New Explorers shows typically have a "mysterious opening", then a quick explanation that tells you what the mystery is, and thus the point of the program. Sometimes it attempts to pique your interest with adventure, then moves on to establish the mystery. It takes about a third of the hour-long presentation to set up a story. For example, if I'm going to tell you about evolution, an effective technique is to join two Princeton scientists, Peter and Rosemary Grant, as they become first in the world to observe evolution over a 20-year period.

The Department of Energy wanted a means to contribute to improved education in Chicago inner-city schools. The Department and *The New Explorers* decided to work together and see what could be done. The Department put together a group of Chicago teachers with the sponsorship of scientists at Argonne National Laboratory. Members of this group worked together to determine how to use Argonne and other Chicago resources to improve the teaching of science in Chicago schools. They created teacher guides and a series of one-day seminars in Chicago where teachers could go to learn how to show the video and use the accompanying hands-on demonstrations in the teacher guides. They'd also take a trip to sponsoring institutions like the Field Museum, the Museum of Science and Industry, and the Chicago Police Department. There were a total of 13 field sites that participated in a *New Explorer* field trip.

This program was very popular with participating teachers because it provided them with a tool that aided their efforts to capture students interest and attention. These videos did the most important thing an educational television producer can do in the classroom: get the attention of the class and hold it for 30 minutes to an hour through storytelling with all the gimmicks—music and mystery, special storytelling techniques, and the impact of pictures television and video have to offer. The seminars were so popular we had to limit teachers getting into them.

Many inner-city students don't read well but they watch television attentively. The most chaotic classroom would get absolutely quiet when the television came on. It may not provide the whole solution, but the students are comfortable with television and are relatively expert at absorbing information from a video screen. This approach is successful in holding students interest, and participating teachers now have a frame of reference for classroom demonstrations or for using scientific materials. One teacher has gone to 25 different seminars of 25 tapes and materials—the best evidence something is working.

We don't expect that a class or teacher will immediately absorb all the science in a particular topic with the first video showing of a story. The beauty of video is that a trained teacher can use it like a blackboard or slide presentation to teach topics like chemosynthesis—what are the chemicals, how did scientists discover tectonic plates, how did they get "down there"? It can also be used to make other related points, for example, the existence of female scientists functioning as equals with male scientists. In fact, half of the *New Explorers* are minorities who can potentially become role models, justifying the series in and of itself.

The Illinois State Board of Education encouraged us to undertake the next level. By fall, 1996, every school in Illinois will be connected by satellite for long-distance learning and speech communication. The Board urged us to connect *New Explorers* presentations with Illinois science standards, state tests, and school curricula. There are now 60 shows and 60 teacher guides. We're approaching a true electronic classroom, bringing together visual materials, Internet connections, personal computers, CD-ROMs, laser discs, toys and books. It's enormously interesting because it consistently turns up surprises, especially when it involves looking into the minds of children, trying to figure out how they learn.

We offer students *reality*—a real scientist working in the real world, brought into the classroom. The best thing would be to take them out to the Galápagos. We can't do that, but a scientist doing field research can come into the classroom on videotape or via satellite. The teacher uses this visit as a tool in a friendly partnership reinforced with field trips into the community. We use this model to contribute what we can.

Academic Presidents' Roundtable
New Directions for Undergraduate SME&T Education

Moderator:
Luther S. Williams
NSF Assistant Director for Education and Human Resources

Panelists:

Victor Ferrall
Beloit College
Beloit, Wisconsin

B. Jean Floten
Bellevue Community College
Bellevue, Washington

Norman Maldonado
University of Puerto Rico
San Juan, Puerto Rico

Karl Pister
University of California, Santa Cruz
Santa Cruz, California

James Rosser
California State University, Los Angeles
Los Angeles, California

B. Jean Floten
Bellevue Community College, Bellevue, Washington

Dr. Floten noted the need to know when it is important for us to change direction, and her belief that this conference really underscored that the time is now in science, mathematics, engineering and technology education.

She observed that faculty renewal has been a consistent theme in this conference—to invest in our own human resource. Bellevue has faculty fellowships with industry, where faculty go into the workplace and work side by side with colleagues, scientists, engineers and technologists. Floten explained, "it is the 'teach somebody to fish' idea. Educating a faculty member gives you a hundred-fold return on that investment."

For the future, President Floten sees more small-group problem solving and reporting; an emphasis on contextual and inquiry-based learning; extensive use of communication devices; individualized, interactive lessons; and integrated management and assessment.

But how do we change higher education to meet changing student needs? Floten referenced this quote from Wayne Gretzky—"Most players skate to where the puck is. I skate to where the puck is going to be." She concluded, "that is the challenge to remember as we contemplate higher education and how to teach these principles more effectively in an information- and knowledge-based age."

James Rosser

California State University, Los Angeles, Los Angeles, California

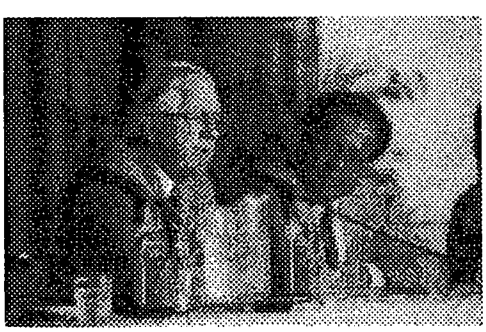
Dr. Rosser explained that last fall his institution started the academic year with a faculty retreat on building and learning in the community for the 21st century. Their commitment is driven by a paradigm shift on campus—from teaching and "seat time" to learning outcomes. President Rosser noted that most U.S. colleges and universities are driven by the same metrics: semester or quarter credit units (if one is a full-time equivalent student) and courses, not by learning outcomes in the context of how institutions get their funding. He believes that "to the extent we will shift in that direction, there must be greater recognition that time becomes less of a dependent variable relative to how we work, and we need to migrate in that direction." Because 60 percent of CSU-LA's bachelor's degree recipients transfer in from two-year colleges, they must change the nature of transfer articulation if they shift from a focus on courses and credits to learning outcomes, given that most students do lower-division undergraduate coursework outside CSU-LA.

Last year CSU-LA moved to change their retention, promotion and tenure policy to include criteria such as formal and informal mentoring, tutoring and other academic support that enhances student retention and achievement. According to Rosser, this sends faculty a strong message—that the university values academic support, retention and achievement, and will evaluate and reward their work in this area. The faculty of CSU-LA, which has a diverse student body, are encouraged to try new approaches to teaching and learning that are grounded in cognitive research and research on learning styles. Said Rosser, "this motivates faculty members to modify and adjust the curriculum to evolving student needs."

Karl Pister

University of California, Santa Cruz, Santa Cruz, California

Chancellor Pister said the basis for creating the Land Grant universities and the Morrill Act of 1862 was to industrialize the United States by developing colleges and ultimately universities committed to mining, agriculture and engineering's predecessor—the mechanic arts. He articulated, "they sought to exploit the country's natural resources and were enormously successful, displacing Britannia to become the world's dominant economic force."



Karl Pister (left) and James Rosser

But Chancellor Pister recognized that the 21st century will bring a new challenge. "We [have] developed most of our natural resources," said Pister, "but the diversity and quality of our human resources constitutes veins of unmined gold," particularly, he noted, in a state like California, a state with no majority population in its school system. Pister asserted that a university in California has to rethink what it means to be a Land Grant university, to extend its resources, knowledge store and human resources into the community in a different way.

For example, a consortium of institutions surrounding the Monterey Bay—two four-year universities, three community colleges, and three county school districts—was created. The goal was to create a structure that would maximize the productivity of all kinds of grassroots activity. Said Pister, "It only happened because our faculties had already established grassroots contacts. This was not done at the top and handed down; it grew and was blessed by consortium members." Building on the original land-grant concept, this is a new cooperative extension serving important areas other than those set forth in the Morrill Act.

Victor Ferrall

Beloit College, Beloit, Wisconsin

Dr. Ferrall believes that part of the rhetoric of liberal education is that it matters less what one learns than how one learns it. This, he believes, is because the objective is to inculcate critical thinking skills and habits, not to make core dumps of information. "But critical thinking is not unidimensional," Ferrall continued, "Learning to think critically like lawyers and mathematicians and farmers strikes me as a sound first approximation of an excellent liberal education."

According to Ferrall, the notion of reforming science and math undergraduate education is not troubling as a concept, but as an articulation. Reform implies a known flaw or weakness rather than a continuing evolution, a process that must be pursued. Ferrall was reminded of comedian George Carlin's wry observation: "If you think there is a solution, you're part of the problem." President Ferrall then suggested we pursue excellence in science and math education, implying that while we may never achieve our goal, we will benefit from its pursuit.

"We in undergraduate education debate endlessly about perceived inconsistencies and conflicts between training majors and educating non-majors, the pipeline versus educated citizenry," said Ferrall. But for him the line between them is not bright. Beloit College shares this view and seeks to get all students to learn what science is by doing science, regardless of whether they intend to become scientists. President Ferrall concluded that surely, in the end, the ultimate goal of higher education is to prepare leaders and good citizens, men and women, in Lord Broughm's great words, "easy to lead but difficult to drive; easy to govern but impossible to enslave."

Norman Maldonado

University of Puerto Rico, San Juan, Puerto Rico

Dr. Maldonado explained how his was traditionally a teaching institution, but that they are moving toward being more a learning and research institution and achieving a balance between those. Said Maldonado, "Thinking about new directions, our approach has to be interdisciplinary, multi-disciplinary, collaborative, and cooperative."

"The literacy of our graduates is important as we face the 21st century," stated Maldonado. He believes this requires a revision of the whole undergraduate curriculum in order to develop five critical student skills. He asserted that students must be self-learners who know how to work in teams; they have to be critical thinkers; they have to understand more history, geography, and social needs; and they must improve their communication skills. "We must learn better Spanish and English, and teach our students computers."

President Maldonado recognized the need to assess and measure how these new skills are helping students and understands that the external realities require fundamental change in the institutional culture. He concluded, "We are preparing to do more and hopefully better with fewer resources. I feel that being accountable to our constituents, assessing our programs and students, and efficiency and effectiveness are the rules of the game."

Norman Maldonado answers questions with NSF's Luther Williams (left) and Beloit Collge's Victor Ferrall

Questions and Answers

Q: **Dr. Williams** of NSF asked how to get a handle on the knowledge base that undergirds learning. How important is dissemination and how assess program effectiveness?

A: **Dr. Rosser** responded that as the focus shifts from teaching to learning outcomes, metrics and benchmarks are needed to assess effectiveness. The shift of emphasis from access to outcomes will be tied to resource accountability as future resources will be based on performance. Institutions must disseminate what works and identify best practices.

A: **Dr. Maldonado** agreed that benchmarking is a top priority and necessary for strategic planning.

Q: **State Representative Nichols** asked Dr. Pister whether we have sufficient mandate under the old extension agreements, or must they be renegotiated in a new federal, state, and county compact?

A: **Dr. Pister** responded that the compact established by the Morrill Act needs to be renegotiated, but the present agriculture cooperative extension idea is so politically entrenched that it probably can be changed only marginally. He felt it would be impossible to overturn agricultural interests in states like California even though it has other industries and needs far greater than the support of agriculture. Broadening the extension model to deal with critical urban problems of health and education is essential.

A: **Dr. Rosser** added that the Morrill Act also led to a problem of equity with respect to historically black Land Grant institutions. Many of the same institutions that were kept from offering doctoral degree programs might have been able to prevent some of the gross underrepresentation existing today in the sciences and engineering. If the Land Grant model is revisited, there must be a commitment to equity and a leveling of the playing field.

Q: **Ms. Nieves**, a student at the University of Puerto Rico, asked what is being done, beyond monetary incentives, to motivate teachers and students to participate in reform efforts and how are students being included as an integral part of the reform.

A: Dr. Floten agreed all institutions must grapple with incentives in higher education. Bellevue has made a terrific investment in professional faculty development. For students, due to the large demand for the courses needed for transfer, such as English composition, one of Bellevue's best incentives is offering interdisciplinary study classes with an English component. They have also looked at priority registration and other incentives to motivate students.

UPR student Raquel Nieves

A: To induce students to pursue teaching careers, in part to solve the crisis of emergency credentialing in his area, **Dr. Rosser** related that CSU-LA offers benefits such as scholarships, priority registration, and paid internships as on-site teacher aides for those students willing to experiment with the new teacher education model. Additionally, they try to give formal recognition, on the transcript, of activities beyond the classroom that the institution values as part of a student's education, such as volunteering in a school with gang or substance abuse problems.

Q: Mr. Pastran, a student at the University of Northern Colorado, asked what is being done to involve students, as partners with faculty and administration, in institution-wide reform.

A: Dr. Pister responded that since the 1960s student involvement has increased dramatically in the University of California system. Students are regular members of critical Academic Senate committees that deal with courses and curriculum. Every campus has formal mechanisms for consultation between the administration and student government. He had monthly open-agenda meetings with the heads of student organizations to get a sense of their issues and concerns.

A: Dr. Maldonado concurred that students participate at all levels at his university. They have student representatives in the Academic Senate, the administrative board, and the board of trustees.

A: Dr. Floten added that a key involvement of students at Bellevue is on hiring committees, where they help prepare position descriptions, and on faculty tenure evaluation committees where they help review faculty portfolios. In curriculum issues an important student contribution is in evaluating what works and what does not from their point of view.

A: According to **Dr. Rosser**, the question is what is the appropriate role for students within the context of accountability, especially given the current relatively litigious environment. Students have mechanisms to participate in issues of curriculum, assessment, and instruction and can share their perspectives on the administration's performance. But a real issue is who is accountable. If there is shared accountability, he is willing to share responsibility for making decisions.

CLOSING REMARKS

Robert F. Watson

NSF Division Director for Undergraduate Education

It seems to me the last words in a conference such as this one should be "so what"... So what have we learned, so what will be the impact, and most importantly so what comes next... I am confident that all of us will leave here with good intentions to build on the activities, the momentum that has been generated, and work with renewed vigor for necessary changes that we can cause in undergraduate education, but it helps if some structure is developed, some specific plans are put into place. There is a great threat that the momentum will be lost, that good intentions will be lost in the everyday pressures of what we all do.

DUE Divsion Director Robert Watson

We at NSF are willing (and somewhat able) to help each sector to sustain the momentum in the coming months. It would seem that the societies might consider adding special events in upcoming regional and national meetings—perhaps some colleges and universities would like to host some area meetings. The foundations could collaborate on new or enhanced programs. Industries and Federal agencies could participate in these, but host their own regional events as well. And of course, the Division of Undergraduate Education stands ready to help. Please let us know how we can collaborate with you on these kinds of activities, sustaining the momentum to help all students learn the science and technology necessary to be successful, each in his or her own way, in our ever changing civilization.

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• APPENDIX A •

Shaping the Future:
New Expectations for Undergraduate Education in Science, Mathematics, Engineering, and Technology

and

From Analysis to Action:
Undergraduate Education in Science, Mathematics, Engineering, and Technology

EHR Advisory Committee Reviews the State of Undergraduate Education in the Nation

The Advisory Committee to the Education and Human Resources Directorate of the National Science Foundation (NSF) completed a detailed look at the state of the Nation's undergraduate education in science, mathematics, engineering, and technology (SME&T) just prior to this conference. The review included a year-long study and national dialog, initiated by the appointment of an Advisory Committee on Undergraduate Education. Luther Williams, NSF Assistant Director for Education and Human Resources, charged the EHR Advisory Subcommittee to address the needs of *all* students, at *all* types of institutions offering undergraduate education. Indeed, the comprehensive scope of this review alone makes it a landmark study of the nation's undergraduate educational system.

The first review of its kind in nearly 10 years, the Review of Undergraduate Education (*Shaping the Future)* provides broad-based, action-oriented guidance for improving the quality of undergraduate education. It concludes that significant improvement will require large-scale changes, or, as described by Harvard professor Gerald Holton, undergraduate SME&T education in America is still too much a filter which produces a few highly-qualified graduates while leaving most of its students "homeless in the universe."

The imperative deriving from the review is that all students have access to supportive, excellent undergraduate education in SME&T, and all students learn these subjects by direct experience with the methods and processes of inquiry.

Voice of the Nation

In the fall of 1995, NSF hosted a series of hearings, and invited comments, recommendations, and concerns from two- and four-year colleges and universities, industry, and other employers of college graduates across the nation. The committee report was based on these testimonies, as well as on other thoughtful insights by educators, employers, and administrators with long and distinguished experience in academe.

In addition to these invited testimonies, the review considered the points of view of the entire spectrum of both the "providers" and "consumers" of undergraduate education. Letters of opinion were solicited from several hundred individuals and organizations; informal comments were invited at numerous disciplinary and educational conferences; focus groups were held with students, alumni, parents, and employers; and extant data on undergraduate SME&T education were re-examined. The recommendations provide a broad-based plan of action, not only for NSF, but for other Federal agencies, business and industry, academic institutions, faculty, administrators, professional societies, state and local government, and the private sector.

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The opportunities we offer during the undergraduate experience must allow students to find career paths, properly educate them for these avenues, and prepare these students to be the future leaders of the Nation.

BOX A.1: The Review of Undergraduate Education
(April 1995 to June 1996)

Conducted by:

NSF Directorate for Education and Human Resources
Advisory Committee on Undergraduate Education

Background and Related Reports:

"A Nation at Risk"
U.S. Department of Education (1982)

"Undergraduate Science, Mathematics, and Engineering Education"
National Science Board (1986)

"Science in the National Interest"
The White House (1994)

"From Analysis to Action"
National Research Council (1996)

Mandate:

- Consider the needs of all undergraduate students at all types of U.S. colleges and universities providing SME&T education.
- Identify the successes, needs, and the opportunities for improvement in SME&T education.
- Cover the full range of general issues in undergraduate education, including:
  - curriculum
  - educational technology
  - pedagogy and exposure to research
  - systemic practices and reform
  - student transitions between levels of education and into employment

Planning for the Future

Consistent with NSF's chartered responsibility to "initiate and support programs at all levels ...," NSF will use the review to ensure that its support of education is part of an effective portfolio of comprehensive programs and effective individual efforts to benefit and support the full range of educational settings in the United States. The report of the committee was submitted in the spring of 1996. To accelerate national progress towards excellent and supportive collegiate SME&T education, four requisite conditions were listed:

- **All links in the "education chain," including K-12, undergraduate, graduate, and professional schools, must work together** to provide, assure and reward sound learning
- **At least *some* SME&T learning should be expected** from every undergraduate admitted to the institution
- **A flexible curriculum** should provide students with greater opportunities and awareness of SME&T training and careers
- **The learning environment should be supportive of all students**, promote active learning, encourage collaboration, and emphasize inquiry more than the rote acquisition of facts

There is an emphasis on the *interrelated* nature of the recommendations in the subcommittee's report. The multiple influences on undergraduate SME&T education must work in concert, as this is crucial to the success of and hence the ultimate well-being of the nation.

Overall, the findings of the review are optimistic, and recognize a variety of promising individual efforts from across the U.S.; but the report also cautions that no one should assume the steps remaining to be taken are exclusively the task of someone else (see Box A.3).

NSF is using the review to determine what steps are now required to bring about large-scale, systemic improvements. The subcommittee's report will provide tangible guidelines for effective utilization by NSF of the investments made in recent years by organizations and agencies seeking to improve undergraduate education.

In consequence of the review, NSF will seek to encourage implementation of those practices that will achieve improved literacy in mathematics, technology, engineering, and the sciences; a technically more capable workforce; better prepared teachers, scientists, technicians, and engineers; and greater participation in SME&T studies and careers by women, minorities, and persons with disabilities.

This review examined the entire scope of undergraduate SME&T education, and has constructed key recommendations for each major group of stakeholders. These recommendations are action-oriented; their implementation will lead to improvements in the quality of learning.

BOX A.2: Testimonies on the State of Undergraduate Education in the United States

To consider a truly national voice on the successes, needs and opportunities for improvement in SME&T undergraduate education, NSF hosted a series of public hearings. Testimonies were received from all disciplines representing SME&T education, diverse two- and four-year colleges and universities, employers, and other stakeholders in undergraduate education.

Disciplinary Perspectives

Convened October 23, 1995: UNDERGRADUATE SME&T EDUCATION – **MRC Greenwood**, Dean of Graduate Studies, University of California, Davis (CA) ♦ BIOLOGICAL SCIENCES – **Rita Colwell**, Professor and President, AAAS University of Maryland, College Park (MD) ♦ MATHEMATICAL SCIENCES – **Alan Tucker**, Professor of Mathematics, State University of New York, Stony Brook (NY) ♦ ENGINEERING – **Eleanor Baum**, Dean of Engineering, Cooper Union (NY); **Winfred Phillips**, Dean of Engineering, University of Florida (FL) ♦ COMPUTER SCIENCES – **Peter Denning**, Professor of Computer Sciences, George Mason University (VA) ♦ TECHNOLOGY – **Don Gentry**, Dean of Engineering Technology, Purdue University (IN); **Durward Huffman**, President, Northern Maine Technical College (ME) ♦ CHEMISTRY – **Ernest Elial**, Professor of Chemistry, University of North Carolina, Chapel Hill (NC); **Angelica Stacy**, Professor of Chemistry, University of California, Berkeley (CA) ♦ PHYSICS – **Robert Hilborn**, Professor and President, AAPT, Amherest College (MA); **Eric Mazur**, Professor of Physics, Harvard University (MA) ♦ GEOLOGICAL SCIENCES – **Tanya Atwater**, Professor of Geology, University of California, Santa Barbara (CA).

Institutional Perspectives

Convened October 25, 1995: **Pamela Ferguson**, President, Grinnell College (IA) ♦ **Thomas Morris**, President, Emory and Henry College (VA) ♦ **Bruce Leslie**, President, Onondaga Community College (NY) ♦ **Gwendolyn Stephenson**, Chancellor, St. Louis Community College System (MO) ♦ **David Pierce**, President, American Association of Community Colleges (DC) ♦ **Frederick Humphries**, President, Florida A&M University (FL) ♦ **William Kerwan**, President, University of Maryland, College Park (MD) ♦ **Paula Brownlee**, President, American Association of Colleges and Universities (DC) ♦ **Saul Fenster**, President, New Jersey Institute of Technology (NJ) ♦ **Judith Ramaley**, President, Portland State University (OR) ♦ **David Ward**, President, University of Wisconsin, Madison (WI) ♦ **Homer Neal**, Interim President, University of Michigan (MI).

Employers' Views

Convened November 1, 1995: **Walter Amprey**, Superintendent, Baltimore Public Schools (MD) ♦ **Eugene Galanter**, Professor of Psychology, Columbia University (NY) ♦ **Peggy Cole**, Director, Program Planning, New York Hall of Science (NY) ♦ **Israel Joseph Galvan**, President, GHG Corporation (TX) ♦ **Alfred Moyé**, Manager, University Relations, Hewlett Packard Company (CA) ♦ **John McMasters**, Principal Engineer, Boeing Commercial Airplane Group (WA) ♦ **Roberts Jones**, Executive Vice President, National Alliance of Business (DC) ♦ **John Sisler**, Manager of Exploration, Shell Oil Company (TX) ♦ **Patrick White**, Vice President, Strategy, Bell Atlantic Corporation (VA).

Social Sciences

Convened February 22, 1996: **Andrew Abbott**, Master, Social Sciences Collegiate Division, University of Chicago (IL) ♦ **John Dovidio**, Professor of Psychology, Colgate University (NY) ♦ **Ronald Ehrenberg**, Vice President, Academic Programs, Professor of Economics, Cornell University (NY) ♦ **Kenneth Foote**, Professor of Geography, University of Texas, Austin (TX) ♦ **Rochel Gelman**, Professor of Psychology, New York University (NY) ♦ **Maureen Hallinan**, Professor of Sociology, University of Notre Dame (IN) ♦ **Jill Larkin**, Professor of Psychology, Carnegie Mellon University (PA) ♦ **Nora Newcombe**, Professor of Psychology, Temple University (PA) ♦ **Neil Stillings**, Professor of Cognitive Science, Hampshire College (MA)

BOX A.3: Some Proactive Recommendations for Excellent and Supportive Undergraduate SME&T Education

Who?	Have a Responsibility To ...
Congress and the Federal Government	• Establish a new social contract with higher education to prepare the Nation for the 21st Century
State Governments and Higher Education Boards	• Provide incentives for improved SME&T education • Encourage inter-institutional cooperation
College Governing Boards and Administrators	• Develop appropriate reward systems • Support SME&T teaching and learning
SME&T Departments	• Set demonstrable learning goals • Engage the broadest spectrum of students and provide flexible career paths
SME&T Faculty	• Affirm that all students can learn, model good learning practices, and build inquiry into their courses
Business, Industry, and Other Employers	• Communicate expectations for graduates • Help to inform public opinion
National and Regional Media	• Become informed and inform the public of the critical significance of SME&T education
Professional Societies	• Promote education and learning equally with research
Accrediting Agencies	• Incorporate principles of effective teaching into the accreditation process
Funding Agencies	• Make strategic investments in support of a common agenda
The National Science Foundation	• Lead the development of a common agenda • Support a balance between education and research • Provide further forums for discussion • Intensify evaluation of results and codify what is known about effective practices

The review provides a set of guidelines to suggest how the results of successful NSF-supported programs can be used as the basis for larger-scale systemic change

The results of the review of undergraduate education are being recognized and discussed as part of the conference, "Shaping the Future: Strategies for Revitalizing Undergraduate Education." This invitational event involves teams of participants in a constructive dialog about the challenges facing undergraduate education, and recognize newly-awarded as well as successful ongoing projects in systemic reform.

The conference also provides an opportunity for awardees to showcase their projects to a wide variety of stakeholders in undergraduate education, including other institutions, professional societies, industry, federal agencies, and the public.

- Information and updates on EHR programs and activities can be found on the World Wide Web at the URL: http://www.ehr.nsf.gov/

- Detailed information and future updates specific to *Shaping the Future* can be found on the home page for NSF/EHR's Division of Undergraduate Education (DUE) at: http://www.ehr.nsf.gov/EHR/DUE/start.htm, which includes information about other NSF undergraduate programs as well as links to the WWW sites of some DUE-supported projects.

Further information on *Shaping the Future* may be requested by contacting NSF's Directorate for Education and Human Resources at (703) 306-1600, or by calling the DUE Information Center at (703) 306-1666 (Mon. - Fri., 8:30 to 5:00 EST).

The NRC Year of National Dialogue: Building Consensus on Improving Undergraduate Science Education

The National Research Council's Committee on Undergraduate Science Education (CUSE) received support from the Exxon Education Foundation to conduct a series of meetings in 1995 and 1996. The four regional symposia focused on how the scientific and higher education communities can improve science education for all undergraduate students, especially those who will pursue careers in pre-college teaching or in fields outside the natural sciences. This effort to engage faculty and administrators in building consensus about how to more effectively structure undergraduate science programs began following the April, 1995, NRC/NSF National Convocation on Undergraduate Science Mathematics and Engineering Education. Sponsored by the Exxon Education Foundation, the Convocation brought together a select group of leaders from all sectors of the higher education community.

The recommendations generated by Convocation participants formed the cornerstone of *From Analysis to Action*, the NRC report on which the regional symposium discussions were based. In order to develop nation-wide consensus for these recommendations, the Regional Symposium Steering Committee sought input from many segments of the scientific and higher education communities:

- Faculty involved with teaching undergraduates in science, mathematics, or engineering, educating future K-12 science and mathematics teachers, or preparing graduate students for careers in academe.
- Academic administrators and executive officers who make decisions about the allocation of personnel, facilities, and resources in higher education.
- Leaders from professional science, mathematics, and engineering societies, and from higher education organizations.
- Representatives from business and industry who utilize the training and talents of graduates from the nations colleges and universities.
- Undergraduate and graduate students in science, mathematics, and engineering
- Teachers of science and mathematics in grades K-12.

Because its recommendations and challenges will have been informed and refined by extensive input and feedback from the communities to which they will be directed, the Steering Committee believes that tangible changes in undergraduate science education are possible.

In addition to the four regional symposia, the Exxon Education Foundation has provided funding to CUSE to conduct ten smaller meetings centered around specific themes. These took place in fall, 1996, and spring, 1997, as part of national meetings of professional societies or in collaboration with higher education institutions. The purpose of these topical fora is to identify and disseminate examples of how specific groups have implemented the recommendations in *From Analysis to Action.*

BOX A.4: Year of Dialogue Regional Symposia

Upper Midwest

October 16, 1995 **Ann Arbor, MI**

Host Institution: University of Michigan
College of Literature, Science and Arts
College of Engineering

Keynote Speaker: Homer Neal
Vice President for Research,
University of Michigan

New England

November 10, 1995 **Waltham, MA**

Host Institution: GTE Laboratories

Keynote Speaker: Gerald Holton
Mallinkrodt Professor of Physics and the History of Science
Harvard University

South

January 19,1996 **Houston, TX**

Host Institution: Johnson Space Center

Keynote Speaker: Marye Anne Fox
Vice President for Research,
University of Texas - Austin

West Coast

February 1 ,1996 **Pomona, CA**

Host Institution: Pomona College

Keynote Speaker: Paul Saltman
Professor of Biology
University of California - San Diego

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Expected Outcomes and Products

The result of these extensive discussions will be the release and wide dissemination in early 1997 of a National Research Council publication that will:

- define scientific literacy in a way that is meaningful for all undergraduate students,
- provide rationales for improving science education for all students, with particular emphasis on students who will pursue teaching and other careers outside of the natural sciences,
- offer a "menu" of recommendations for enhancing existing curricula and structuring new undergraduate science programs,
- suggest how pedagogy might be restructured and enhanced for more effective teaching of undergraduates (based in part upon feedback from the field testing phase of "Science Teaching Reconsidered," a handbook prepared by CUSE members). Pedagogy must also challenge faculty and administrators at individual college and university campuses, higher education and professional scientific organizations, and public and private funding agencies to examine critically those systems of rewards, incentives, and personnel policies that compromise or limit opportunities for faculty to enhance undergraduate science education.

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NRC YEAR OF NATIONAL DIALOGUE
Steering Committee

Norman Hackerman, Chair
The Robert A. Welch Foundation

Hyman Bass
Columbia University

Denice Denton
University of Wisconsin - Madison

Ramesh Gangolli
University of Washington

Melvin George
St. Olaf College

Donald Kennedy
Stanford University

Harvey Keynes
University of Minnesota

Glenda Lappan
Michigan State University

Sharon Long
Stanford University

C. Bradley Moore
University of California - Berkeley

Jeanne Narum
Project Kaleidoscope

Karl Pister
University of California - Santa Cruz

CENTER FOR SCIENCE, MATHEMATICS, AND ENGINEERING EDUCATION
COMMITTEE ON UNDERGRADUATE SCIENCE EDUCATION

C. Bradley Moore*, Chair
University of California at Berkeley

Isaac D. Abella
University of Chicago

Neal B. Abraham
Bryn Mawr College

George Boggs
Palomar College

Denice Denton
University of Wisconsin - Madison

Michael P. Doyle
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Marye Anne Fox*
University of Texas at Austin

Dorothy Gabel
Indiana University

Ramesh Gangolli
University of Washington

Frederick T. Graybeal
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John K. Haynes
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Eileen Delgado Johann
Miami-Dade Community College

William E. Kirwan
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Paul J. Kuerbis
The Colorado College

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Professor of Biology
Stanford University

Dorothy Merritts
Franklin and Marshall College

John A. Moore*
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Penny Moore
Piedmont High School

W. Ann Reynolds
City University of New York

James H. Serum
Hewlett-Packard, Inc.

David T. Wilkinson*
Princeton University

*Member,
National Academy of Sciences

• APPENDIX B •

Abstracts of Institutional Plans for Undergraduate Education in Science, Mathematics, Engineering, and Technology

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Institutional Plans for Undergraduate Education in Science, Mathematics, Engineering, and Technology

A primary conclusion of the *Shaping the Future* report is the need for efforts at the institutional level to capitalize on the small-scale but promising improvements that are being made in undergraduate education:

> "The evidence from this review is clear—the improvements achieved have not been widely implemented and are not sustainable without significant change in the culture, policies and practices of higher education. It is not enough that individual faculty members in isolated ways advance student learning. Many contributors to this report have suggested that what we need is not more innovation but more implementation, so that local improvements are both spread throughout the institution and made sustainable over time. Otherwise, gains will be transitory and depend on the comings and goings of individual faculty and administrators."

In preparation for the conference, forty-four institutions prepared summaries describing their individual institutional plans. Representing two-year colleges, four-year colleges, universities, these descriptions provide a rich collection of the institutional efforts underway on campuses across the country to achieve excellence in undergraduate science, mathematics, engineering, and technology education.

EMERGING THEMES IN COMPREHENSIVE CHANGE

The following abstracts address systemic reform from a number of perspectives, including

Promoting Changes in Institutional Culture and Curriculum Structure

- Involving faculty, students, and administrators alike in the planning and implementation of institution-wide reform.
- Transitioning from discipline-based studies towards more "seamless" curricula.
- Supporting interdisciplinary team teaching of science and mathematics in the context of real-world problems.
- Promoting a reward structure cognizant of innovative teaching and mentoring.

Introducing New Teaching/Learning Models such as

- Active student learning, discussion sessions, and module-based science and mathematics courses for non-science majors; and
- Student collaboration to enhance communication, teamwork, and critical thinking skills.

Supporting Faculty Development by

- Expanding mentoring programs;
- Offering forums to allow faculty to share ideas and materials with demonstrated success;
- Providing a supportive teaching environment; and
- Preparing faculty to work collaboratively in an interdisciplinary Fostering efforts to improve communication with non-science majors.

Student-Centered Activities that

- Involve undergraduates in peer instruction with faculty mentors;
- Enhance tutorial and mentoring programs;
- Broaden opportunities for undergraduate research experience; and
- Improve training of graduate student instructors.

Arizona State University

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Arizona State University (ASU) is positioned to become a prototype 21st century metropolitan research university. Our science learning programs can potentially improve citizens' science literacy and serve as a national model for large, state-supported universities, especially those that interact with community colleges. Its 42,000 students—30,000 of them undergraduates—make ASU the sixth largest U.S. university. With 2 million people, Phoenix is the largest metropolitan area served by a single comprehensive Research I university.

Reform goals. Science literacy is the capacity to explore—at least at an elementary, inquisitive level—natural phenomena and products of human technology. It is a critical component of higher education and a three-step process:

- General science education can turn students into critical thinkers. All undergraduates must meet this level; non-science, mathematics, engineering and technology (SME&T) majors must be able to think critically about such issues and have SME&T skills at the recommended ability levels.
- Students are problem solvers who must be able to recognize SME&T problems and use science processes to solve them. All SME&T majors should have these skills; we would like as many non-SME&T majors as possible to have them as well.
- At this stage students recognize, articulate and solve novel SME&T problems. These leaders and creators are the most skilled students, regardless of major. They need courses *and* access to experiences like undergraduate research and other opportunities that challenge and broaden their talents. Two task force reports—*The University for the Next Century* and *Instructional Evaluation at ASU*—reinforce and shape significant institution-wide reform of undergraduate SME&T education. At ASU we teach students how to be lifelong learners and productive, satisfied citizens in a changing technological society; we involve students and teachers in the learning process by continuing to conduct research and use technology to improve the teaching and learning processes; we make quality public baccalaureate and post-BA education accessible to qualified students; and we create new partnerships to share and integrate the university's cultural, artistic, technological and intellectual life with the community.

Reform plan. An ASU faculty task force formed to develop a comprehensive SME&T reform plan. They examined ASU's undergraduate SME&T education courses, learned about the national SME&T agenda; shared reform experiences, secured support from SME&T department chairs and deans of colleges of Liberal Arts and Sciences and Engineering and Applied Sciences, and formed an action plan. Reform will occur in stages. Stage 1 will reform introductory science and mathematics courses. We will start with non-SME&T majors because we can positively influence 18,000 students a year, and because departments variously incorporate critical thinking, cooperative learning, and research experiences into basic courses. Later stages will build on this foundation to increase access and improve education quality for SME&T majors. Departmental chairs are crucial in institutionalizing integrated course offerings, as is coordinating and collaborating with the Maricopa County Community College District (MCCCD), the origin each year of more than 25 percent of new admissions. ASU proposes turning all basic science courses for non-SME&T majors into labs, lectures and seminars that emphasize critical inquiry, based on a similar revision of ASU's large-enrollment, non-major biology course. For faculty members we propose a five-week planning seminar of creative activities built around expectations for SME&T learning and starting with basic science courses for non-SME&T majors.

Institutional strategies. Institution-wide reform efforts address critical questions in SME&T education, including:

- How can instruction better emphasize learning concepts and apply science processes?
- How should collaborative learning be incorporated into reform?
- How to include undergraduate research experiences in a public university's student-to-teacher ratio?
- How can we implement curriculum integration for continuing students and transfer students?
- If interdisciplinary experiences is an essential feature of SME&T reform, how can faculty continue their career progression while engaging in novel forms of education?
- How can students become better learners by using technology and how can productivity measures assess this change?
- Without losing valuable information, can students be taught in ways that increase critical learning skills and prepare them for active citizenship?
- What forms of learning enhance the creative abilities of students and what kinds of pilot projects might be imported for use at ASU?

Faculty development. Curriculum improvements and reforms are in place in ASU SME&T departments. We propose to extend existing reforms in individual departments to cross between all SME&T departments using a proven faculty development model. After reaching a consensus for goals, methodology, implementation strategies and evaluation, institutional reforms will be implemented starting in the spring of 1998. Initially, planning involves all faculty members who teach introductory courses for non-SME&T majors, department chairs, deans, and ASU's provost and president.

Faculty reward structure. Several departments at ASU have found innovative ways to reward faculty for the creative combination of research and education. One example highlights shared teaching assignments that are considered full-time commitments by the department. ASU's institution-wide reform must be sustainable regardless of the availability of external funding. Consequently, a large portion of planning will be carefully evaluating reform costs and outcomes. The university will fund a number of programs as pilots and carefully monitor the changes that such programs may bring if infused throughout the institution. The provost and the colleges of Liberal Arts and Sciences and Engineering and Applied Sciences will help fund the expansion and evaluation of several SME&T reforms.

Student experiences. Many corporations and professional organizations have developed outcome success measures for students in SME&T courses. ASU wants to incorporate these into a staged process of education reform: first to non-SME&T majors, then majors and graduate students. In all cases the goal is to offer a basic level of science literacy and the ability to work effectively in a fast-changing technological world.

Barriers. One barrier at ASU is based on urban student lifestyles. Most ASU students have work and family responsibilities that take them off campus and hamper delivering education reform. Working initially with non-SME&T majors allows more flexibility for reform than working with majors or graduate students. In the disciplines there is greater reluctance to try significantly different approaches. ASU will work with the Maricopa Community College District to articulate agreements and give incoming first-year and transfer students similar opportunities.

- **Bellevue Community College**

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Bellevue Community College (BCC) is a two-year public community college and Washington state's third largest higher education institution. More than 16,000 students enroll each quarter. The mission is to provide an academic environment that encourages students to become responsible, analytical, creative, and productive citizens; provides excellent, accessible services and education programs; meets the community's changing educational needs; promotes pluralism; and leads and partners efforts to promote community culture, business, and technology.

Reform goals. The goals of the *Information Literacy Across the Curriculum* reform initiative are to ensure and improve quality in instructional programs in information literacy by developing online and electronic media research and critical thinking skills that students need in educational and professional careers.

Plan overview. In 1989, the college approved a five-year education plan that identifies learning outcomes that all students need to function effectively in today's society. The plan integrates these competencies throughout the curriculum and includes regular assessment. One learning outcome, technical literacy, responds to the movement toward an information-based society.

As an information-based society, it is crucial that students and educators have skills needed for lifelong learning and the technology-based workplace. The proliferation of online and electronic media resources demands effective application of research and communication tools and the ability to apply critical thinking in their uses. To prevent a population of *haves* and *have nots*, educators must make sure all students are information literate by providing tools for managing, analyzing, and applying digital information. Information literacy is the ability to identify a problem and its information content, and then to be able to locate, evaluate, and synthesize the results into a usable solution.

Information Literacy Across the Curriculum is an ongoing integrated project to infuse information literacy into the curriculum. Thorough evaluation and collaboration will create a disseminated program whose members share materials locally, regionally, and nationally.

Institutional strategies. To meet these needs, BCC proposes to:

- develop student and faculty skills used in information literacy;
- use information literacy to develop critical thinking skills focusing on evaluation, synthesis, and application of the information;
- teach faculty to integrate electronic communications and information resources in classes;
- develop collaborations between and among faculty, librarians, students, and technical support personnel; and
- assess the extent to which infusing information literacy content yields enhanced general critical thinking skills among students.

To develop student and faculty information literacy skills, BCC will offer workshops, training sessions, and one-on-one consultations for students acquiring information literacy skills and faculty incorporating students' use of newly acquired or enhanced information literacy skills. In the fall of 1996, BCC identified and recruited several students and five faculty from various disciplines, including social sciences, science, business, educational development, health sciences, and arts and the humanities, as an initial training team. These disciplines were chosen so that the curriculum and classes have broad appeal. The team will undergo intensive training in the skills needed to use electronic communication tools and as well as in navigation tools for searching digital resources. By the end of the training session, faculty and students will be able to develop electronic course materials and integrate on-line searching, critical thinking, and information use into the teaching/learning process and their curriculum. Student team members will be Information Literacy Assistants for students and faculty. Once faculty and students are trained, pilot project faculty members will infuse their classes with the skills and techniques for learning and the materials developed during the fall sessions.

The BCC Institution-wide reform plan focuses on developing information literacy skills for students, especially their critical thinking skills. BCC library staff will consult with faculty to develop discipline-specific case studies, assignments, and projects that incorporate electronic resources requiring the use of critical thinking skills and will provide ongoing support for faculty on incorporating critical thinking skills related to information literacy into their curricula. BCC and the NorthWest Center for Emerging Technologies (NWCET) will develop workshops for faculty and Information Literacy Assistants.

Workshops will consist of weekly sessions on topics that include:

- creating a home page for faculty-prepared course materials and syllabi;
- easing students into using technology; and
- teaching faculty to use the Internet for discipline-based research and innovative applications relevant to undergraduate education.

To disseminate courseware products and information gathered during the pilot project and throughout the year, BCC, NWCET and the University of Washington (UWired) will conduct symposia to develop collaborative efforts toward using *Information Literacy Across the Curriculum*. Key topics include: developing strategies and steps to improve teaching and learning by integrating information technology and improving policy making, planning, and implementation through better collaboration and cooperation. The three-day symposium will be offered to 25 faculty, librarians, and administrators from the Washington state community college system. Additional symposia will be offered based on demand.

A month after project start-up, an evaluation design process will identify the purposes for the evaluation, audiences, key questions, methodologies, data analysis, and reporting procedures. Based on the evaluation design and key objectives to be evaluated, external evaluators will design student and faculty survey instruments that will be reviewed by key project staff, pilot tested, and revised before use with target audiences. Potential evaluation instruments include skill-based assessments, focus groups, and interviews with stratified samples of students and faculty. A January 1997 interim report will allow program modifications; a final report will be prepared by September 30, 1997.

- **Beloit College**

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Beloit College is a private, selective, undergraduate liberal arts college with an enrollment of 1200 students. About 25 percent of graduates major in science or mathematics (biology, biochemistry, chemistry, computer science, geology, mathematics, physics) with 80 percent continuing for advanced degrees, mainly Ph.D.s and M.D.s. Most graduates have at least one summer or semester of full-time research experience in a university, government, medical or industrial laboratory. Beloit College is among the "Science 50," the fifty liberal arts colleges in the nation that produce the most scientists per capita.

Reform goals. Beloit College has a strong tradition of giving science and mathematics majors direct experience in the active, collaborative process of science. It plans to use this model in all courses so all students learn what science is by doing it, whether or not they plan to work in a scientific discipline.

Plan overview. Beloit College science and mathematics faculty are major participants in several inter-institutional reform efforts that have changed the way students learn science and math. An institution-wide curricular review is underway. A quarter of faculty members will be replaced over several years, and the science and mathematics building is scheduled to be renovated in a few years. The college is asking fundamental questions about structuring student learning experiences, faculty effort, and physical facilities for the coming decades. It plans to use its historical strengths in on-campus student-faculty research, off-campus experiential education, and a growing commitment to collaborative approaches to classroom and laboratory learning at all levels to change the way undergraduates experience science.

Institutional strategies. Institutional reform through inter-institutional collaboration is the hallmark of faculty and curriculum development over the past decade. The BioQUEST national biology curriculum reform project and the ChemLinks Coalition (one of five projects in the NSF *Systemic Changes in the Chemistry* initiative) are based here. Significant portions of the NSF-supported *Teaching General Chemistry: A Materials Science Companion* and its CD-ROM were produced and tested on campus. The Keck Research Consortium of the 11 most productive geology departments in liberal arts colleges was based at Beloit. The *Journal of Undergraduate Mathematics and its Applications* is edited here, as was a volume of the NSF-funded calculus reform project of the Associated Colleges of the Midwest and the Great Lakes Colleges Association. Membership in the Pew Midstates Science and Mathematics Consortium has created opportunities for regional collaboration with other liberal arts colleges and research universities on student-faculty research, faculty development, and curriculum reform. Beloit College has helped to lead Project Kaleidoscope's national alliance and taken advantage of its workshops and networking.

Beloit participation in national education reform efforts in the sciences and mathematics has encouraged local reform. The BioQUEST philosophy and materials permeate the biology curriculum. The *Lab First* approach to general chemistry for all students is one of Project Kaleidoscope's *Programs that Work*, a success that led to establishing *Workshop Human Biology* here. Howard Hughes Medical Institute grants support a *Girls and Women in Science* program for students and 6th grade girls, summer research opportunities for entering students, workshops for secondary teachers, and curricular innovation in the sciences. Beloit's math modeling teams have placed internationally by building on class experience with group approaches to solving real problems. A new *EthnoMathematics* course is catching the attention of other schools. Institutionally, Beloit addressed curriculum and pedagogy issues through a *Year of Dialog* last year, to be followed this year by restructuring the curriculum, and through an ongoing series, *Talking About Teaching*—a discussion of pedagogy issues. The role of science and mathematics in liberal arts education and its interdisciplinary, experiential, and international aspects are issues on the table.

This summer Beloit installed a fiber optics network for all academic and residential buildings, giving the rest of the campus access to people and information that science and mathematics students and faculty have had in Chamberlin Hall for eight years. Faculty training has begun, and Beloit is discussing the future role of communications technology for students and faculty.

This fall Beloit begins planning for a major renovation of Chamberlin Hall, a 30-year-old building that houses the sciences and mathematics. Beloit will combine the planning process with campus-wide discussions on curriculum and pedagogy issues to explore the role of science and mathematics and how students will learn in future decades. Translating programmatic ideals into physical spaces within budget constraints will force Beloit to prioritize staffing, class size, classroom and laboratory activities, the relative importance of student-faculty research, expectations for departmental and interdisciplinary involvement, social and physical structures needed to build a community of scholars among students and faculty, and the technology needed to support these approaches.

Beloit will start the planning process with local curriculum and pedagogy discussions, and with visits to and from other schools with experience in curriculum reform and facility renovation. Its local curriculum reform experience has produced small projects to renovate teaching spaces and accommodate active, collaborative approaches to learning, and incorporate new technologies. Beloit is used to change, so a critical part of planning will be to anticipate the need for continuing change. We expect a shared commitment to emerge that supports a model of hands-on, collaborative learning for all students from the start, and a corresponding model for faculty involvement in student learning. We think the collaborative process of reaching that commitment will be at least as important as developing and implementing the model itself.

- **California Institute of Technology**

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The California Institute of Technology is an independent private university with 900 undergraduates and 1,100 graduate students. The education mission hasn't changed since 1921—to train the creative scientists and engineers urgently needed in our educational, governmental and industrial development.

Reform goals. Institution-wide reform seeks to involve faculty and undergraduate students in creating computer-based teaching tools on topics that span a range of technical disciplines in the physical and social sciences.

Plan overview. Caltech initiated an institute-wide program to develop computer-based teaching tools. Materials cover a range of technical disciplines including the physical, chemical and biological sciences; earth and planetary sciences; mathematics and applied mathematics; chemical, electrical, mechanical, civil, environmental and aeronautical engineering; and economics and the social sciences. To accomplish this, Caltech involves its most valuable resource—undergraduate student skills—in the instructional process. Undergraduate students work closely with Caltech faculty for 10 weeks in the summer to improve visualization, computing and communication aids for teaching technical courses. Undergraduate summer work products are computer-based materials for institute science and engineering courses. Caltech would like the effort to become part of a national model for systemic reform, focusing on comprehensive, coordinated institute-wide efforts to incorporate multimedia materials into routine science and engineering coursework.

Institutional strategies. Initially the Caltech plan emphasizes projects that significantly enhance the broad goals of institute teaching. Faculty members work with students to develop computer-generated course-enhancing materials such as animation and visualization, multimedia presentations, lecture note organization, laboratory preparation, interactive tutorials, and homework assignments.

The new program, modeled on Caltech's Summer Undergraduate Research Fellowships (SURF) program, requires students to collaborate with faculty members to design and develop computer-based teaching tools. Students submit proposals for projects they want to develop. A faculty committee reviews proposals and makes awards.

Students work 10 weeks in the summer, then write a technical paper and give an oral presentation. Summer products are computer-based instruction aids for Caltech courses. Proposals usually emphasize high-priority topics. The committee sets priorities and implements flexible, coordinated plans for developing teaching tools. In any given year, the committee targets a short list of courses for reform. Short-list courses need enthusiastic instructors and students who believe the topic is an institutional top priority.

Caltech and the Jet Propulsion Laboratory (JPL) have unique databases, educational videos and other materials critical educational resources for students at all university levels. This project represents an era in which students and faculty are partners in the instructional process.

The key to program success is faculty creativity in implementing new teaching methods, and the understanding skills of undergraduate students. Students are encouraged to "surf the 'Net" and use the best materials available—adapting them, using them as examples, and modifying them to course teaching needs.

Students often develop original animations and presentation materials for Caltech instructors and courses. Student creativity is crucial.

A preliminary faculty and student survey shows many more faculty volunteers and student fellows are interested in the teaching partnership than the program can accommodate. This response underscores faculty commitment to teaching science and engineering and undergraduate acceptance of the program.

The program leverages faculty time and creativity; students become partners in the Caltech teaching enterprise and have a much different role than as passive lecture receivers in traditional instruction; and they work with faculty members to identify areas that deserve attention, and are responsible for developing and using their own teaching materials. Students have more input into and responsibility for the content of courses used to teach fellow students. That students develop large parts of course material presentation, methodology, and emphasis is the program's most significant feature. This involvement broadens students' traditional experience in college and better prepares them to communicate technical issues to nonscientific peers. This initiative combines Caltech faculty expertise, student creativity, and Caltech and JPL technology resources to improve teaching through computer-based course material.

Animation and visualization: Elementary animations vastly improve the instructional process. Examples include visualizing vector fields in electricity and magnetism; dynamic processes in physics, chemistry, biology, earth and planetary sciences; and three-dimensional concepts in every science.

Multimedia presentations: Caltech can prepare multimedia presentation materials using extensive video libraries of the *Mechanical Universe, Project Mathematics!*, and the *Chemistry Animation Project*. The institute intends to use materials in a personal computer-ethernet environment for instructional purposes.

Lecture note organization: Some instructors or courses will not initially be amenable to extensive use of teaching materials. At a minimum, lecture notes will be translated into electronic form for clarity of presentation and dissemination to students on demand through the 'Net. Instructors may or may not use the materials in lectures, but students benefit from increased access, ability to familiarize themselves with the material before it is presented in lecture format, and freedom to concentrate on topics depending on their background and familiarity with the topic.

Laboratory presentation: We would not attempt to replace laboratory experience with computers, but we can better prepare and train students in procedures they are likely to encounter in their laboratory experiences—freeing up time for investigation rather than struggling with frustrating impediments in operating an instrument, for example, in which they could be trained on-line before the lab.

Interactive tutorials and tuned homework assignments: Some materials can be adopted to a format that links multimedia materials to exercises, questions and homework problems of graded difficulty levels. Students can probe a topic at different depths so students who want to learn more can do so. Students get feedback on problem-solving skills by working through a graded-difficulty problem set, with answers reinforced electronically through other visualization tools.

- **California State University - Fullerton**

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California State University-Fullerton (CSUF) in Orange County is one of 22 campuses of the California State University System. The comprehensive university serves a diverse undergraduate population of nearly 22,000 students. CSUF aspires to combine the best qualities of teaching and research universities—where engaged students, faculty, and staff work closely to make learning preeminent.

Reform goals. The CSUF Undergraduate Reform Initiative is a three-year plan for academic needs of four student groups: beginning students starting science, mathematics, engineering, or technology (SME&T) majors; junior and senior SME&T majors; nonscience majors who want to be elementary school teachers; and nonscience majors seeking general education in science and technology.

Plan overview. Project goals are to: increase beginning science and engineering majors; give SME&T graduates workplace knowledge and experience; make certain future teachers have the understanding, skills, and attitudes to promote student success; and create citizens who are more literate in science and technology.

The strategy is to build on successful projects and focus them on institution-wide initiative goals. Three interdisciplinary faculty teams will lead the reform effort: Team 1 will work on the curriculum and present foundation courses; Team 2, general education and teacher preparation; and Team 3, interdisciplinary enhancements for science, mathematics, and engineering majors. Each team leader will be positioned to develop curricular and instructional innovations and involve colleagues in the initiative.

Institutional strategies. The foundation courses team will look for ways to make the first-year instruction in science and mathematics more student-centered, meaningful, and effective. It will continue to refine and expand the innovative use of technology piloted in current projects. Using client-server instructional systems that help prepare, exchange, and assess student work will be part of this effort. A focus will be on enhanced analytical and critical thinking and communication skills within disciplines. An interdisciplinary team will work with mathematics faculty members to apply examples and problems from relevant fields to math courses, and will improve sequencing and coordinating courses in disciplines that support student majors.

For science and math courses in general education and teacher preparation, the team will work closely with the university-wide effort to reform general education. Recognizing that more than 70 percent of elementary teachers start school in community colleges, CSUF is working on a science articulation project with 10 Orange County feeder community colleges to develop three interdisciplinary general education science courses to help students see science interconnections. Course content and instruction meets national science education standards. Community colleges and CSUF will develop and offer the course to prospective elementary teachers.

To enhance interdisciplinary SME&T majors, the team will look for ways to better prepare students for the business world by embedding communication skills, combining science and technology with focused work in business, using contemporary computer laboratories, and building on rich traditions of undergraduate research—now supported by NSF and the National Institutes of Health—to expand learning opportunities by solving problems. Team-based clinics, applied mathematics projects, internships, and lab research will help students prepare for science and technology careers.

The School of Natural Science and Mathematics reallocated its resources to find ways to use technology-based instruction in all disciplines. Funds are in place to develop an electronic classroom. Matching funds will supplement NSF-funded projects, including a math simulation and modeling lab, a computational chemistry and physics lab, and a molecular science development project conducted jointly with UCLA under NSF's *Systemic Changes in the Chemistry Curriculum* initiative. This year CSUF will complete an $11 million communication network infrastructure project that provides an on-campus video, data, and telephone network and enhances student-faculty communications.

With the leadership and support of the president and vice president of Academic Affairs, the initiative will catalyze campus-wide activity, spurring the campus culture to support a spirit of reform among CSUF faculty.

- **Chemeketa Community College**

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Chemeketa Community College is a five-campus, comprehensive, public institution that offers professional-technical and transfer education, developmental education, and lifelong learning for the 388,770 residents of its 2,600 square-mile district. The college district includes four counties whose populations have grown significantly since 1990. Chemeketa is the state's second largest postsecondary institution and has the state's highest Hispanic enrollment. During the 1994-95 academic year, 38,337 students attended classes; 55 percent were women, 45 percent were men; full-time equivalent (FTE) was 8,479 and the median student age was 32. FTE distribution was as follows: lower-division transfer, 37.8 percent; vocational-preparatory, 27.3 percent; developmental education, 15.6 percent; and other, 17.4 percent. Chemeketa defines its purpose as—

- *Vision:* Chemeketa Community College is a dynamic community of learners and innovators.
- *Mission:* Chemeketa Community College's mission is to empower through intellectual growth, meaningful career preparation and advancement, and enhanced personal effectiveness; and
- *Values:* We develop and use effective approaches to learning and leading, continually improving program and service quality.

Reform goals. To reform mathematics courses to reflect AMATYC standards, including the "rule of four" (graphical, numerical, symbolic, verbal); to increase student proficiency in mathematics; to raise student success rates in mathematics; to better prepare students to complete certificate, degree and transfer programs; and to better prepare students for the technological workplace.

Plan overview. We reformed precollege algebra sequences, college algebra, trigonometry, calculus courses, probability and statistics. Now we will reform three mathematics sequences that support professional-technical programs. Interdisciplinary faculty teams completed the initial reform by investigating professional-technical and transfer courses in partnership with K-12, business and industry. The teams researched best teaching practices in the instructional community, including authentic assessment. Now students work in groups in laboratory or research settings, use technology, and engage in active learning and inquiry methods recommended by AMATYC standards. Reform efforts to date have generated new catalog course descriptions, new course outlines with performance-based outcomes, new classroom practices, new technology (graphic calculators, a calculator-based laboratory system, spreadsheets, a computer projector for teacher/student classroom demonstrations), and U.S. Department of Education Title III-funded lab supplies for student investigations. When a core faculty team reformed college algebra, student retention and performance dramatically improved. We expect a similar improvement from institution-wide reform. We need increased faculty development to support such reform because only a few faculty members have experience teaching the new courses. We will continue to study innovative teaching methods, synthesize cross-disciplinary content to include reform of content and pedagogy and how technology enhances both.

Institutional strategies. Curricular reform began in 1991 with a grassroots mathematics faculty effort to boost student-centered learning and retention. This project provides release time for continued course reform and faculty development, and includes institution-wide math reform at the community college level. To complete the evolution, this project will help us reform technical mathematics courses. Institution-wide reform will raise students' mathematics proficiency levels and raise the success rate in science, engineering, and professional-technical fields, including early childhood education and mathematics for elementary teachers. Complete institution-wide reform of math at Chemeketa tied to K-12 and business/industry standards will offer a model for similar reform at other colleges, in other disciplines. Technology is critical to math instruction reform because it helps students learn mathematics conceptually. Using technology in math courses is fundamental to Chemeketa reform efforts. Using technology in math courses is often students' first exposure to technology and forms the basis for their learning technology in their professional-technical, engineering and sciences courses. Understanding technology as a tool is critical to cultural literacy and preparing for careers.

Chemeketa supports faculty development with a formalized process in place since 1990. Chemeketa's Opportunity Center for Teaching and Learning offers continuing support through in-service training from nationally recognized consultants; collaborative affinity groups like Accelerated Learning, Cooperative Learning, Learning to Learn, Multimedia, Performance-Based Outcomes, and Authentic Assessment; Staff Development Resource Directory; Staff Development Training; Faculty-to-Faculty Internships; Faculty-to-Industry Internships; Faculty Release Time; Innovation Grants; Training Match Grants; Integrated Instruction Grants; Professional Development Conferences (academic and methodology); and technology training. Such opportunities create math faculty members who excel in pedagogy and content reform and who offer leadership to other college faculty members through presentations at conferences. The faculty presented at the November 1996 National AMATYC Conference and participated in a panel at the June, 1996, National Calculus Reform Symposium.

Other collaborations: Industry partnerships have helped identify student needs for essential math in professional-technical and transfer programs. Examples of partners include Intel Corporation, Salem Memorial Hospital, environmental and resource management firms and state and local government agencies.

High school partnerships: Chemeketa has been an active partner with regional K-12 schools in the statewide reform efforts directed at increasing skills and competencies in students, who will reflect this increase through the achievement of certificates of initial and advanced mastery. Mathematics reform has been an integral part of these collaborative efforts. Chemeketa mathematics faculty, in collaboration with regional high schools, was responsible for revision of the Level 2 State-Wide Regional Mathematics Skills Contest to reflect the mathematics reform format.

Regional high school students may start lower-division transfer courses during their senior year through Chemeketa's Step Ahead program. Chemeketa's math reform effort affects these programs through designing collaborative courses, visiting classrooms, and sharing best teaching practices like technology use, the rule of four and group learning. Regional high school students may start professional-technical programs in their junior year through Chemeketa's 2+2 program. Community college and high school design teams meet quarterly to ensure seamless student transitions from high school to college and the workplace. Collaboration is ongoing and essential.

- **City College of New York**

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Several elements make City College uniquely suited to improve student training in science and engineering and enhance the participation of underrepresented minorities and women in these fields. Characteristics include: significant enrollment of minorities; significant experience in curricular reform; high-quality research activities in science, mathematics, and engineering for undergraduate and graduate students; strong experience in outreach and retention for a diverse, nonresidential student population; and the presence of minority faculty and significant numbers of minority doctoral students who are role models for other minority students.

More than 14,000 students are now attending City College; 3,471 of them are candidates for master's degrees. More than 80% of City College undergraduates are from minority groups. The ethnic composition of City College undergraduates is 38.2% African American, 30.2% Hispanic and Puerto Rican, 16% Asian, and 0.3 percent Native American. The May 30, 1996, issue of *Black Issues in Higher Education* said that among traditional white institutions, City College ranked second in the nation in the number of African-American's awarded baccalaureate degrees, fifth in the number of African-American awarded master's degrees, ninth in Hispanics awarded master's degrees, and sixth in master's degrees awarded to minority students from all categories.

The City College School of Engineering has one of the largest undergraduate enrollments (2,507 students) of any state engineering school. City College ranks among the top nine producers of minorities earning baccalaureate degrees in engineering, computer science, and mathematics; sixth in master's degrees to Hispanics in these fields; and third in master's to African-American students in these disciplines. Twenty-nine percent of Hispanic undergraduates in engineering and 30% of African-American undergraduates in engineering from the six-state, mid-Atlantic region are enrolled at City College. In New York State alone, 45% of Hispanic engineering undergraduates and 49% of African-American engineering undergraduates are enrolled at City College.

The City College Division of Science consists of biology, chemistry, earth and atmospheric sciences, mathematics, and physics. It ranks 11th in the country in the number of African-American baccalaureate degrees awarded in the physical sciences.

Reform goals. City College proposed plan for science and engineering education reform has the following goals:

- to more effectively engage and motivate students in their science and engineering studies and promote their mastery of content as well as problem solving, communication, and teamwork skills;
- to change the reward system and on-campus culture that guide faculty priorities so many more faculty members are engaged enthusiastically in undergraduate teaching and curricular reform; and
- to build a foundation of resources that provide ongoing support for curricular innovation in science and engineering.

Plan overview. The project builds on the experiences of several successful curriculum development projects, letting their methods be used as widely applicable curricular models and their faculty as mentors to colleagues. Elements that characterize the most successful curricular projects will be extended through course sequences in science, mathematics, and engineering. These include:

- letting students help each other learn through collaborative and peer leadership strategies;
- designing courses with active, student-centered learning;
- embedding systematic development of learning, analytical thinking, and communication skills in teaching all content areas;
- aligning objectives, benchmarks for student performance, learning activities, and outcome assessment in each course;
- addressing the variety of learning styles in the student population;
- planning early and continuing hands-on design experience by students working in teams; and
- teaching students to function in high-technology environments.

These plans were developed in response to the characteristics of our urban students, including inadequate precollege preparation for required college course work in mathematics and science, diversity in learning styles and language competencies, and restricted opportunities (given the nonresidential status of the college and demands of off-campus employment), to achieve a strong sense of community.

Institutional strategies. The college will implement a coordinated set of activities that extend proven innovative teaching models throughout the science and engineering curriculum and engage faculty in curriculum development:

- Detailed curricular plans for specific science, engineering, and mathematics courses and curriculum modules developed by cross-disciplinary faculty teams. They will create learning materials, activities, and environments that help students integrate skills and concepts across courses and disciplines and better prepare students for the professional workplace through training in technology use, synthesis of information, and teamwork.
- A faculty resource center, the Center for Learning and Teaching will be established and be open daily for faculty use.
- A teaching caucus will meet regularly to promote, advise on, and evaluate curriculum reform initiatives. The caucus membership will include faculty from science, engineering, and mathematics departments, as well as faculty from departments such as psychology, English, English as a second language, and others, along with administrators from student support programs.
- A new system for developing faculty members' expertise in teaching, for assessing their candidacies for new positions, for tenure, and promotion will be operational. This system will weight heavily the commitment to teaching and teaching achievements. A key element will be the requirement that faculty candidates for promotion and tenure develop teaching portfolios for internal and external review.

The City College institutional reform project is expected to enhance the college's success in recruiting and retaining SME&T students, substantially improve the number and quality of SME&T degree recipients, better prepare graduates for the SME&T professional workplace, establish administrative structures needed to ensure the long-term operation of new programs and activities, and provide an SME&T educational model that other institutions can replicate.

- **Clark Atlanta University**

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Clark Atlanta University formed in 1988 when Atlanta University (1865) and Clark College (1869) consolidated. Clark Atlanta is a comprehensive university with more than 5,200 undergraduate and graduate students and more than 350 faculty members—110 of whom are in science, mathematics, engineering and technology (SME&T) disciplines. Clark Atlanta graduates meet standards of excellence in contemporary higher education. They are taught creativity and given a perspective on the world that helps them excel in careers and personal lives, to seek new knowledge and solve the problems of humankind.

Reform goals. The goal of Clark Atlanta's reform initiative—in the form of an Earth System Science program—is to help students think and solve multi-disciplinary problems while honing their understanding of interactions among earth system components. Faculty members use a systems engineering design approach to formulate this interdisciplinary program structure.

Plan overview. Clark Atlanta's Earth System Science program has the following elements:

- An enhanced interdisciplinary faculty development program;
- A post-freshman summer "practical experience" program;
- The inclusion of interdisciplinary case studies in all freshman orientation classes; and
- Developing and teaching *Critical Thinking Across Scientific Disciplines*, a sophomore course; and
- An in-depth capstone course for senior science and math majors, *Science: An Integration of Knowledge*.

Institutional strategies. Faculty for developing, teaching, and implementing interdisciplinary science courses for majors and nonmajors will be selected from the Schools of Arts and Sciences, Education and Business. With the department chairs of faculty members who help design interdisciplinary science courses, deans determine what portion of a faculty member's time for interdisciplinary studies makes up their teaching load. The dean and chairs of each faculty member's department devise and implement an evaluation plan to assess a faculty member's performance in interdisciplinary studies. The evaluation is part of a general faculty evaluation used to support merit promotion and tenure decisions.

- **Community College of Philadelphia**

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The Community College of Philadelphia is a comprehensive, urban community college that serves about 45,000 students annually in credit and noncredit courses, workshops and seminars. Nearly 58 percent of students are from ethnic minorities. It is an open-admission, associate degree granting institution that urges students to achieve greater personal insight, to appreciate world diversity and interdependence, to increase their intellectual curiosity, to improve their ability to think critically and express ideas—to fulfill themselves through service to others, and to prepare for future work and study.

Reform goals. The College reform effort seeks to fully develop its Culture, Science and Technology (CST) curriculum, in which science is seen as the systematic pursuit of reliable knowledge about the natural and social worlds. *Technology* is defined as producing and appreciating knowledge to solve particular problems. *Culture* contains, among other elements, all the knowledge that society members learn, share, accumulate and pass on. The curriculum gives students a basic understanding of culture, science, and technology essential for success as workers and citizens. An estimated 3,400 undergraduate students will enroll in the curriculum each year.

Plan overview. In January, 1996, the Associate in General Studies Degree curriculum was discontinued by the College. The curriculum, enrolled 11,500 students annually. The major problem was that students took courses almost whimsically. Often students enrolled in courses unrelated to each other and out of sequence, so degree completion often resulted in disconnected courses with little curricular coherence. Creating a new CST curriculum is one of several alternatives to this arrangement. Developing the curriculum was the CST Faculty Steering Committee's responsibility. The committee is made up of faculty members from the biology, chemistry, computer studies, English, learning labs, math and social sciences departments. The committee's year-long planning and research resulted in a curriculum proposal the college approved in April ,1996. Steps were taken to implement the new curriculum by fall, 1996. A project chair was appointed and the Steering Committee will be expanded. During the fall semester, 1996, the steering committee planned and offered the first student orientation; revised courses to integrate culture, science and technology topics; offered faculty development workshops; and developed assessment strategies. During spring 1997, student orientation and faculty development initiatives will continue, materials for identified elements in interdisciplinary instruction will be developed and adopted, three learning communities will be formed, and initial project assessment will be completed. During the project's second year (1997-98), student orientation and faculty development initiatives will continue, revised courses will be implemented, supplemental instruction and collaborative learning activities will expand, and project assessment and evaluation will continue.

Institutional strategies. College faculty members are interested in interdisciplinary coordination and recognize the need to revamp the undergraduate experience. Linkages will be established among courses so desired interdisciplinary outcomes are achieved. The most successful college efforts have occurred in mathematics, the sciences, and technology.

The college's recent (1995-96) curriculum reform efforts will be implemented in the CST curriculum. The curriculum will contain seven required dimensions underlying the College's curriculum reform. These include: written expression, quantitative reasoning, scientific reasoning, cultural studies, interpretive studies, artistic and oral expression, and cross-cultural studies. The CST curriculum will meet the college's American diversity requirement, and its requirement for computer competency.

Faculty development. Recognizing the need for new pedagogical approaches, a series of learning experiences (workshops, seminars, conference attendance) will be provided for faculty and staff in areas important to project success. Workshop examples include:

- supplemental instruction,
- collaborative learning,
- multimedia instruction using technology,
- innovative pedagogical methods,
- interdisciplinary instruction; and
- learning communities.

Student experiences. Student orientation is conducted each semester to help students get involved with the program early. Students are encouraged to support their peers as they work together to meet CST curriculum requirements. Each student is assigned to a learning community, required to use the college's computer, writing, and science lab network, and to have a planned program of supplemental instruction, including tutoring.

Assessment. Community College of Philadelphia understands the need to fully evaluate new programs. Project staff will develop measurable evaluation criteria and document all efforts, activities, and people served. Impact surveys will be conducted to gain perceptions about curriculum progress and institutional benefits. A summary evaluation and curriculum audit will be conducted. External evaluators and staff of the Office of Institutional Research will participate in the assessment process.

- **Drexel University**

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Drexel University in reexamining its mission has emphatically restated the central role of undergraduate education in preparing graduates for careers in a technological world. Drexel offers 48 bachelor's programs, 33 master's programs, and 19 doctoral programs in five colleges: Arts and Sciences, Business and Administration, Engineering, Design Arts, and Information Science and Technology. In 1994-95, Drexel awarded 1,233 bachelor's, 820 master's and 62 doctoral degrees. Drexel's cooperative education program is one of the oldest (dating from 1919), most successful and most extensive in the nation and provides students valuable experiences of the real world working environment as part of their undergraduate education. While maintaining student status and institutional connections, students are typically employed for three, six-month co-op periods over a five-year undergraduate curriculum. Drexel has been, and continues to be, at the forefront nationally in use of microcomputers as a tool of educational implementation across the university. Microcomputers have played an important role in both how we teach as well as what we teach.

Reform goals. Our goals are to improve the quality of undergraduate education using many approaches, methods and procedures that have contributed to reform at Drexel and expand these approaches university-wide. Subject integration, hands-on active learning techniques, small group interaction, team projects, and extensive use of computers and other electronic and communication technologies are being incorporated into our academic program offerings suitable for all undergraduates, including appropriate sequences for majors and nonmajors. The plan includes a faculty development program which addresses the issues of how we teach as well as what we teach.

Plan overview. Drexel is a national leader in restructuring engineering and science education as a result of a multi-year effort by faculty and administrators and aided by support from NSF, other granting agencies, and private industry. The results are an integration of science, mathematics, and engineering fundamentals with hands-on lab experiences and a learning community that includes the humanities for the engineering curriculum developed under the Enhanced Educational Experience for Engineers (E4) program. Drexel has also been in the leadership of exporting these concepts to other universities and upper division courses in an inverted curriculum through the Gateway Engineering Education Coalition. In the biological sciences, the Enhanced Bioscience Education (EBE) program gained national recognition for the way it engages bioscience majors in experiential learning and project-based inquiry during their freshmen and sophomore years. In keeping with the mission of our technological university, the faculty, with administration support, are developing university-wide approaches that serve as national models for engineering, science, and mathematics instruction for all undergraduate students.

We are initiating sweeping changes on a campus-wide basis by providing opportunities and incentives for faculty to learn and incorporate new instructional approaches into their classrooms and laboratories. This is accomplished through a series of pedagogy- and discipline-based workshops by outside consulting faculty and Drexel faculty following university-wide discussions of curricular needs. The goals are to renew student interest in engineering, science and mathematics and quantitatively change how well they learn the subjects.

Institutional strategies. Planning seminars and workshops are conducted in cooperation with the Drexel Teaching-Learning Institute. Group leaders who participate in the E4 and EBE programs with faculty from the Division of Instruction and several outside consultants familiarize faculty with innovative instructional technologies. Topics include curriculum design, implementation and evaluation, team teaching, collaborative education, learning communities, effective use of the computer in the learning process, and technical training in using specialized instructional software. To emphasize this further, the University has created a central administrative presence and emphasis through the establishment of an office of Vice President for Educational Research and Development which will place emphasis on innovative educational methodologies and technologies.

Faculty members redefine core principles and topics that should be base content for each course. Specific new courses are offered during the academic year following their design. As more faculty become familiar with active learning techniques and incorporate them into classes, the university will acquire a cadre of professionals who are themselves resources for faculty development. In this way, these techniques and approaches will spread into other courses across the university. A few linked courses are planned for students in particular majors. Course pairs will be designed by faculty in the students' major and faculty in the basic sciences, engineering or mathematics who will work together across department and college boundaries. Students will be block scheduled into both courses during the same quarter. A second approach will be to design broad-based courses team taught by a faculty member from the students' major and a basic sciences faculty member.

The urgency for change in the educational process is apparent. Systemic changes and a new educational culture is taking shape. The incoming engineering class of more than 500 students is enrolled in the Drexel Engineering Curriculum, patterned on E4 principles. The number of sections of each curriculum segment has more than tripled and new faculty participate in the core curriculum. As we embark on the challenges of scale-up and institutionalization, a way is needed to introduce them to core curriculum philosophy, objectives, instructional methodologies and evaluation techniques. Multimedia instructional materials such as electronic texts and tutorials, simulations, demonstrations, instrumentation labs, virtual instruments and experiments continue as course development activities.

The administration, faculty senate, and department representatives will establish a more coherent plan for effective faculty development, for mentoring new faculty, and for increased university support for undergraduate education. Systemic change requires that departments and faculties rethink their traditional roles, and the university will continue to support these ventures, including reallocation of resources.

Students in the elementary and secondary teaching curriculum enroll in the first quarter of EBE in fall, 1996, as a significant step in revising science and mathematics offerings to be more hands-on and emphasize collaborative learning. Added course development will enhance science and math linkages with the teacher education program.

- **Eastern Iowa Community College District**

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Through Clinton, Muscatine and Scott Community Colleges, the Eastern Iowa Community College District serves more than 270,000 students in eastern Iowa. The colleges offer vocational-technical training, college transfer programs, continuing education, business and industry services, and Job Training Partnership Act (JTPA) programs. More than 8,000 credit students attend the colleges; more than 54,000 area residents are enrolled in continuing education programs. Articulation agreements between EICCD and area high schools and four-year institutions make it easy for students to transfer. Ties with business and industry help us create competency-based, vocational technical programs that ensure graduates will meet employers' entry-level needs. The colleges offer 36 vocational-technical training programs in fields such as agribusiness, health, computers and electronics, industrial trades and office technologies. Students in 28 liberal arts and sciences concentrations can focus on physical and life sciences, social sciences, mathematics, English, fine arts and the humanities, and preprofessional programs such as engineering, law, chiropractic and health.

The Eastern Iowa Community College District strives to provide accessible quality educational programs and services that accommodate personal and community needs and expectations. These efforts reflect a commitment to excellence, lifelong learning and cooperation with all community segments.

Reform goals. Develop the infrastructure needed to create and maintain a professional on-line learning community; develop a new curriculum model using the online community; and develop ways to disseminate and continue to use the professional online learning and the community-based curriculum model.

Plan overview. A compelling challenge exists for technical education to devise innovation curriculum to meet the demands of the information age. This reform project addressed that challenge by creating a new curriculum model to reinforce students' interest and enthusiasm for their discipline through participation in a vibrant, interactive, Professional Online Learning Community whose pilot project involves environmental technology education. Products from the project will include: a user guidebook; revised instructional material, an instructional guide and a student guidebook for a ten-course environmental technician curriculum; and a new multidisciplinary course, *Environmental Ethics*, with instructor and student guidebooks. These educational products will feature student use of the Professional Online Learning Community and will be disseminated through EICCD's national curriculum distribution network. The project is designed as a prototype for developing curriculum using this concept in all fields of technical education. Dissemination of project results will touch hundreds of instructors and improve the education of thousands of students nationwide.

Institutional strategies. Reform efforts will highlight curriculum change, technology use, collaboration and partnerships.

• Florida Agricultural and Mechanical University

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Florida A&M University (FAMU) was founded in 1887 and is one of the three oldest universities in Florida's State University System. The fully accredited university recently had its accreditation reaffirmed in 1988. Student enrollment has increased steadily over the past 10 years. In the fall of 1995, FAMU enrolled 10,334 undergraduate and graduate students in 12 colleges and schools. This is twice the size of the university's student body in the 1985-86 academic year. Eighty-seven percent of the student population is African American; about 76 percent of these students are Florida residents. The university grants BS and BA degrees in 94 disciplines; MS degrees in 36 disciplines; and doctoral degrees in four disciplines.

Florida A&M is positioned to make a substantial contribution to the national goal of producing greater numbers of minorities who enter AME&T careers. The Board of Regents has approved the classification of the institution as a comprehensive university. This classification will permit the university to initiate more graduate degree programs. Over the past year, the Board has approved planning to implement Ph.D. programs in industrial engineering and education leadership and MS degree programs in environmental sciences and computer software engineering. The university recently received funding to initiate a program in public health. To support faculty research and training activities, the university has implemented an aggressive program to pursue external support for research and training. The impact of these activities is being recognized by the academic community at large. Among the more than 1,000 graduates at the 1996 Spring Commencement were four students who received NSF predoctoral fellowships to enroll in Ph.D. programs. The 1996 graduating class included 100 students who received BS degrees in engineering, 41 biology graduates, 16 chemistry graduates, 46 CIS graduates, and 9 physics graduates.

Reform goals. The goals of institution-wide reform include: graduating students who: understand the uniqueness of the natural world and appreciate the relationship between life and the universe; are technically informed citizens who can discuss scientific and technical topics; will become talented and creative scientists and engineers in the 21st century; and serve as creative and enthusiastic teachers who convey the excitement of science to the next generation of citizens.

Plan overview. Curriculum reform activities will be initiated under the supervision of the university president who chairs the Curriculum Reform Committee. Daily activities will be implemented under the supervision of the project director, who will serve as vice chair of the Curriculum Reform Committee. The project director is associate vice president for Undergraduate Studies, and serves on the staff of the provost and vice president for Academic Affairs.

The project director's responsibilities include: meeting with faculty to review the goals and objectives of curriculum reform and solicit its participation; recruit/identify teaching teams to develop multidisciplinary courses; help develop institutional incentives that elevate the reward system for effective teaching; and collect and review student/faculty evaluations and student performance data that measure the impact of curriculum reform.

Institutional strategies. Institution-wide reform activities include the following:

- developing a multidisciplinary general science course that uses an integrated cooperative instruction model incorporating an inquiry format and that will be developed initially as a one-semester sequence and expanded in the second year to a two-semester sequence (this two-semester sequence will satisfy the general science education requirement in the core curriculum for all nonscience majors);

- implementing a structured faculty professional development program that permits the use of current technological advances to enhance faculty teaching skills;
- developing innovative ways to deliver SME&T instructions that include ample use of current technology to transform the learning process from a passive activity to one in which students are active participants; and
- implementing experimental reform activities initiated in this effort as a wedge to modify the teaching practices of all university faculty.

- **Georgia Institute of Technology**

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The Georgia Institute of Technology, a unit of the University System of Georgia, is a public Research I institution with 9,500 undergraduate students and 3,500 graduate students. Georgia Tech was chartered to concentrate on technology and technologically-oriented areas of discovery. As such it has a unique, state-wide obligation for education in engineering and architecture and special responsibilities in computing, management, the sciences, and technologically-oriented aspects of humanities and social sciences.

Reform goals. The goal of our plan is to introduce an active, integrated, real world approach into the core curriculum—one that draws students into research-like activities, fosters cooperative learning, and uses our strategic advantage in networking and information technology. In fall 1995 the University System of Georgia made a decision to convert from a quarter-based to a semester-based calendar in the fall of 1998. One objective of this conversion is the implementation of a system-wide core curriculum for the 33 units that have undergraduate programs with allowances for differences in institutional missions. Draft plans for the new core curriculum are to be submitted to the chancellor's office by November 1996. Because of the short time frame in which this curriculum must be developed, many ideas included in this document cannot be implemented initially. It is expected that the proposed reform will be piloted with 100 entering freshman in the second year after conversion to the semester calendar, and after evaluation, expanded to ultimately include the entire entering class.

Plan overview. The Georgia Tech student body is diverse in ethnicity, shared in gender, but homogeneous in its educational objectives. Most students take a common set of core courses in their first and second years. We expect to provide the basis for interdisciplinary instruction and cooperative learning by scheduling students in groups of 25 for the same sections of first year courses (chemistry or biology, English composition, calculus, history or international affairs and computer science). Within these sections students will be further divided into teams of four or five students for collaborative problem solving and writing exercises. Faculty will meet regularly in the term prior to initiation of this program to develop coordinated syllabi and plan exercises that cut across disciplines. Regular meetings of participating faculty will discuss the progress of the courses and coordinate in-class and outside activities. Internet communication, problem-solving, and research will be an integral part of instruction in these coordinated classes. Network connections are already available in each dormitory room and a campus contract has been negotiated to provide low-cost, off-campus access to the Internet for students and faculty. It is expected that by the time this program is initiated all students entering Georgia Tech will be required to have their own computer, and that a common set of software will be available to each student through site licenses.

We anticipate the development of new laboratory courses that will provide the opportunity for interdisciplinary instruction and, in some cases, for remote acquisition of data. For example, an introductory analytical chemistry course, taken only by chemistry majors is based on a 350-gallon saltwater aquarium that represents a well-established dynamic ecosystem. Forty students take individual water samples each week for analytical measurements. The aquarium cannot support removal of individual samples by larger numbers of students, however, by outfitting the aquarium with computer-linked sensors, that can be monitored remotely via the Internet, and by having teams of students take water samples and work together in analyses that cannot be done by in-tank sensors, the aquarium-ecosystem can support the experimentation of a much larger number of students. This aquarium could be used as a platform for discussion, writing, and even experimentation in other courses. The aquarium can be monitored by middle- and high-school students through the Web site.

Institutional strategies. Georgia Tech has made a multi-million dollar commitment to install a high-speed fiber optic network that connects all campus academic, research, and living quarters. The institute is committed to enhancing undergraduate studies by creating a new position—Vice Provost for Undergraduate Studies and Academic Affairs. A national search to fill this position has been completed with the appointment of Dr. Robert C. McMath of Georgia Tech. Dr. McMath will oversee and coordinate many aspects of undergraduate studies, including curricular reform and the incorporation of educational technologies into the learning environment both inside and outside the classroom. Resources will be available to provide training for faculty in the use of these technologies and for their maintenance. It is expected that Foundation support will be available to provide for faculty release time to develop the course syllabi, Internet resources and problem-based exercises necessary to implement the desired core curriculum reform.

- **Grinnell College**

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Grinnell College is a coeducational, four-year residential liberal-arts college that attracts academically talented high school seniors from throughout the United States and the world and offers the Bachelor of Arts degree in 25 major fields. The college enrolls an average of 1,250 students from 48 states and 46 countries. The faculty, whose primary mission is to teach, number 133 and all full-time faculty hold Ph.D. or terminal degrees. The student-faculty ratio is 10:1. The college mission is to graduate independent, critical thinkers equipped to pursue successful careers and satisfying lives as socially responsible citizens. Grinnell's open curriculum, in which the only requirement outside the major is the first-year tutorial, is designed to instill in students the qualities of individualism, social commitment, and intellectual self-awareness. A liberal-arts education shapes these outcomes by giving students the freedom and responsibility to direct their own learning. More than one-third of Grinnell's entering students enroll in an introductory science course and more than one-third graduate with a science degree.

Reform goals. The goal of Grinnell's institution-wide science reform plan, the New Science Project, is to create an environment in science disciplines in which students traditionally underrepresented in the sciences—minorities, women, students from high schools that send few graduates to college, and first-generation college students—can reach their academic goals. By *success*, we mean the students will choose their majors and careers based on their interests and not on external messages that they are unwelcome, or incapable in the sciences. By giving all students an opportunity to make curricular choices in fulfilling their introductory course work in the sciences, we expect to increase student access to, and success in, these disciplines.

Plan overview. The New Science Project, supported by grants from the Lilly Endowment and NSF, was developed at Grinnell in 1992 following our identification of three constraints facing students from groups underrepresented in science disciplines: unsuccessful acclimation to college life; learning styles that do not respond to traditional pedagogical approaches; and a lack of role models and contexts for students of science. The project began responding to these constraints by instituting a week-long pre-orientation program for targeted new students prior to regular New Student Days; offering interactive introductory courses in the form of one-credit workshops in biology and chemistry; revising the calculus sequence in mathematics to include more active classroom learning; offering a four-credit, lectureless, workshop course in physics; and providing early research opportunities. In the second phase of the project, we will build on our experience by developing a four-credit workshop biology course patterned after the physics workshop course; adding a new introductory chemistry sequence with each section based on a specific topic, such as environmental or materials chemistry; and developing a year-long, alternative mathematics course that combines pre-calculus and calculus I material. The availability of these alternatives will allow students to choose among methods of instruction, those courses that are best suited to their own learning styles. We will provide additional academic support for students by expanding our Math Lab to include peer tutoring in biology, physics and chemistry. This new Science Learning Center will coordinate academic services for students and offer group or individual help from professional staff members and student tutors.

Institutional strategies. Grinnell's open curriculum, small class sizes, and institution-wide focus on individual students is an ideal climate for curricular change. We developed a tradition supported by the administration for constantly modifying and developing courses and experimenting with new teaching strategies. In this context, Grinnell's Science Division changed its pedagogical emphasis from a lecture-based format to one that requires active student learning in the classroom and laboratory. These changes were fostered over six years by intense faculty discussion in the Science Division. These discussions resulted in a cohesive effort across the sciences to develop laboratory-based curricula and in extensive involvement by Grinnell faculty in national and regional science education reform efforts, such as Project Kaleidoscope, *ChemLinks* and the calculus reform movement.

Student experiences. The New Science Project aims to increase access to, and success in, the sciences for students underrepresented in these disciplines by providing introductory courses in which the emphasis is on active learning. These courses are open to all students, widen the opportunities for initial success in the sciences for those students who learn best in an experiential environment. Whenever possible, students in these courses will be exposed to the objects of study before they are taught about current theories and dogma. This approach provides a context for studying science for students lacking strong backgrounds in scientific theory. The Science Learning Center provides crucial assistance to those students experiencing substantially more conceptual difficulty than others or who tend to avoid group mentoring sessions. Appointment-based, one-on-one time with knowledgeable peers allows students to use the Science Learning Center resources without worry of social or academic stigma. The Center, coordinated by professionals, will be open to students seeking drop-in tutoring on weekdays, Sundays, and five evenings per week. Such access and support prevents early frustration and encourages persistence.

Assessment techniques. We have developed an assessment system that measures the New Science Project beginning with student performance in introductory science courses and ending with student entry into graduate science programs or science-related careers. We plan to assess all aspects of the New Science Project each year over five years. We will track the performance of students targeted as New Science participants as they continue to intermediate-level science courses, choose science majors, and enter graduate or professional programs in science or science-related careers. Our assessment plan includes interviewing New Science participants to determine the extent to which they have been enabled by having curricular options in introductory science courses and by the availability of the Science Learning Center.

- **Harvard University**

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At the start of a major fundraising campaign soon after Neil Rudenstine became President and Jeremy Knowles Dean of the Faculty of Arts and Sciences, they announced six strategic objectives:

- renewing a shared commitment to learning;
- improving and enhancing educational practices at all levels;
- keeping the opportunity for a Harvard education open to everyone;
- preparing students for a world with porous boundaries;
- fostering interdisciplinary exchanges with new technology and facilities; and
- making science and technology an important part of undergraduate education so students are well-prepared for lives and careers that will rely heavily on understanding these subjects.

These missions set the tone for broad reviews of Harvard's graduate and undergraduate programs and for the introduction of five university-wide initiatives. Two—dealing with the environment and with mind, brain and behavior—have special relevance in opening new undergraduate paths that reach across and beyond science, mathematics, engineering, and technology.

Curricular change. At the behest of an Educational Policy Committee (EPC), created to further the above objectives for undergraduates and chaired by Dean Knowles, each of Harvard's 41 undergraduate concentrations (majors) has examined its goals and requirements, their rationale, and how that rationale is conveyed to students, the effectiveness of academic advising, and opportunities for participatory small group instruction, independent work, and synthesizing experiences. After program leaders meet with subcommittees of nine faculty members on the EPC and a review by the entire EPC, modifications are proposed, negotiated, and adopted. Individually designed, coherent programs that cross concentration boundaries are encouraged. In science, mathematics, engineering, and technology, the curricula of introductory service courses have been reviewed. Serving the needs of concentrators from fields with varied objectives and preparation levels is a complex problem. Meetings with instructors stress that the introductory course in every science is, for most enrollees, the last course they will take in that science. An orientation and training program for Teaching Fellows requires practice teaching, observation, and appraisal. Also discussed are the professional responsibilities of instructors. Two curricular innovations that have had broad impact outside Harvard are the Peer Instruction approach to large lecture instruction and the Harvard-based Calculus Consortium. Project Star, a science program for students in public and high schools, also has widespread influence.

Student experiences. Harvard offers many opportunities that combine research and education for individual undergraduates and small groups. NSF Research Experience for Undergraduate programs and others give undergraduates summer research opportunities. Often research begun in the summer provides the germ for senior research projects and theses. For decades, more than 100 students in several science programs took junior research tutorials. The program has more than doubled. Every science program offers students participatory small group instruction of this type and 500 hundred students take them.

Two less conventional programs are (1) freshmen seminars in which small faculty-directed groups of students learn science by designing and building equipment and conducting experiments, and (2) design courses in which teams of engineering students tackle real-world integrated systems problems and present their conclusions to audiences of students, faculty, and representatives of industry, government, and universities. Design courses emphasize oral and written presentations, working with customers, and satisfying economic, environmental, and temporal constraints. Participants in such courses have found them so enjoyable, challenging, and educationally worthwhile that the EPC is trying to incorporate resource-intense *Learning Together* experiences elsewhere in the curriculum.

Technology use. At Harvard, the use of networked computers and other features of information technology is rapidly growing; 92 percent of Harvard undergraduates own computers. Most are directly connected by Ethernet to a campus-wide high-speed network that connects dormitory rooms, classrooms, offices, laboratories and kiosks in libraries and student centers. In the spring of 1996, 70 percent of science majors took at least one course that required a computer. Future uses of electronics technology and the Internet in education were the themes of speeches by President Rudenstine at Harvard commencement in June 1996 and at a recent large International Conference on the Internet and Society at Harvard. Working closely with a faculty information technology committee, Harvard Computer Services now has an Instructional Computing Group that helps faculty use computers in their courses, a facility for trying new technology.

Faculty reward structure. Teaching evaluations get substantial weight in promotion reviews and, in science and engineering, promotions to tenure are increasing. Several prizes had been established to recognize outstanding teaching. Hoopes Prizes go to students who write outstanding theses and to their faculty mentors.

Assessment. The effectiveness of some innovations has been analyzed. For instance, using ClassTalk, several years of data on Peer Instruction have been collected. Its demonstrated benefits led to its adoption by others at Harvard and nationwide. Over the past five years, institution-wide efforts have been made by scientists, mathematicians, and engineers to encourage more students to major in a science field: to keep as large a fraction of women as men who say they want to major in science when they enter; and to improve the quality and coherence of education. Over this period, the number of science majors has risen 15 percent, the previous difference of 15 percent in the persistence rate for women and men has shrunk to 5 percent, and the number of students receiving highest honors has increased to 30 percent. We believe that the steps we have taken contributed to these improvements and hope that efforts directed to Learning Together and to making more effective use of electronic technology will lead to more improvements.

- **Indiana University-Bloomington**

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Indiana University is a large public university that serves a diverse student body on eight campuses. The Bloomington campus enrolls 25,000 undergraduates annually. We serve the state by putting students and student learning first and giving the state outstanding intellectual and scholarly resources. Our success as a great university depends on a faculty engaged in path-breaking research, scholarship and creative work, and in outstanding teaching at all levels.

Reform goals. We focus on improving math and science instruction to non-science majors inside and outside the college who choose to take advantage of our opportunities. We further focus on training scientists who are well-educated in the liberal tradition and offer them a strong foundation in the arts, humanities, and social and historical inquiry. The plan is to bring better math and science instruction to non-science majors and offer science and math majors a stronger foundation in the liberal arts.

Plan overview. We are creating new courses or expanding innovative types of courses in three areas. The TOPICS curriculum, instituted in 1995-96, is expanding. This curriculum replaces a portion of the discipline-based survey courses that fulfill undergraduate distributional requirements with courses that are based in one of three general areas of inquiry and that are organized around a central issue or question. We are introducing a new series of mathematics courses that put math instruction in a strong non-mathematics disciplinary context. We are completely reworking the curriculum in computer science for nonmajors. The new curriculum consists of seven modular courses and is one of the university's first cross-campus curricular efforts.

Institutional strategies. Curriculum reform is our main focus. This requires a significant effort from dozens of faculty members and administrators, and sometimes significant resources for planning, pilot programs, new materials and facilities. TOPICS program planning costs were paid by the College of Arts and Sciences. Planning and program development for innovations in computer science and mathematics instruction are funded by Indiana University's Strategic Direction Initiatives and by an NSF grant. The efforts are as follows:

- *The TOPICS curriculum:* TOPICS courses are designed to introduce freshmen to the foundations of a liberal arts education—critical thinking, problem solving, and oral and written expression—at the outset of their college careers. They are smaller than most introductory-level classes, and rather than providing a survey of a discipline or subdiscipline they are designed to explore a central question, theme or issue in depth. TOPICS courses are offered in Arts and Humanities, Social and Historical Studies, and Natural and Mathematical Sciences. All students who get BAs in the College of Arts and Sciences must take one TOPICS course. Students who matriculate in 1997-98 or later must take three TOPICS courses, one in each area. Each course takes a problem-oriented approach to its question or theme. The question is examined from various angles, and the methods used to address these kinds of questions are made explicit. Students learn to frame their own questions and bring evidence to bear in addressing these questions. They engage in forms of analysis, problem solving and knowledge generation that characterize the broad area of study. They do substantially more writing than in typical introductory-level courses. Faculty throughout the College apply to teach TOPICS courses and develop their own courses. They receive special resources and help promote TOPICS curriculum goals: additional graduate student assistance, course development grants, and first priority for a full range of teaching-resource services.

- *Mathematics in the disciplines:* The new program of mathematics instruction restructures the way in which mathematics relates to the undergraduate curriculum. At the core is a series of new courses—building to 40 that are team-taught by a mathematics professor and a professor in another discipline. Each course teaches math in the context of another field, and features problem-solving and modeling approaches; team projects and student activities play a key role in the learning process. The new discipline-based math courses are being developed and implemented on a three-year cycle. Ten were approved for development and implementation in 1996-97; disciplines include biology, business, chemistry, criminal justice, economics, history, philosophy, physics, nursing and the social sciences. Two more components of educational restructuring are a new general academic infrastructure for students, including an interdisciplinary academic club and student mentoring and peer tutoring programs, and a new Institute for Undergraduate Education to facilitate collaboration and coordination across departments and disciplines. Working out the logistics of team teaching, including how it counts as part of a faculty member's teaching load, is a challenge of this program.

- *Computing for nonmajors:* Adults face increasing technological demands at home and at work. The goal of curriculum reform in computing for nonmajors is to prepare graduates to use new computing technologies and continue to learn new technologies. This is quite different from the educational goals of a computer science curriculum for majors. New computer science courses are organized in modular fashion. Other than the introductory course, they are interchangeable and can be adapted to each campus. Yet the commonalities across all campuses allow for easier transferability among campuses. The new modules are designed to provide students with active learning opportunities to improve their problem solving skills, strengthen their analytic reasoning abilities, and test their general knowledge. The seven modular courses incorporate the latest technologies, including the Web, to implement the self-paced nature of the lecture and laboratory components. After an introductory course, students can choose among any of the following modules, each of which constitute a half semester: Programming Concepts, Computers in Data Analysis, Database Management Systems, Using the World Wide Web, and Multimedia Communication.

Miami University

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Miami University is a state-assisted institution in Oxford OH, chartered in 1809. It has strong undergraduate programs in the presence of selected graduate programs and research. It operates under an enrollment cap at 16,000 students (about 14,000 are undergraduates). Miami's undergraduate science programs are an important source of scientific personnel for the nation. Miami science departments have 2,235 undergraduate majors, 210 graduate students, and 150 faculty. A significant number of Miami science graduates pursue advanced degrees; Miami is ranked 70th nationally in the National Science Foundation's most recent report (NSF 92-332) on the undergraduate origins of doctorate recipients in science. In recognition of its excellence in undergraduate education, the September 18, 1995, *U.S. News & World Report* annual issue devoted to colleges and universities rated Miami University 8th in the country among national universities in the category Faculty Commitment to Undergraduate Teaching. Miami emphasizes the role of faculty as teacher/scholars. Faculty are expected to teach and conduct research or other scholarly activities. In 1994 Miami University received the Theodore Hesburgh Award for Faculty Development to Enhance Undergraduate Teaching, a national award presented by TIAA-CREF. Miami University also initiated the Lilly Conference on Teaching that for 15 years has drawn innovative educators to the campus for four days of presentations, talks, demonstrations, and workshops on new teaching and learning techniques.

Reform goals. Miami University proposes to conduct and evaluate a systemic project aimed at converting current research-based educational initiatives at the university into an expanded and comprehensive research-rich undergraduate curriculum. The goal is to stimulate the desire and increase the skills of students for continuous learning by creating curricular changes that provide more and better undergraduate research opportunities. The types of research opportunities we propose are those in which students with faculty mentors design, develop, and conduct their own research projects and disseminate their results. A second goal of the project is to evaluate short- and long-term effects of mentored independent undergraduate research experiences. A major focus will be the impact of these educational experiences on students' ways of thinking and knowing. Miami University students can participate in research and scholarly projects. The university uses alumni contributions to provide academic-year small project grants ($150 to $500) to 40 undergraduates a year. External agency resources, such as from the Howard Hughes Medical Institute and from the National Science Foundation, provide specific support for student summer research projects.

Many students also participate in directed or independent research projects for regular credit or as part of the University's Honors Program. Miami University recently implemented the Undergraduate Summer Scholars (USS) program, an initiative to enhance its students' undergraduate experience. This program provides 100 students at the end of their junior year the opportunity to work for a concentrated 10-week summer period on research and other creative activities under the individual guidance of a faculty mentor. Students initiate the process, identify a faculty mentor, and submit a student/faculty application with project description. The program is designed to allow faculty and student pairs the freedom and responsibility to identify objectives for the student and determine how these objectives will be reached. In the first year (1995) of the program, 207 applications were received and 100 USS positions allotted for student projects in 25 departments. Each USS award consisted of a $2,000 student stipend, a $500 stipend to the student's faculty mentor, and a $300 project allowance. Students enrolled for 12 summer credit hours, for which instructional fees were waived. Follow-up questionnaires revealed overwhelming support for the program. Ninety-nine percent of respondents thought participation was worthwhile, that it was a challenging experience, that they would recommend participation to others, and that it was important for the University to continue the program.

Plans and strategies. Miami University identified four objectives to help meet its systemic project goals, and several strategies for achieving the objectives, including:

1. Encourage the integration of more research-intense activities throughout the undergraduate curriculum; adopt an institutional goal to incorporate more research-intense activity in the undergraduate curriculum; systematically meet with science chairs and faculty to discuss research-related educational opportunities and consider curricular changes that give faculty more time to mentor student researchers and evaluate programs; organize an annual faculty retreat on undergraduate research.

2. Develop an infrastructure that supports high-quality independent student research experiences under faculty mentorship; provide a systemic support program of advising, seminars and regular meetings for participants in student research programs; orient first-year students when they arrive with information and expectations concerning independent, active learning and the opportunities provided for student-centered research experiences.

3. Expand and improve interdisciplinary academic-year undergraduate research experiences and the Undergraduate Summer Scholars program; fund interdisciplinary scientific undergraduate research grants (mentored by faculty) in Miami's competitive academic-year undergraduate research program and the Undergraduate Summer Scholars program; establish a competitive Undergraduate Research Travel Fund so students who participate in either program can present papers at professional meetings and undergraduate research conferences.

4. Evaluate the effectiveness of this model program and undergraduate research experiences and disseminate this information to the college-university community; using data collected before and after the Undergraduate Summer Scholars program, evaluate and compare changes in the ways of learning and knowing of students who participate in the intensive program with students who don't participate; Initiate a longitudinal study of undergraduate research participants, their progress in becoming independent learners, and their subsequent opinions on undergraduate curriculum and career success; disseminate evaluation results to the academic community at meetings and in hard copy and electronic professional journals.

Middlesex County College

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Middlesex County College (MCC) is a publicly supported, comprehensive community college committed to serving all who can benefit from postsecondary learning opportunities. The college offers a range of curricula and programs that offer access to the educational process in a lifelong learning context for diverse populations in its service area. The college views creating an environment responsive to individual educational needs as essential to fulfilling its mission. With a 200-acre campus in Edison NJ, MCC enrolls nearly 12,000 students annually. It is one of the largest and oldest of 19 community colleges, offering transfer degree programs that include an associate in arts degree in liberal arts; and associate in science degrees in business administration, criminal justice, engineering science and science. Associate in applied science programs are offered in business, education, health science and engineering technologies.

Reform goals. The goal of institutional reform in science, mathematics, and technology education is to ensure that graduates have the knowledge and technical skills needed for employment, further education and participation as informed citizens in the nation's civic life.

Plan overview. Institutional reform efforts at MCC are multi-partite efforts that engage faculty across disciplines in cooperation with other community colleges, four-year institutions and local school districts. The college has forged alliances with business, precollege educators, and other colleges to increase the level of college preparedness of school populations, revise and streamline curricula among applied academic populations, devise strategies to increase enrollments of underrepresented populations, integrate technology into instruction, offer students cooperative and intern experiences, and increase the general level of communications across disciplines.

- Under the New Jersey Center for Advanced Technological Education led by MCC, a consortium of institutions restructures engineering technician education by creating a new interdisciplinary technician program.
- An NSF Advanced Technological Education program project is producing interdisciplinary instructional modules that put mathematics instruction in the context of scientific and technical disciplines. The project also incorporates increasing teacher-faculty training in educational technologies and technology-oriented classroom strategies.
- By participating in the NSF-funded Women in Engineering Science and Technology (WEST) project led by the New Jersey Institute of Technology, two MCC faculty members developed and implemented a mentoring program for female students that four other community colleges now use.
- Under the New Jersey State-wide Systemic Initiative, MCC is a Statewide Resource for Mathematics and Science, is providing in-service workshops to school districts to help them incorporate interdisciplinary, hands-on, technology-rich instructional activities to middle- and high-school students.
- MCC faculty, funded through the Eisenhower program, provide intensive in-service to middle- and high-school teachers in integrating problem-solving, collaborative learning activities, and technology into mathematics and science curricula. The college leads a consortium of six community colleges that are using the MCC model for in-service teacher preparation.
- Since 1993, the Middlesex Tech Prep Initiative, spearheaded by the college, has involved faculty and high school teachers in curricula reform and articulation.

Institutional strategies. Restructuring is the focus of revitalizing undergraduate mathematics and science: A thematic systems approach that addresses the needs of non-science and -technical majors. Liberal arts and business program students are required to take math and science courses to fulfill general education requirements for graduation, but the courses do not relate to their majors and have little relevance to applications in daily life or career enhancement.

We take a thematic systems approach to delivering SME&T education. This structure requires interdisciplinary development and delivery and helps students understand the critical role of mathematics, science, and technology in society, and the nature of mathematics and science endeavors. The strategy is to motivate students to investigate issues and problems whose solutions require applying math and science concepts. Instruction is organized around themes that reflect crucial scientific and technological issues like energy, transportation, space, the environment, the human body and telecommunications. All are systems-related; involve several science, math and technology disciplines; and involve key social issues. A critical need is to engage mathematics, science, technical, and humanities faculty in designing, developing and implementing projected curricula to develop module-based courses for each theme. Working in interdisciplinary teams, faculty will create, pilot-test, and implement courses that thematically incorporate instruction in mathematics, science and technology. These integrated offerings will replace current choices for non-science, non-technical majors. The restructured curricula will help students learn relevant, meaningful aspects of mathematics, science, and technology. As a result, students will better understand and be more likely to learn and read about current issues in which technology and the sciences play major roles and will be capable of making informed decisions regarding scientific and technological questions.

- **Montana State University**

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Montana State University (MSU) is a land grant institution with 11,000 students and a history of strong commitment to undergraduate, graduate, and outreach programs in the sciences and mathematics. MSU has a 25-year tradition of involvement in science and mathematics education endeavors that reach out across the campus, state, and nation. A balanced blend of internally and externally funded projects at MSU have created considerable momentum to improve undergraduate and graduate programs in science, mathematics, engineering, and technology (SME&T) areas. Some projects were undertaken by MSU alone; others put MSU in a leadership position working with other two- and four-year colleges. Cooperation that bridges traditional disciplinary, intra-institutional boundaries is a hallmark of these projects. At MSU and in Montana, the SME&T community is willing to work toward change. Examples of current initiatives follow:

- More than two decades ago, MSU founded the Science-Math Resource Center to carry out inreach and outreach efforts in SME&T education. A dozen years ago, SMRC began sponsoring informal weekly noon seminars and participants became known as the Brown Bag Group. Today the 60-member Brown Bag Group has become the driving force behind many SME&T reforms at MSU and models the interdisciplinary cooperation the institution is known for.
- Course reform. The NSF systemic initiative SIMMS, based at MSU and the University of Montana, implemented a model mathematics curriculum in state high schools that spurred MSU math faculty to dramatically change several large undergraduate courses to keep pace with high-school reforms.
- The NSF Teacher Preparation Collaborative, or STEP, a state-wide project headquartered at MSU, funded teams of science, mathematics, and education faculty to improve content and pedagogy in more than 50 SME&T courses, including 20 on the MSU campus. The project has attracted significant numbers of Native American students to prepare for careers in mathematics and science teaching.
- MSU's recently established Undergraduate Scholars program provided research internships in the sciences for 141 undergraduates this year.
- The All Nations Alliance, an NSF AMP project based at MSU and Salish Kootenai College, reaches out to a national consortium of 24 two- and four-year colleges to support the recruitment and retention of Native American SME&T undergraduates. MSU also supports the American Indian Research Office (AIRO) which for two decades has recruited minority students to careers in the biomedical sciences.

MSU's active Women in Science and Engineering (WISE) group is in the midst of a comprehensive, quantitative and qualitative study of the recruitment and retention of women in SME&T fields at MSU. WISE recently developed faculty and teaching assistant training kits on effective strategies to increase women's participation in SME&T fields. The National Teacher Enhancement Network, a recent NSF grant based at MSU, has delivered 22 distance delivery science and mathematics courses to more than 500 teachers in 48 states over three years. These interactive distance delivery courses blend current science with modeling effective pedagogy. NTEN's success led to the recent approval of a new MS degree in Science Education. Starting in June, 1997, this multi-disciplinary program, designed by a team of scientists and science educators, will provide distance delivery, on-campus, and field-based courses to a national audience of science teachers. We expect this program to provide a model for other post-baccalaureate SME&T graduate programs.

Next steps include better coordinating, sustaining and disseminating information about initiatives like those described above. A grassroots MSU faculty group working with full support of the university's central administration recently completed a planning process for a permanent institute whose mission will be to promote and facilitate excellence in SME&T education. The center will be in the Provost's office, guided by a steering committee composed of faculty and administrators from SME&T disciplines, including many members of the Brown Bag Group. This center will become operational during the next 24 months. Led by a full-time director and a formative assessment and evaluation specialist, the center will engage in:

- Curricular reform to achieve student-centered programs in a research university setting that encourage participation in SME&T fields for all students, including majors and nonmajors.
- Professional development to involve all SME&T faculty and graduate teaching assistants in learning how to implement new approaches to course content and delivery that increase the success of all students.
- Research and dissemination including ongoing research and evaluation to monitor and improve MSU's programs, as well as to test new models for implementation and dissemination nationally.
- Off-campus linkages to create a "seamless" educational process in which an individual's transition from high school to MSU, or from MSU to the work-place, can occur with a minimum loss of time and effort, and to work closely with precollege teachers and postcollege employers toward this end.
- Student recruitment, including widening the talent pool of SME&T students, particularly by encouraging and promoting opportunities for Montana's women and minority students, who are still seriously underrepresented in these fields.
- Campus coordination by providing a continuing forum for the exchange of ideas relating to SME&T education, and helping MSU's departments, colleges and externally funded projects to further coordinate efforts in this area.

- **Morgan State University**

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Morgan State University is Maryland's designated public urban university with responsibility for offering programs from the baccalaureate through the doctorate. The university's mission is to serve a student population that is diverse in its socioeconomic characteristics and precollege preparation, ranging from individuals with exceptional academic records to those who need to enhance their academic competencies to be successful in college. This mission emphasizes serving as a vehicle of upward mobility for the broad cross-section of people who can complete a degree, many of whom would be unable to do so without the academic and personal support that the campus offers.

Reform goals. Given the diverse precollege experiences of Morgan students, the university seeks to ensure that all students, without regard to matriculation profile, are prepared to pursue in-depth study in their chosen major by the end of their sophomore year. The university seeks to modify its educational and instructional delivery modes to prepare all its graduates to function as citizens in a complex and increasingly global society.

Plan overview. During the past decade the university has made two significant reforms in undergraduate education. It broadened its general education requirements to include more mathematics and science course work for all students and imposed a mandatory passing of a comprehensive examination in the major. Both requirements have led to a more rigorous undergraduate experience. The rates at which entering students graduate and alumni find employment and/or enter graduate school are well above those of a decade ago.

The new plan for institution-wide renewal will be broader, based on an outcome assessment model to ensure continuing and systematic quality control in all operations affecting undergraduate services. Nationally standardized and tested measurement instruments, used selectively for placement, general education assessment, and evaluating knowledge in a major will be deployed systematically throughout the institution. Specific strategies will depend on objective assessment results at three critical points—on entry as freshmen or transfer students, at the end of the sophomore year, and on completing graduation requirements. These will be supplemented by subjective measures of attitudinal change, student satisfaction with all aspects of the undergraduate experience, evaluation of post-graduation experiences, and employer satisfaction. The campus will use a central academic and support services group to monitor and offer feedback on assessment results and will then make changes.

Central to the Morgan Outcome Model is the assurance that its graduates have attributes that help them meet the university's goals of functionality and adaptability. These goals include critical thinking, excellent communication, effective interaction in teamwork, an appreciation of major trends that affect society and the economy, and willingness to engage in lifelong learning.

Institutional strategies. Morgan's reform plan uses strategies to improve education at three critical points in each student's academic career: It will take actions that ensure that the university community understands students' diverse precollege environments and optimize the college transition for students from all backgrounds; it will make general education a way to change the undergraduate experience to support the university's educational goals; and it will ensure that student academic performance in major fields meets emerging national and international standards.

Specific actions will depend on the results of assessment processes, but some actions can be anticipated. More students will be involved in transitional experiences before entering college, in special freshman year courses, and in support activities. Course work will become more interdisciplinary and will be more closely aligned with Morgan's goals for graduates. The general education program will emphasize the understanding of major forces that shape the world and the acquiring of tools for upper-division work and lifelong learning. All courses will stress communications skills, student research, and other forms of inquiry. All students will become more aware of informational sources as well as traditional and emerging approaches to accessing and communicating information. More students will participate in internships or will be involved in other real-world experience in their majors.

To effect these changes, the university will engage in a large-scale faculty development effort and in other institution-wide reforms that include examining faculty review and reward structures. Particular emphases will include understanding how people learn, understanding the nature of Morgan's students, using many instructional strategies to optimize learning among students whose learning styles differ, incorporating interdisciplinary approaches in all courses, and using state-of-the-art computing and communications technologies to enhance the educational process.

- **New York University**

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New York University, a member of the Association of American Universities, is the nation's largest independent university, with an enrollment exceeding 50,000 full- and part-time students in 13 schools, colleges and divisions. Over the past decade, NYU has conducted a major campaign to strengthen science education for science majors and nonmajors. NYU's long-term plan for science education addresses all facets of the educational enterprise: facilities, instrumentation, curriculum, teaching experience, research experience and access. It aims to strengthen science learning and teaching by revising curricula to make science relevant to daily experience and more immediate to students; redesigning laboratories to emphasize discovery learning and allow more individual activity; changing student learning styles to include small group learning and problem solving and to incorporate electronic learning technologies; and encouraging students to explore careers in science and science teaching.

Major initiatives include

- a new integrated science/mathematics curriculum taken by all non-science majors called Foundations of Scientific Inquiry (FSI). This program aims to improve science literacy and was developed with NSF support by the Faculty of Arts and Science, which encompasses the 5,500-student College of Arts and Science;
- a multi-million dollar science facility development plan that has renovated undergraduate labs for chemistry, anthropology and neural science and is dedicating new lecture and lab facilities designed for the FSI program;
- educational technology projects that link computer scientists, life scientists and educators in prototyping, developing and assessing multimedia products;
- a summer research apprenticeship program for science majors to prepare them for graduate programs and science careers and a faculty development project aimed at improving pedagogical outcomes in science and math for undergraduate nonmajors;
- the New York Collaborative for Excellence in Teacher Preparation, which links NYU's Faculty of Arts and Science and School of Education with the City University of New York and the local public school system in a five-year NSF project to improve training for K-12 math and science teachers;
- an NSF-funded program of undergraduate faculty enhancement in teaching biology, in conjunction with Xavier University of Louisiana and Spelman College of Georgia, under the auspices of the NYU Faculty Resource Network, which links 28 institutions including 13 historically black colleges.

Reform goals. Reforms aim to

- improve the scientific and technical literacy of all nonscience students;
- engage undergraduate faculty in a productive dialogue about the role of science in undergraduate education; and
- develop and disseminate a model, portable undergraduate science/math curriculum relevant to a range of student bodies.

Plan overview. A central focus is to adapt the college FSI curriculum to the needs of students in other liberal arts and non-liberal arts programs. This project will design and test customized curricula that would help faculty at a range of institutions teach rigorous quantitative and scientific reasoning to non-science students. The project will produce teaching materials, including instructors' lecture materials and student workshop exercises, pilot tutorial and enrichment workshops. A particular goal is to develop computer-assisted lab projects tailored to student interests, preparedness levels, and study programs. FSI experience highlights student interest in research topics and establishes the usefulness of multiple learning tracks that emphasize different areas of science depending on the students' interests and background, proceed at different paces and include different modules. FSI is a three-course sequence integrating physical, biological, and mathematical sciences; providing coherence and verticality in science studies; and fostering interdisciplinary teaching and learning *Quantitative Reasoning: Understanding the Mathematical Patterns in Nature* teaches how to take verbally presented problems, recognize their mathematical patterns, and solve them. Modules include: The Art of Making Estimates; Growth and Decay Phenomena; Introduction to Probability; and How Big the Sun, How Far the Star? *Natural Science I:* An Introduction to the Physical Universe includes modules on Basic Physical Concepts; The Analysis of Starlight; Atoms, Molecules and the Chemical Bond; and Debates about the Earth. *Natural Science II:* Our Place in the Biological Realm includes Metabolism; Brain and Behavior; Normal is a State of Mind; Genetic Variation and Individuality; Evolution and the Nature of Science.

Institutional strategies. Develop and pilot customized courses for students with diverse backgrounds in preprofessional, performance art, and teacher training programs. Tailored versions of the FSI curriculum include abridged versions that constitute the first college-level science education some students will experience or that will complement areas poorly represented in their programs. FSI's modular design lends itself to custom design in that modules can be assembled into one- or two-semester courses to emphasize any combination of topics. The original philosophy—presenting selected topics in enough depth to convey the nature of scientific thinking and how science is done—is preserved. The principal adaptation is to calibrate courses to students' backgrounds.

- Introduce educational technologies that recognize and accommodate different learning styles. The project will experiment with new technologies, including software applications, multimedia reference materials, and interactive computer simulations of experiments, to develop curricular approaches and instructional materials that make science more accessible to diverse students. The technologies facilitate an inquiry-based pedagogical approach tailored to individual skills. They can illustrate abstract and dynamic concepts like physical forces or probalistic phenomena, and demonstrating subjects ranging from electromagnetism and statistical mechanics to population genetics.
- Address the range of student skills by developing a remedial tutorial program for weak students, and enriching the experience for strong students by engaging them as tutors and making materials available for projects that could replace exams or be part of an honors section.
- Sponsor faculty forums to build consensus for the role of science education in educational settings, and address the skills scientists need to communicate with non-science students.
- Export the NYU experience through institutional partnerships with the public higher education system, small liberal arts colleges, and predominantly black colleges. The modular, flexible curriculum and the availability of published curricular materials make it portable and easily adapted to meet the interests of different bodies and training programs. Materials for several modules are published by McGraw-Hill's College Custom Series.
- Encourage faculty participation as FSI instructors by providing course materials and awarding a small research stipend.

- **Northeastern University**

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Founded nearly a century ago in downtown Boston, Northeastern University (NU) is one of the largest U.S. private universities and offers programs ranging from practitioner certificates to Ph.D.s. Seven colleges offer full-time undergraduate education to 10,747 students through 110 degree programs in the professions and the liberal arts, while another 9,399 part-time students enroll in University College. NU's undergraduate programs couple classroom learning with experiential education, most often as cooperative education. This combination of formal and informal learning links skills, competencies, and attitudes developed in the classroom to the workplace.

Reform goals. NU's comprehensive curricular reform project, the Academic Common Experience (ACE), seeks to erase traditional distinctions between general education (gen-ed) and specialization in a major field. Our goal is to articulate a developmentally valid model that advances student learning in a coordinated way across the curriculum and enhances individual faculty and academic unit responsibility for learning.

Plan overview. In our ACE program, gen-ed and study in a given major are integrated by placing responsibility for general education with faculty responsible for the major. The project's broad objectives include:

- identifying a set of shared general education goals with their learning outcomes and competencies for all students in all majors;
- local, major department faculty responsibility for student achievement of these goals;
- incorporating shared goals into departmental major curricula using disciplinary and liberal arts courses, modules and non-classroom experiences like cooperative education;
- creating curricula by unit faculty that facilitate cumulative learning of shared goals;
- coordinating this implementation through a university-wide oversight mechanism; and
- enhancing faculty responsibility for student learning and faculty expertise in competency-based education, teaching gen-ed skills in disciplinary contexts, assessment, and interactive pedagogies.

The NU community identified shared gen-ed goals that undergird this model, and the project secured formal approval of the university's governance bodies. Implementation began in three volunteer pilot colleges enrolling 5,000 undergraduates. Implementation plans will expand the program throughout the university.

Institutional strategies. ACE is a new model for undergraduate education that rests on our firm belief that the skills and perspectives of general education are integrally connected to mastery of a discipline; curricular planning and teaching must focus on student learning; valid learning happens outside and inside the classroom; and pedagogical methods and faculty culture may need to change for NU to offer a developmentally sound education program. The best education builds on past knowledge to prepare students for the future. It stimulates a sense of inquiry and a love of learning. It helps students develop skills transferable from discipline to discipline and from classroom to life. These skills are best acquired while learning information and ideas across a broad range of liberal arts courses, in a specific discipline. The natural and social/cultural worlds offer contexts for learning these transferable skills. A variety of perspectives explicate these contexts by revealing facets of their complexity. True learning builds cumulatively over time, crosses disciplinary boundaries, occurs inside and outside the classroom, and continues through life. This requires educators to recognize the interconnectedness of learning.

NU faculty, students and administrators joined together in an open, consultative process to identify a set of shared goals for all undergraduate programs, including:

- skills like effective thinking, effective communication, information literacy, and interpersonal skills;
- perspectives like the historical perspective, ethical perspective, personal perspective, and aesthetic perspective;
- contexts like the natural world, the social and cultural worlds; and
- connections between disciplines, between the theoretical and applied, between the academy and the working world, between individuals and society, and between college study and lifelong learning.

Shared educational goals will be translated by academic units to discipline-specific objectives. Each unit will do an educational audit of these objectives to identify which objectives students achieve in their curriculum, and which are poorly achieved. Following a plan of learning devised by the college or department faculty, students achieve objectives several ways across the discipline (liberal arts courses, major courses, modules in disciplinary courses and non-course experiences like cooperative education). The objectives should be integrated with the study of specific subjects and identified as course objectives. Each curriculum will be coordinated to foster cumulative learning over a four- or five-year undergraduate career. The major becomes an element of gen-ed, and gen-ed becomes the responsibility of the major program.

The connection between in-class academic study and practical application outside the classroom is important at NU. Students can forge a two-way link between theory and application through experiences like lab research, professional work, hospital service—any of which can lift learning to a higher plane. Shared goals provide the educational framework for experiential learning, as objectives derived from the goals can be identified for out-of-class experiences.

The ACE model creates a new environment for learning and requires a change in how faculty think about education. It asks departmental faculty as a group to assume responsibility for general education and deliver curricula that develop cumulative learning. It leads faculty toward greater responsibility for and assessment of student learning. It integrates gen-ed goals, disciplinary expertise and experiential education. It changes how faculty design curricula and prepare courses. Pedagogical methods may also need to change: a program to guide student learning of information literacy calls for integrating technology, building team skills calls for classroom interaction rather than lecturing, and so forth. Faculty development—early, extensive, ongoing—will be crucial to successful implementation. We estimate it will take six more years to integrate the ACE model throughout the university.

- ## Oakton Community College

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Oakton Community College is the public community college serving more than 435,000 residents of north suburban Cook County, Illinois. Founded in 1969, the college operates two campuses—in Des Plaines and Skokie—and offers courses at 60 other community locations. Oakton offers a comprehensive educational curriculum that includes baccalaureate preparation, vocational degree and certificate programs in 34 areas, an institute for business and professional development, and an extensive community education program. The college employs 154 full-time and 479 part-time faculty. In the fall of 1995, nearly 11,000 students enrolled in credit courses on a full- or part-time basis. Another 16,000 adults annually enroll in the adult and continuing education program. Oakton's mission is to serve the post-secondary educational needs of residents, employers and employees of organizations in its district. The college offers equal access to quality education that promotes student awareness, responsibility and independence; enables students to adapt to the needs of a globally interdependent, technologically sophisticated society; and respond to community diversity.

Reform goals. Oakton's goals are to keep more students in science and math courses, improve their scientific literacy and critical thinking skills, and better prepare students for technologically and scientifically oriented futures. The institution-wide reform process will establish a collaborative learning model to improve student learning by effecting changes in the teaching of first-year core SME&T courses; broadening and strengthening the course development and teaching process; creating an institutional mechanism to access and extend reform to other courses and departments.

Plan overview. Oakton plans to establish three interdisciplinary core teams, one for each of these three, first-year core courses: biology, chemistry and mathematics. The teams will include faculty from diverse disciplines, students, alumni and business representatives. Each team will develop methodologies that address the interdisciplinary nature of science and mathematics, the needs of traditionally under-represented groups, the use of technology, and discovery approaches to learning critical thinking and problem solving. Key components include:

- preparing a course teaching guide for all who teach the core areas;
- evaluating the effectiveness of the interdisciplinary approach to facilitate and enrich the teaching and leaning processes;
- enhancing professional development activities; and
- institutionalizing a process to transfer course content and strategies across sections taught by different faculty members.

This interdisciplinary approach to SME&T builds on connections between business and education to enhance the teaching and learning process, to accommodate learner needs and use new technologies.

Institutional strategies. The Oakton faculty is preparing students for the requirements of 21st century technology by addressing the following areas:

Faculty development. To make sure faculty can implement interdisciplinary teaching strategies and pedagogy, and understand new resources and assessment tools, the project management team will

- develop a course guide for faculty members who teach courses for each three-course sequence;
- develop and implement a faculty mentoring program where senior faculty mentor faculty members with less experience;
- research and review other ways to facilitate and ensure the transfer of course content, standards and methodologies across sections, and to adopt methods that are feasible and effective at Oakton.

Curricular change. To begin the institution-wide reform process, the college will appoint department and multi-disciplinary faculty, and other staff, student and community representatives to each core team. All core team members, once oriented to project goals and expectations by the principal and co-principal Investigators, will:

- establish a common developmental framework for conducting development/research activities like literature searches, Internet searches, attendance at professional meetings, visits to other campuses and corporate entities and internal workshops with specialists;
- develop or strengthen connections with area employers to make sure course content includes applications relevant to changing work-place requirements;
- schedule biweekly working meetings during the semester and summer so core team members can review and examine core course objectives, content and learning materials, and design activities to build student critical thinking and problem-solving skills;
- investigate the incorporation of content/activities from other disciplines to make learning materials more relevant; and
- produce three course teaching guides for faculty who teach first-year core courses-biology, chemistry and mathematics.

Because technology is an essential element in restructuring curricula to make the learning process more active and interactive, core teams will also establish learning approaches that increase the use of modern instrumentation and computer techniques based on available resources and analyzing discovery approaches to student learning activities.

Learning by doing is a key way to build individual competence and demonstrate the interrelated nature of learning. Core teams will be asked to identify and design classroom and laboratory hands-on activities and to involve student use of real-world laboratory and computational equipment and instruments. This might include visits to industrial or government labs as a way of reinforcing "doing" as a way to improve student academic performance and enhance instruction delivery. Data on course enrollment, retention and grades will be used to assess the impact of the reforms, especially their ability to improve student retention. In addition to student surveys and focus group interviews, faculty will be encouraged to use classroom assessment techniques to generate student feedback on classroom teaching and learning processes.

Faculty reward structure. The college's practice is to offer faculty released or overload time to participate in pre-approved institutional or professional projects. Writing articles or editing publications related to the faculty member's field or a related field help determine salary schedule lane advances.

Resource allocation. Oakton will help support this project as part of its institutional match, and use the funds for more staff involvement to coordinate and manage project activities.

- **Panola College**

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Panola College is a two-year public community institution established in 1948. Its mission is to provide excellent education for all constituent interests—from university parallel transfer courses to occupational programs. A main goal is to help every student see learning as a continuous, evolving process, and to function effectively in a fast-changing world.

Reform goals. The project has several desirable outcomes. The most important outcome is improved education for students, who will have a better, broader knowledge base and the skills to extend it into the technologically expanding work-place. The next priority is a faculty that is enthusiastic about keeping up with the latest teaching innovations and open to collaboration opportunities. The college will have a permanent interdisciplinary technology center with potential for sustained growth and improvement beyond initial funding, and an evolving curriculum with interdisciplinary technology applications in every discipline's syllabi. We expect to see an administrative policy of recognition and incentive for faculty involved in analyzing student learning styles and developing curricular materials for dissemination.

Plan overview. Panola's Interdisciplinary Technology (PIT) project

- establishes a resource and activity center for students and faculty with open access to the latest instructional technologies, with on-site multimedia computers, peripherals, software and course-specific inter-actives;
- targets every student in a diverse and non-traditional population, offering experiences rich in varied technologies and multi-disciplinary connections;
- seeks to produce a model set of interdisciplinary curricular activities, giving students a more complete education at each study level; and
- uses faculty teams to revise curricula and syllabi to strengthen teachers' understanding of other disciplines and the wealth of educational resources.

Institutional strategies. PIT Center is a remodeled area of the Student Center building large enough to accommodate class and individual activities. Thirty multimedia computers and peripherals, including laser disc players, scanners, a video camera, and course-specific interactives, allow activities that range from English writing labs to experimental physics projects. Time is blocked for undistracted coursework and unstructured study. Open exposure to many disciplines is one of the project's strengths. Like interactive hallway exhibits, these experiences are high-profile events that stimulate interest and discussion. Lessons and labs can be revised and expanded to incorporate ideas generated in this setting.

Faculty and curriculum. Two- and three-member faculty teams, each member from a different discipline, are working to develop cross-curricular activities using the technology center. The teams identify, review and request software and other media resources. The aim is to add an applied technology element to each discipline's syllabus, enriching interdisciplinary connections to make each more relative. Faculty members who develop interdisciplinary lesson activities with objectives, technology applications and evaluations receive recognition and a nominal stipend. Some may be simultaneously involved in several teams, networking and propagating ideas. Faculty members are urged to develop skills in technology applications and share them in formal and informal peer training. Faculty members are already more involved professionally and participate in more off-campus meetings and workshops.

To involve as many students as possible early in the project, the first model activities link English classes to the sciences. Writing assignments include extracting physics interactives from media experiences. Non-science articles by and about scientists are among the reading selections. A campus-wide reading list focuses on selections with explicit links to science. Popular literature (Tom Clancy's *The Hunt for Red October*, Michael Crichton's *Sphere*) and classics are catalysts for evocative discussion. Beyond the English-science collaboration, teams link history, mathematics and art; journalism, history and science; music, physics and mathematics; Spanish, art and music, and more.

Faculty members can be creative with any idea that helps students appreciate how what they learn connects to their lives. To draw attention to science and technology in ordinary events, teachers use video excerpts from popular and documentary films in lessons. Selections from newspapers, periodicals, and evening news broadcasts are identified for inclusion in diverse disciplines.

- **Rensselaer Polytechnic Institute**

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Rensselaer's mission is to educate tomorrow's leaders for technology-based careers and to celebrate discovery and the responsible application of technology to create knowledge and global prosperity.

Reform goals. Our audience and mission drive us to provide the highest quality educational experience at an affordable, accessible cost. We developed studio courses to replace traditional lecture-recitation laboratory courses in science, mathematics and engineering with alternatives that promise higher quality courses, greater educational effectiveness and cost containment. We broke the traditional paradigm of high-cost, high-quality courses as alternatives to low-cost, low-quality courses.

Plan overview. First we created interactive studio courses to replace the large enrollment introductory courses. The remainder of curriculum is being redesigned to give students a typical course load of four, 4-credit courses each term (the 4x4 program). Reform is taking place in all schools, all departments, and in many courses at the same time. A Curriculum Reform Implementation Team (CRIT) manages the reform under a mandate from the faculty senate, which reviews and approves all changes. The end result is a better place for students to learn and faculty to teach.

Institutional strategies. We start with a pilot program for 40 to 60 students, then hold Instructional Development Program luncheons to discuss results. Faculty workshops introduce techniques in studio strategies, cooperative learning, or specific computing skills. The program scales up to full scale (650 to 1,100 students) with a faculty mentoring program that assigns faculty to courses as adjuncts to more experienced faculty members. Program cost is covered by savings in other areas, external funding, and by institutional resources in start-up phases. Because faculty and students are full partners in the innovation process, we need a model facility that departments can use during initial deployment stages.

Once the program reaches a critical size it can move to a permanent home. We altered traditional incentives to faculty, including appointment, promotion and tenure processes to reward educational innovation and research and publication. Transitional incentives include funding faculty and departments that want to participate in educational innovations through a campus strategic initiatives program ($3 million over three years) and through grants. We recognize faculty members who participate in the programs during campus-wide events. Graduate students in studio courses work with faculty—a dramatic departure from usual practice at research universities, where teaching assistants receive minimal training and are thrust into teaching situations with little supervision. Faculty members are modeling better ways to teach and introduce new pedagogies. Teams of faculty, graduate students and undergraduates develop new materials.

Rensselaer started its institution-wide reform program five years ago. It is now in mid-phase. To do this we will

- appoint a presidential panel on institution-wide reform that involves faculty, students and administration;
- develop a plan to make traditional facilities more appropriate for interactive learning formats;
- create a faculty-student development room to pilot alternatives for new facilities and to do the faculty development and mentoring needed for institution-wide reform;

- synthesize a full-implementation reform recommendations plan from final reports of faculty-student-staff process teams;
- finish replacing the large enrollment introductory lecture-based courses with interactive studio courses;
- revise curricula in every major so a typical student course load consists of four 4-credit courses; and
- convene two national meetings of the Partnership Program of EDUCOM's National Learning Infrastructure Initiative, to work with institutions seeking a similar reform process.

Technology is a critical enabler for curriculum reform but pedagogy drives course design. For example, the CUPLE Physics Studio is a multimedia physics course that includes tools for microcomputer-based laboratories, video analysis tools, object-oriented modeling tool visualization, and simulation software. Studio Calculus combined the studio model with heavy use of symbolic mathematics introduced by the Maple Calculus program. Biology, chemistry, introduction to engineering analysis, and laboratory introduction to embedded control (LITEC) have their own approaches. Metrics include student performance, attendance and attitude. To design the course we used earlier work to identify activities with a demonstrated positive effect on student learning, then evaluated against each metric. Student attendance significantly increased (from 50 percent to more than 90 percent), and student satisfaction increased (more than 85 percent prefer studio courses). As measured by traditional assessment and interviewing protocols, students are developing a better conceptual understanding of the material. Studio courses offer an alternative to traditional courses that improve student learning, attendance and attitude toward the course.

Rensselaer provides extensive support for this program. Specific items include:

- an Anderson Center endowment of about $143,000 a year to support faculty and curriculum development;
- more than $1 million a year for three years marked for Interactive Learning Initiatives;
- authorized more than $25 million for interactive learning; and
- an anonymous donation of $320,000 was made for a long-term longitudinal evaluation that takes students two years past graduation.

- **The Richard Stockton College of New Jersey**

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Located in rural southern New Jersey, Stockton is a primarily undergraduate college of liberal arts, sciences and professional studies. Opened in 1971 with a commitment to innovation, flexibility and adaptability, Stockton has 4,700 full-time students and 194 full-time faculty. Its mission includes student access, affordability and academic excellence.

Reform goals. The Stockton project's main goal is to promote numeracy among undergraduates to provide them with the quantitative skills and perspective needed for academic success, informed citizenship, and consumer awareness.

Plan overview. After two years of planning, Stockton implemented a Quantitative Reasoning Across Disciplines (QUAD) program in the fall 1995. To support the program, many faculty members agreed to emphasize the significance of quantitative reasoning in special "Q-designated" courses. Students must complete a specific number of these courses before graduating. The project brings together 24 faculty members representing all academic divisions, to participate in a series of course development and research seminars that began in the summer 1996. During the 1996-1997 academic year, participants work in four small disciplinary teams (each with a student) to develop and test curricular materials and approaches for Q-designated courses. After summary sessions in May, Stockton hosted a regional conference in August, 1997, on infusing quantitative reasoning across the curriculum.

Institutional strategies. Stockton's experience in developing the QUAD program highlights several ingredients that contribute to successful institution-wide reform, including:

- Strong multidimensional, institutional support. Stockton's president initiated the quantitative reasoning movement by assembling talented faculty, administrators and students to brainstorm possibilities. She later provided an infrastructure for program development by establishing a central task force to oversee the process and four divisional task forces to work out discipline-specific concerns. When a proposal was prepared, the administration promised start-up funds to nurture the fledgling program.
- Broad-based participation of all academic community members. The Central Task Force, for example, consists of faculty members from several disciplines, administrators, staff and students. During all planning phases, one faculty member in each division acted as liaison to that divisional task force. About 50 people were directly involved in program construction. When concerns arose they helped guide the planning process instead of reacting against some predetermined initiative.
- Misconceptions about the significance of quantitative reasoning across the academic spectrum are well documented. Mathematics instructors alone cannot effectively communicate the connections between quantitative reasoning and other disciplines. In response, Stockton infused quantitative reasoning throughout the curriculum, transforming existing courses and creating new ones. As a result, Q-designated courses link students with faculty from many disciplines to consider quantitative reasoning's role in these areas.
- Because faculty determine the extent to which curricular initiatives are embedded in institutional practice, customized faculty development programs are essential. At Stockton, we offer a summer institute to faculty members who want help to develop and teach courses that emphasize the importance of quantitative reasoning. Seminars on topics of interest to faculty are held during the academic year.

Thanks to external support, Stockton will expand its faculty development program to continue institution-wide reform.

- ## St. Andrews Presbyterian College

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St. Andrews is an accredited, private, undergraduate liberal arts and sciences institution. The main campus offers undergraduate degrees in 20 fields and has seven preprofessional programs. A satellite program at Sandhills Community College in Pinehurst, North Carolina, offers four undergraduate degree programs. Enrollment for 1995-96 was 721—54 percent female, 14 percent minority, 8 percent foreign, and 5 percent physically challenged. The college's key mission, through integrated educational programs, is to graduate informed, articulate individuals who understand the complex nature of problems in a diverse but interdependent global community, and who have the knowledge and skills to lead productive professional lives.

Reform goals. St. Andrews is re-envisioning its General Education (SAGE) program to prepare students for a more complex global community. In this context, the goal of our project, *Making the Connection: Science, Math and The Public Interest*, is to help all students understand basic science and quantitative skills so they can cope with scientific and technological aspects of public issues in a global community. The University of North Carolina-Pembroke agreed to work with St. Andrews on the project to reform their undergraduate requirements. A private liberal arts and sciences college collaborating with a larger public university offers a broad base for testing, evaluating, and ultimately disseminating the program to others.

Plan overview. The new science and math program (SAMS) replaces traditional math and science teaching to nonmajors through disciplinary breadth courses. It is a national concern that breadth courses lack connectivity, fail to cover a broad scope of relevant scientific issues, and inadequately educate typical undergraduate students in analytical and quantitative skills. These aspects of general education need courses designed to provide basic but broad scientific, technical, and quantitative skills to a diverse student body. In spring, 1996, St. Andrews pilot-tested the concepts for a visionary, two-course sequence for non-science and non-math majors that integrates quantitative skills and scientific and technological topics of public interest chosen from the natural and social sciences. Key program features:

- integrate quantitative skills into multi-disciplinary science topics;
- replace broad courses in lab science and mathematics;
- are designed for "typical" undergraduates whose educational preparation in science and math is generally weak;
- include perspectives ranging from the physical to the social sciences;
- course topics focus on issues crucial to the public interest;
- use math/science majors as tutors and mentors to other students;
- replace textbooks and lab manuals with a casebook that integrates theory, lab and quantitative components; and
- emphasize using calculators, networked computers and the internet to ensure students are competent in the latest technologies.

Faculty development. Such pervasive changes require substantial faculty training. The extensive experience of St. Andrews faculty in interdisciplinary teaching is crucial to implementing this key element. St. Andrews science, math and other faculty and a significant number from UNC-Pembroke will train over the project time period. To prepare faculty, summer workshops will emphasize course expansion to two terms in 1996, training more faculty in 1997, and disseminating to others in 1998.

Evaluation and assessment. It is crucial to ensure the new curricula are rigorously evaluated and assessed. An advisory committee with outside consultants will follow course piloting and implementation. The committee will help St. Andrews and UNC-Pembroke develop the curriculum and assessment tools. A key objective will be to compare gains in math and science competency for students in the new program with those in traditional breadth courses. Students will take the new sequence in their sophomore or junior years, not randomly as traditional courses are taken. All students are tested on entrance for quantitative skills. Those with inadequate basic math skills will complete a remedial math course as freshmen. Most students who progress to the sophomore year are good candidates for completing undergraduate education and should be ready for the new math-science program. Students who act as tutors in the new program must be juniors or seniors who have completed at least basic requirements for mathematics or science majors.

- **Salish Kootenai College**

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The mission of Salish Kootenai College is to offer local and other Native Americans quality postsecondary educational opportunities. College curricula reflect identified needs and interests of Native Americans by providing adult basic education; vocational education; and academic, cultural and community interest programs, courses and activities. The college helps tribal institutions and departments with staff preparation, planning, research and evaluation services. It strives to provide opportunities for individual self-improvement for survival in a fast-changing technological world while maintaining the Salish and Kootenai people's cultural integrity. Salish Kootenai College offers curricula and programs to the baccalaureate level, designed to meet the special needs of Native Americans. The mission is supported by science and environmental science programs that meet specific education, research and community needs. Improving access to environmental careers and public awareness of environmental issues for American Indians is a national priority because Western tribes control more than 61 million acres of land in reservations. Because so few tribal members are qualified environmental scientists, tribes must depend on the Bureau of Indian Affairs or hire non-Indians to manage their environmental resources. Either choice detracts from the Native American goal of self determination. All tribal members are called on to participate in resource decisions affecting their lands. A science and environmentally literate tribal membership is critical to the wise use of reservation resources. Most traditional curricula don't develop student environmental awareness or critical decision making skills.

Reform goals. The Environment in the Curriculum project addresses the needs of Native American students who are enrolled in environmental sciences and in a range curricula at Salish Kootenai College.

Plan overview. Environment in the Curriculum formally begins in FY 97, but faculty members have been integrating the course independently over the past two years.

Institutional strategies

- The project will research, develop, field test, evaluate, modify and install eight environmental science and nonscience course pairs into the SKC curriculum. The course pairs will focus on specific environmental problems and analyze actual data sets.
- We will develop instructional modules relating environmental science to the curricula of 10 nonscience courses in addition to those included in course pairing. A representative from the participating discipline will prepare the modules, with the help of environmental sciences faculty.
- The project team will prepare and maintain World Wide Web pages, providing course and activity information and descriptions, and asking for feedback and suggestions from the science education community.
- We will develop and publish a manual that other tribal colleges can use to design similar curricula, as measured by presentations at the annual meeting of the American Indian Higher Education Consortium. The manual will contain a discussion of the rationale, general suggestions for developing course partnerships, course syllabi, project descriptions and analyses of successes and failures.

- **Sinclair Community College**

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Sinclair is a public, comprehensive community college in Dayton OH. Founded in 1887, Sinclair is Ohio's largest single-campus community college and one of the United States' largest, with an enrollment of more than 20,000 students. Sinclair belongs to the League for Innovation in the Community College, and has an open-door policy and six academic divisions—allied health technologies, business technologies, engineering and industrial technologies, extended learning and human services, fine and performing arts, and liberal arts and sciences.

Reform goals. The goal of the institution-wide reform activity here is to align college services with community needs. We'll integrate institutional initiatives into a comprehensive strategy that allows Sinclair to respond to fast-changing student, employer and community needs. The result will be timely, higher quality education at a lower cost.

Plan overview. Institution-wide reform at Sinclair leverages several change drivers into an integrated transformation strategy. These drivers were created to give students and faculty new opportunities and to lead the change process for Sinclair's traditional delivery systems. The plan calls for initial implementation of these systems in manufacturing programs. Through this effort, faculty, facility, technology and operating policy requirements will be determined and required changes identified. Lessons learned from this experience will be applied throughout the college.

Institutional strategies. Major change drivers are:

- The Sinclair Quality Initiative (SQI) is a continuous quality improvement effort launched in 1991. It created an institutional effectiveness model to help identify opportunities for improving programs and services. Essential to the model are six core indicators used to assess effectiveness, including access to success, lifelong learning, student development, community focus, quality work-place and stewardship.
- The Miami Valley Tech Prep Consortium at Sinclair operates three integrated workforce development programs—Tech Prep, School-to-Work and Transformations. The consortium received the 1996 Parnell Tech Prep Award for excellence given by the American Association of Community Colleges. In 1996, the Department of Education named it the nation's best Tech Prep Program.
- The NSF Advanced Technological Education National Center for Manufacturing Excellence. Sinclair received a grant to establish a National Center for Manufacturing Excellence through the Advanced Integrated Manufacturing (AIM) Center, a partnership between Sinclair and the University of Dayton. The grant, awarded through NSF's ATE program, is for $1 million a year for up to five years, and is a catalyst for improving science, mathematics, and manufacturing engineering technology at high school, community college, and university levels. The grant's work influences other program areas through its modular, integrated approach to curriculum development and its focus on building customer needs into the curriculum.
- The Center for Interactive Learning (CIL) is a $15 million, 60,000-square-foot building that will be complete in 1998. It will have labs for instructional technology, interactive classrooms, video production facilities, technology exhibit areas, video conferencing capabilities, team space for project development, and an extensive area for equipment and cabling to support Sinclair's academic information infrastructure. The CIL will help determine how to improve the teaching-learning process by using emerging technologies, and assess the impact of technology on college operations. It will

answer questions like, What skills do faculty need? What is the ideal student/instructor ratio? What support resources are needed? and What facilities are most appropriate?

- The Sinclair Assessment Initiative (SAI). Sinclair's steering committee on the assessment of student learning and development designs assessment procedures to measure and enhance the educational experience. It created methods to assess student learning and development at entry, during their education, and upon graduation. Faculty members are trained in key assessment issues and practices. Sinclair's assessment approach is a national model; college representatives visit Sinclair each year to benchmark the plan. Community colleges nationwide have adopted Sinclair's approach. As these change drivers are operationalized throughout the college, every area will be affected. Sinclair is now developing the job profile, roles and responsibilities of faculty members of the future. They will be technologically astute, able to work with interdisciplinary teams to address customer needs, and rewarded in different ways than they are now.

- The curriculum—once 3-credit hour, 11-week courses—will become focused modules that respond better to customer demands and are more suited to delivery through CIL. College facilities have changed dramatically in manufacturing, turning the classroom into the Teaching Factory. CIL will have an added impact on facilities requirements.

- Partnerships are a key to success for Sinclair's reform initiative. Relationships with employers; other educational institutions; local, state, and federal government agencies; and a host of external experts will help Sinclair better serve its constituents into the 21st century.

- **Spelman College**

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Spelman College is a private liberal arts, historically black college for women. Founded in 1881 with 11 students, the college has evolved into a distinguished institution committed to educating leaders. Today the college enrolls nearly 2,000 women worldwide, employs 140 full-time faculty members, and offers a challenging liberal arts program that prepares students to reach the highest levels of academic, community, and professional achievement. Spelman is an undergraduate institution offering 22 majors in 18 departments. All students must take courses in African American studies, women's studies, international studies, foreign languages, mathematics, and science. The college was recently recognized by the Carnegie Foundation as a highly selective, national liberal arts college and chosen for a cooperative agreement with NASA and NSF for the Model Institutions for Excellence Program (MIE). Spelman has a comprehensive science program of academic instruction, faculty research, student research training, and academic enrichment. The academic program is offered through the departments of biology, chemistry, computer science and mathematics; the physics program; and the dual-degree engineering program. More than a third of Spelman students major in science, engineering or mathematics, and 30 percent of recent graduates held majors in these areas.

Reform goals. Spelman is making broad institutional reforms. *Spelman 2004*, a document outlining broad principles for the institution Spelman will become over the next decade, was adopted during the 1995-96 academic year. A planning effort based on this document is underway. The broad goal of institutional reform is to develop a community of scholar-learners where diverse faculty, staff and students actively engage and challenge each other to cross established boundaries, respond critically and creatively, and seek solutions to theoretical and practical problems in the context of a changing world.

Plan overview. Institutional reform in the sciences is comprehensive and involves every department and special program. All science faculty members are engaged in the planning process, and collaborative efforts are in place with faculty from other disciplines. The broad areas are curriculum reform, teaching methodology, faculty research and student research training, student enrichment activities, and infrastructure building. Several initiatives are underway, including an interdisciplinary approach to upper-level courses led by the Center for Scientific Applications of Mathematics (CSAM) under a grant from the Kellogg Foundation. Through a FIPSE grant, we piloted an interdisciplinary science course for general students that will become part of the core curriculum requirements and replace discipline-based science requirements. As a third example, computer technology is being integrated into the calculus sequence through the MIE agreement. The decision to adopt a symbolic, numerical, and geometric approach to teaching calculus was made by the entire mathematics faculty after extended discussions and a workshop.

Institutional strategies. Reform efforts use several institutional strategies, including an effort to secure a new state-of-the-art science center over the next two years. We developed the concept of Project Focus teams, where one or more faculty work with three to six students in a topic area. We also offer research opportunities to sophomores and students who are not at the top of the class. As a way to broaden the base for research, many new students will participate in campus research for a year. We seek more collaborations with universities, government laboratories and industry to supplement campus-based research with opportunities elsewhere. We are revising introductory courses and modifying teaching methodology. We are changing the emphasis from learning massive amounts of content to a focus on interactive science learning as a process. We experiment with group learning, problem solving as a basis for critical thinking, investigative laboratories, and using new technology such as computerized microscopes with video systems, and the Internet.

Other developments include a new student tracking system for institutional assessment, an enhanced institutional effort to facilitate graduate school entry, collaboration with the writing program director to offer a technical writing course, and an emerging environmental sciences major that represents cross-disciplinary thrusts from several departments.

- **Stanford University**

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Stanford University is a private university with 6,500 undergraduates and an equal number of graduate students. Undergraduate degrees are awarded by the School of Earth Sciences, the School of Engineering, and the School of Humanities and Sciences. The Graduate School of Business, the School of Education, the School of Law, and the School of Medicine award only graduate degrees.

Reform goals. In 1993, President Gerhard Casper charged a commission on undergraduate education to examine the quality of undergraduate education at Stanford and recommend curriculum and academic environment changes. One major recommendation was to create a new sequence of courses that promote scientific, mathematical, and technological literacy among nonmajors. Developing the science-mathematics-engineering core is a priority for building on the academic excellence of Stanford's science and engineering departments, offering innovative, meaningful courses to all undergraduates. The science-math-engineering core is part of a major new initiative, under the umbrella name Stanford Introductory Studies. Other program aspects include establishing freshman seminars so that every freshman has a small seminar experience with a faculty member, and expanding the new sophomore college—a program of short intense summer courses for students before their sophomore year.

Plan overview. The science core design committee began working in January, 1995, to design a program, bring it to life, and sustain it. To attract faculty, the program must support curriculum development and delivery, and a teaching environment promoting individual interest, collegial interaction, rewarding feedback from students, and administration support. To maintain the enterprise they needed a mechanism that could be repeated to encourage new course development. The committee's recommendation in spring, 1995, was a request for proposals (RFP) to faculty in all science and engineering departments. It solicited proposals from interdisciplinary faculty teams for three-quarter tracks to be offered for at least three years, beginning in fall, 1996. The RFP described program goals and components for each track, but encouraged faculty to think creatively about program themes and curricular innovations. The committee crafted guidelines for course content, the role of mathematics, and stipulated that all courses include laboratory work. The courses are intended to be problem-driven, proceeding from questions and experiences of interest to students—the nature of energy in the physical world, the molecular basis for living and non-living things, the interplay between the physical world and biological systems, the statistical description of populations and complex systems, and the design process in making practical and durable products and systems.

Institutional strategies. Three tracks started in the fall of 1996. All tracks will be team taught by university faculty, each bringing expertise from their own fields. The tracks are: *Earth Resources and the Sustainability of Life*, *The Heart: Principles of Life Systems*, and *Light in the Physical and Biological Worlds*. Eighteen faculty members are designing and teaching the courses. We need a straightforward, repeatable way to support the program. The principles of financial support must be applied uniformly across tracks. Different courses have specific needs, but principles should be the same and faculty should be treated equally. The Provost approved a plan whereby for developing courses each faculty member receives a fixed amount that can be used as extra salary, release time, or to support other projects. This support will continue if commitment to the course goes beyond the faculty member's other departmental teaching responsibilities. Independent of the support for individual faculty, the Provost committed university funds to renovating laboratory space for exclusive use of the courses.

- **State University of New York- Binghamton**

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All undergraduate students must understand the process of scientific discovery and the ability to apply technological developments wisely and effectively. Our proposed *Science Across the Curriculum* (SxC) program is based on the premise that student learning of scientific concepts and technological information will work if built on students' existing academic interests. Our strategy will enhance the scientific interests of Binghamton faculty in all disciplines.

Plan overview. We designed a three-tiered program that can be implemented in our institution's existing structure and curriculum.

- Tier 1 provides a foundation for four years of formal learning. Students take both a mathematics and a science course, the latter with a hands-on laboratory component as part of the university's new general education curriculum. We make these courses challenging and stimulating to science and non-science majors alike by including investigative laboratory projects using modem instrumentation; discussions of relevant social issues; and assignments in which students use the arts to teach each other scientific concepts.
- Tier 2 hybrid and linked courses integrate non-science faculty science, mathematics and engineering faculty in courses delivered to a common set of students. Hybrid courses explore emerging academic disciplines and reflect the increasingly interdisciplinary interests of faculty members. Linked courses bring disciplines together through assignments, discussions and joint lectures.
- Tier 3 focuses on student learning of science in the context of as many non-science courses as possible through four years of undergraduate education. Reflecting the increasing relevance of scientific and technological information in all aspects of society, many non-science courses now offered already address scientific issues. In our plan, faculty members teaching science and non-science courses will rely on each other for cross-disciplinary support. Faculty collaboration may include consultation; materials like reading references, videos, data, specimens or software; participation in another faculty member's class electronic discussion group; one or more visiting lectures; one or more periods of class discussion; design of one or more student assignments; or collaboration in which faculty may contribute to science classes.

Institutional strategies. Establishing connections between science and non-science faculty is essential to the success of this integrative program. Using resources of the new Center for Learning and Teaching on the Binghamton University campus, we plan to create a social and technological infrastructure to promote such connections among faculty, undergraduate and graduate students, and members of the professional staff across the disciplines. Plans include a steering committee to initiate contacts between science and non-science faculty members; workshops led by faculty members who have integrated science and nonscience in their classes; seminars on science topics of broad interest to nonscience faculty; informal convocations tied to events like a Science-in-Art exhibit; Web sites describing collaborative nonscience/science teaching, (e.g., http://www.clt.binghamton.edu/sxc/sxc.htm) with links to other Internet information sources; electronic discussion groups through which faculty relate their experiences or seek collaborative arrangements; upper-level undergraduate students helping faculty in SxC teaching, from identifying possible links through course development to helping in the classroom; contacts with members of the business and professional community outside our institution who can provide expertise unavailable on campus; and a system that recognizes and rewards faculty contributions to this and other educational reform programs. With regard to the issue of recognition, the university administration is united in rewarding teaching initiatives that enhance learning across the disciplines. Our entire institution is turning toward enhancing synergy. The goal is to have *Science Across the Curriculum* become a part of our institutional identity, along with *Writing Across the Curriculum* and *Languages Across the Curriculum*, which are already institutionalized. The reward structure will encompass instruments such as discretionary salary increases, recognizing collaboration as a component of service and teaching performance, and a contribution toward work evaluated for tenure and promotion.

Surveys and interviews of students and faculty members involved in SxC courses will be conducted to measure change in student attitudes toward learning science. For instance, students may be asked before and after a course to rank the order in which they would read a list of magazine articles or indicate their preference among television programs varying in the scope and depth of scientific information. Faculty members may be asked for perceptions of the program and suggestions about how it can be improved. As an institution with 12,000 students and 475 faculty, the university structure provides near-ideal conditions for this initiative. Our university has at its core the Harpur College of Arts and Sciences, enrolling 72 percent of 9,315 undergraduates, 39 percent of whom are science and mathematics majors. One-third of faculty and students on campus know the language, concepts, and culture of at least one science discipline. We have in place activities that relate to teaching improvement and general education that bring faculty of various disciplines together. Other advantages are a research faculty large enough to offer scientific and technological expertise in various subjects; a faculty small enough that friendships and acquaintances across disciplines already exist; research-active faculty members who understand the value of cross-disciplinary collaboration, and who are dedicated to undergraduate education; a significant proportion of faculty and students who are science-and technology-oriented; and academically successful, motivated students who are eager to excel. We hope SxC will give our students a basis for lifelong study of science as it relates to their professional and personal development.

- **Texas State Technical College - Sweetwater**

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At TSTC-Sweetwater, our mission is to train technicians in several advanced technologies who can perform the competencies required of their study program at levels designated by industry representatives on technical program advisory committees and accrediting/certifying bodies; know the principles of technology that undergird their courses of study, including computer literacy, chemistry, the physical sciences, and the math skills to cope with today's technological workplace; use superior interpersonal communication skills essential in the workplace, including technical communication skills, an understanding of team operations, and a sense of quality in the workplace.

Reform goals. The theme of TSTC's systemic reform plan is integrating technical program content with general academics; real-world economics with the college experience; teamwork distribution among students and faculty; and quality throughout college operations.

Institutional strategies. An apparent lack of motivation from a large portion of students now entering college has resulted in poor performance and a high attrition rate. The closest current curricular intervention lies in the traditional orientation course approach. But orientation attempts to cover either logistics or study skills but not motivation. So STC proposes to revise its orientation course by doubling it from one to two credit hours and expanding its coverage. New courseware will stimulate students to apply the economics of personal finance to their lives and careers. The new units include assignments and group work in which students examine economic realities for those trying to get by on minimum wage and current statistics on the region, state and nation's cost of living. Students will budget an achievable, desirable standard of living and compare that to wages and salaries available in different fields and with differing education levels. The desired outcome will be for students to realize the need for an education in a marketable field and the positive results that can accrue from completing that education. Other material will include discussions and exercises on the importance of quality in the workplace and how that translates into behavior. Lessons from industry in recent years have emphasized the importance of technical and basic skills in the workplace. Technical college graduates may get a job in their discipline based on their level of technological competency. But to perform and retain the job they must be equally competent in the foundation disciplines of math, science and communication skills. As these are integrated in the workplace, TSTC proposes to integrate them in the curriculum through a comprehensive approach across curricula and among faculties. According to TSTC's industrial partners, technical writing skills are imperative for technicians in modern industry. With corporate right-sizing, more work is pushed closer to entry levels. The consequences are that AAS-degree graduates are now expected to prepare technical documents for several audiences To address this need, TSTC will revise its AAS degree plans to require a course in technical writing. With a prerequisite of basic freshman composition, the course would be a collaborative effort between technical program faculty and the English department. Assignments would be drawn from the technical programs, with technology faculty evaluating products for content, while the English faculty focuses on form.

To revitalize the undergraduate curriculum, TSTC will implement the following strategies:

- Create a new applied lab portion of mathematics, science, composition, developmental and speech courses. This one-hour-per-week lab involves team teaching by general education and technical instructors. In this way, the "disciplinary purity" of academic subjects required by regional accrediting associations will be maintained while allowing students and faculty to directly apply composition, computational and public speaking skills to business-and industry-generated and discipline-related projects.

- Encourage greater input by technical program advisory committees concerning general academic skills required of potential employees. These specifics, introduced during expanded orientation courses, will serve as potent starting points for discussions, exercises and assignments completed during applied lab sessions.

The final piece of curricular reform will be to develop methods that integrate teaming across the curriculum as a college-wide effort. Just as writing across the curriculum was developed integrate composition in all disciplines, another program will give faculty members ways to inject teamwork into their programs. A critical component of this plan will be faculty development. Several initiatives are needed to achieve proposed outcomes:

- Teamwork training combining groups of technical and general academic faculty giving them conceptual and interpersonal skills;
- Development time and assistance to prepare interdisciplinary assignments;
- Training and development time to prepare revisions and courseware for the new orientation course; and
- Training on how to teach teamwork skills.

The final piece of curricular revitalization involves assessing student achievements in integrating academic and technical skills. This will take the form of a capstone course or project. Already a required part of all AAS degree plans, this experience will close the loop begun on initial enrollment with the orientation experience. It will require every graduation candidate to master all competencies in his or her technical program curriculum at standards, including technical competencies, computational skills, writing competencies, oral presentations and teamwork.

- ## University of California at Berkeley

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The University of California at Berkeley has a student population of 30,000, of which 21,000 are undergraduates. While most students are from California, every state and more than 100 foreign countries are represented. A large fraction of this population is of minority background. The University's mission is to serve society as a center of higher learning, transmitting advanced knowledge, discovering new knowledge, and serving as a repository of organized knowledge. That obligation includes undergraduate education, graduate and professional education, research, and other public services that are shaped by the central mission of discovering and advancing knowledge.

Reform goals. Efforts center on improving lower division SME&T courses by expanding the Intensive Discussion Section model, and through developing new and innovative curricular materials. These efforts attempt to overcome difficulties that impede student success in large introductory courses and help increase the number of potential SME&T majors while increasing the population's general scientific knowledge. These efforts help produce graduates well matched to the needs of future employers.

Plan overview. The Physics, Math and Chemistry Departments are working in parallel to expand the intensive discussion section (IDS) model, based on that developed by the UCB Professional Development Program. In this model, students sit around tables where they can easily interact in groups of two to four, or work independently. Students spend much time on worksheet problems that stress creativity and give students the chance, working together, to explore solutions. Students are encouraged to communicate about concepts and methods with classmates to further their understanding and to learn to interact effectively with peers.

IDSs have successfully advanced certain underrepresented students through introductory calculus courses; the model was recently adopted in physics and chemistry (with support from the NSF-funded California Alliance for Minority Participation) with the same success. A two-year pilot program is expanding IDSs for all students in lower division physics, math and chemistry, and is improving cross-disciplinary exchange in these subjects. The faculty will continue to teach large lecture sections to provide a framework for the restructured discussion sections and laboratories taught by graduate student instructors (GSIs). Current activities concentrate on developing materials for the IDSs, and on improved GSI training. The training includes discussing the use of group study, the dynamics of IDSs, proper design and use of the worksheet, and an introduction to non-academic issues that students face and how instructors can help. The Mathematics Department is adding a computer-based calculus laboratory to its introductory courses. These labs, based on MatLab, help students better understand calculus concepts, especially their geometric content, and help them solve more realistic problems. This gives them a better understanding of the power of calculus as a tool for real applications. UC Berkeley is one of eight diverse educational institutions involved in the Synthesis Project, whose mission is to reform engineering education by developing new curricular and pedagogical models that integrate multi-disciplinary content, teamwork and communication, hands-on and laboratory learning experiences, open-ended problem formulation and solving, and examples of best practices from industry. Multimedia courseware integrates diverse analytic, design, experimental and intuitive skills required by a practicing engineer. The ModularChem Consortium, MC^2, is based at UC Berkeley and works to develop new curricula, multimedia materials and methods to enhance appreciation and learning of chemistry. To accomplish this, a modular approach to teaching chemistry in the first two years of undergraduate curriculum is being developed and evaluated. The modules, typically two to four weeks of classroom or lab materials, present fundamental chemistry to students in the context of a real-world problem or application and emphasize links between chemistry and other disciplines. Another effort has begun to integrate calculus, chemistry, physics and engineering education through technology enhanced visualization, simulation and design cases. Building on an evaluation of our own and others' computer studios, we are working on a model with an environment for integrating hands-on activities, paper exercises, and team use of computers. This work is part of the development of materials to be used in IDSs.

Institutional strategies. The recent growth and coordination of efforts by separate departments was stimulated by faculty from different disciplines who worked together on grant proposals such as the NSF incentive award for institution-wide reform of undergraduate education, and a recent proposal to Hewlett-Packard for Technology Enhanced Learning. This work has helped faculty recognize shared goals of improving the efficiency and efficacy of teaching gateway courses to SME&T careers, strong interrelations between mastering material in one course and mastering material in allied science or mathematics courses, and the need to improve the training of GSIs who are central to incorporating cooperative learning models in the teaching culture of SME&T departments. Department faculties are committed to playing an active role in these reform efforts. In preparing for the shifts taking place in the Fall 1996 semester, faculty committees from each department approved and are overseeing the changes, and are working with the GSIs in their implementation. In each department a large number of faculty rotate through teaching SME&T gateway courses. Within a few years many faculty members will have used the new instructional models, creating a critical mass of faculty to assure that the reforms become part of the regular teaching program with support from the university budget. Ongoing evaluation of the new approaches is important. The campus Instructional Technology Program helps evaluate such efforts. It will monitor retention and enrollment rates for students in SME&T courses and majors, and evaluate new program effectiveness through questionnaires and interviews with students and teaching staff. Eventually, evaluation efforts will involve surveying graduated students and their employers to assess program effectiveness. Evaluation results will be used to plan future efforts, with immediate attention toward developing improved GSI training programs. It is clear that GSIs, who work most closely with students, are key to any successful reform effort.

- **University of Hartford**

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The University of Hartford is a private university with a diverse population of 4,500 FTE undergraduates, 1,100 graduate students, and 480 FTE faculty in nine colleges. A strong commitment to undergraduate education is supported by small average class sizes and emphasis on quality teaching, scholarly and creative expression, and dedicated community service.

Reform goals. The university expects to develop a national model of excellence in SME&T education at small comprehensive universities. This model will enhance the consistency and coherence of student science experiences, encourage student-centered learning experiences, foster student success in introductory SME&T courses, and encourage persistence among students in pursuing SME&T work.

Plan overview. Our objective is to attract more students, particularly female and minority students, to SME&T fields. By creating environments where students engage in collaborative learning projects, work in study groups with specially trained peers, and use educational technologies that increase interactivity and foster intellectual synthesis, we aim to improve teaching and learning in introductory courses through increased curricular and pedagogical coordination and consistency in SME&T disciplines.

Institutional strategies. The project seeks to create a new freshman year SME&T experience by revising introductory SME&T courses to emphasize student-centered learning styles and develop student skills of concept-building and synthesis. The reform builds on and integrates the following programs in place at the University of Hartford:

Student experiences. Gateway mathematics courses in the College of Arts and Sciences have been modified to include a "high-tech, soft touch" approach that combines TI Graphing Calculators with in-class group lab work and out-of-class supplemental instruction. Shadow sections of introductory precalculus courses are run by student leaders who attend class lectures and facilitate several supplemental instruction sessions a week, emphasizing study skills and problem-solving approaches for that course.

- In a program for women in SME&T funded by the Department of Education at Hartford College for Women, students engage in collaborative learning in supportive classroom cultures; outside the classroom they attend metacognitive sessions that nurture scientific thinking and study skills applicable to SME&T fields, and fight culturally induced anxiety about working in these fields.
- The College of Engineering has re-conceptualized its first-year curriculum to include work in teams on small scale, practice-oriented research projects and experience with current technologies. For example, first-year engineering students in *Principles of Design* are given research problems in rehabilitation identified by a professor from the department of physical therapy. Based on his research about patients' physical needs, students design rehabilitative devices.
- Introductory biology courses now incorporate small group, intensive laboratory units using modern research techniques; they are team-taught by two to three faculty members. Biology faculty are experimenting with BioQUEST-led pedagogical innovations including coupling digital video microscopy with student-conceived and -executed research experiences.

Curricular change. A widespread goal is to enhance and revise 10 to 12 introductory SME&T multi-section courses by instituting student-centered pedagogies and learning tools.

Technology use. Interactive multimedia biology projects give students several pedagogical advantages. Interactivity lets instructors illustrate and assess student progress. Sensory-rich lessons exploit various intelligences. Simulations let students examine cause and effect in lessons optimized to strengthen concept-building and problem-solving skills.

Faculty development. A FIPSE-funded Advanced Education Computing Grant taught a cadre of faculty to author and use interactive multimedia in the classroom to foster student-centered learning. A faculty development project for innovative pedagogies in the natural sciences sponsored by the Keck/PKAL introduced science faculty to collaborative and problem-based learning techniques, interactive multimedia tools, and pedagogical methods most responsive to the needs of women students. Plans are underway to create a forum for cross-disciplinary, cross-college conversations about new pedagogies and teaching tools for use in SME&T courses. A core group of eight faculty members and administrators who have learned about innovative pedagogies, enhanced teaching tools, and methods of integrating these into introductory level SME&T courses at the University of Hartford will disseminate the results among departmental colleagues.

- **University of Michigan - Ann Arbor**

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The University of Michigan - Ann Arbor is a public Research I university that annually enrolls 23,000 undergraduates and 13,000 graduate and graduate-professional students. The Ann Arbor campus has 18 schools and colleges and 3,000 faculty. Its mission is to serve the people of Michigan and the world through preeminence in creating, communicating, preserving and applying knowledge, art and academic values, and developing leaders and citizens who challenge the present and enrich the future.

Reform goals. A primary goal of institution-wide reform in undergraduate education is to creatively effect dramatic improvements in integrating faculty research expertise into undergraduate curricular and extracurricular education. The current initiative will infuse interdisciplinary courses and materials into the curriculum, based on the hypothesis (1) that interdisciplinary understanding is increasingly important, and (2) that interdisciplinary learning offers important chances to engage students in research.

Plan overview. The plan is to establish an undergraduate curriculum development testbed to increase interdisciplinary course sequences in global change, a special strength in university research and instruction. The testbed will help people better understand institutional and systematic barriers to expanding interdisciplinary instruction, develop and test ways to eliminate barriers, and develop exportable templates and modules for developing interdisciplinary courses. Key testbed elements include establishing a university-wide introductory sequence in global change and a capstone course in earth system science, and evaluating the course sequence as a general model for interdisciplinary course sequences; developing state-of-the-art instructional tools; exploring enhanced incentives for interdisciplinary teaching, including new teaching-credit schemes; and using the university's global change lab to develop research-intensive learning experiences.

Institutional strategies. Many creative undergraduate education reforms face two critical issues—faculty reward structures and the resource-intensity of many suggested reforms in most university administrative and budget structures. Our effort faces these issues in the context of interdisciplinary instruction and enhanced undergraduate research experiences.

- *Interdisciplinary instruction*. It is impossible to increase interdisciplinary instruction without motivating faculty to engage in interdisciplinary instruction. Typical disincentives and possible corrections are that faculty, particularly junior faculty, are unwilling to commit to teaching efforts that take them away from tenure-granting departments. A possible solution is to build valuation of interdisciplinary instruction into tenure, promotion and salary-review criteria. University undergraduate colleges have a 10-year reform history that emphasized undergraduate teaching in faculty reward decisions. The testbed will build on this by involving deans in modeling and testing interdisciplinary instruction, eventually generalizing criteria-valuing interdisciplinary instruction. Academic departments typically need to maximize the creation of instructional credit for the faculty and graduate assistant teaching base. But contributing faculty and TAs in a team-taught, interdisciplinary course to total departmental credits effectively halves the base. In this respect, interdisciplinary instruction is more resource-intensive for the organizational unit than intradisciplinary instruction. This creates a disincentive for departments to give faculty such assignments. One solution may be to provide resources for interdisciplinary-course TAs from college or central rather than departmental sources, or grant full-course credit or a fraction greater than half a credit for each faculty team that teaches an interdisciplinary course. This means double-counting student credit hours across department and college divisions. The testbed will pilot solutions for the new model course sequence. It will examine related resource issues and get deans involved in developing a common policy that governs faculty credit for interdisciplinary instruction.

- *Undergraduate research experience.* Research-intense undergraduate experiences are more resource-intensive—often in terms of faculty effort—than lecture-style learning. Approaches include increasing the faculty pool that supervises research experience by using research and clinical faculty, and integrating research experiences into the curriculum so that students receive a more equitable distribution of resources. The testbed will explore ways to better integrate research into the curriculum and facilitate student transition from curriculum-based research to extracurricular research activities.

- **University of Michigan - Dearborn**

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The University of Michigan - Dearborn is a public comprehensive university, one of two regional campuses of the University of Michigan. Its mission is to serve students in metropolitan Detroit and southeastern Michigan by providing quality undergraduate and master's degree programs through the College of Arts, Sciences and Letters (CASL), and the Schools of Education, Engineering, and Management. All 8,214 students commute to campus to get degrees or certificates in 58 programs. The student body is composed of nearly equal numbers of males and females; 14.2 percent are self-identified minorities.

Reform goals. The goal of the university's reform effort is to institutionalize a process of instructional reform that creates a critical mass of faculty across disciplines who know about and practice alternatives to traditional lectures as a means of instruction, establish a community of teachers that will evolve into a community of learners in which the faculty act as guides and students participate in an active, collaborative manner, and identify or develop new instructional technology applications. Our intent is to reform introductory courses and move to upper-level courses. Faculty across the university have engaged in reform efforts for nearly a decade, but the efforts are largely disconnected and don't transcend disciplinary boundaries, although in one instance an effort transcended institutional boundaries. The most notable reform effort to date occurred in mathematics and statistics, where faculty used innovative teaching methods to develop and adopt software and computers to further student learning and understanding, and build a process to implement reforms.

Reforms include developing and integrating computer-based laboratory exercises through the three-semester calculus sequence (with NSF support), extensively using cooperative learning in remedial mathematics, and adopting a constructivist, hands-on approach in all math courses for elementary teachers. The calculus reform efforts were extended to neighboring colleges, including Eastern Michigan University and Sienna Heights College. Other efforts are initiated in the calculus-based physics sequence, where instructors are turning students from passive note-takers to active learners in group settings, and in the introduction of general chemistry discovery laboratories. Cooperative learning is extensively used in recitation, and course content is reduced to allow a focus on applications and theory of each major chemistry area, giving students a better appreciation of how chemists approach problems. With support from local industry, the School of Engineering created the Center for Engineering and Practice to incorporate engineering practice, design, innovation and concepts of manufacturing technology at all levels by integrating the teaching and manufacturing environment. This pairs industrial partners with engineering faculty, who involve undergraduate and graduate researchers and high school students in different projects. Besides the obvious connections between practitioners and students, this effort prompted a significantly revised engineering curriculum.

UM-Dearborn identified ways to extend its reform efforts:

- We need a tested process to assess effective reforms in one discipline or course for broader applicability and use on campus.
- Faculty working in SME&T reform efforts are scattered across three academic units. We lack a critical mass of faculty who know about diverse learning styles, alternatives to lecturing and pedagogical advances, cooperative learning, or using instructional technology to support learning.

- There is little formal or informal discussion about teaching among the faculty—we teach in pedagogical isolation.
- K-12 teachers do not experience science as they're expected to teach it. Students graduating from Michigan schools must be able to use, construct, and reflect on scientific knowledge. Faculty must be prepared to receive students who have learned in different ways.
- There is no sense of a "community of teachers" among faculty and adjuncts, nor a "community of learners" among the faculty, adjuncts, and students. We tend to resolve instructional issues by discipline rather than by knowledge.

Institutional strategies. The University of Michigan's institution-wide reform effort began in fall 1996. For faculty, the reform process begins with a Pedagogy Forum. This is followed by training and support as they adopt new pedagogical methods ranging from non-technical changes like using cooperative learning and group projects, to technical use of computer software for in-class demonstrations and homework. It concludes by presenting innovations to the Pedagogy Forum. Initially the forum, which meets monthly, will be led by faculty from the School of Education or experts in pedagogy in fields like science or mathematics. Once established, the forum is a vehicle for spreading innovation in instructional style and technology use campus-wide. We initially expect to integrate the software program *Mathematica* into the sciences, beginning with chemistry and physics, adopting a course in economics followed by a similar course for science majors, and developing hands-on lab experiences for non-science concentrators. Adding more earth sciences material converts this to a three-semester sequence of science courses for K-12 teachers. We will also give talented undergraduates a chance to facilitate learning in introductory course recitation sections. As reform efforts progress we will disseminate the results, initially through the Commuter 26—a group of public, urban, non-residential universities like UM-Dearborn.

- **University of Nebraska - Lincoln**

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The University of Nebraska-Lincoln, a land-grant and a comprehensive teaching and research university, will build on its historical commitment to academic excellence through teaching, research, and service as we plan for a future that depends on creating and disseminating knowledge, educating an informed, sophisticated citizenry, and a well-educated workforce.

Reform goals. Our primary goal is to provide a high quality educational experience for all students that integrates knowledge across mathematics, science and engineering disciplines through meaningful inquiry-based experiences, engaging students in the process of becoming lifelong learners.

Plan overview. The College of Arts and Sciences, which delivers 55 percent of the university's undergraduate instruction, in partnership with Teacher's College, the College of Agricultural Sciences and Natural Resources, the College of Engineering and Technology, the University of Nebraska Museum, and the Nebraska Math and Science Initiative (NMSI-Nebraska's NSF-funded state-wide systemic initiative), will lead the university's many mathematics, science and engineering initiatives. Evidence of university commitment is seen through the designation of mathematics and science education in the College of Arts and Sciences as an area of strength, through the Center for Science, Math and Computer Education, and through UNL's longstanding support for the NMSI. UNL is redesigning its lower-division offerings in math and science to prepare graduates for the changing technological and scientific world they will face in the 21st century. A special emphasis of our plan is to support innovations in the use of instructional technology in classes in mathematics, science, and engineering, including innovations that underwrite the university's commitment to mathematical sciences and their applications across the curriculum. We are committed to projects that support active learning by means of instructional technology that are designed for those lower-division courses that are part of general education. Since the delivery of large numbers of these offerings in math and science are in part provided by graduate students, part of our redesign will focus on the professional development of graduate students in instructional modes adapted to active learning. We place particular emphasize on approaches that enhance the success of women and minorities who historically have been underrepresented in science, mathematics, and engineering.

Institutional strategies. UNL has made a substantial commitment to the development of its faculty and graduate students as teachers. For example, a NSF-funded ILI (Instrumentation and Laboratory Improvement) grant was a catalyst for a complete change in how undergraduate mathematics instruction is delivered at the university. All sections of calculus use the reform materials developed by the Calculus Consortium at Harvard. Students working in collaborative groups complete substantial writing projects, making effective use of graphing calculator technology. In subsequent courses such as differential equations and matrix theory, students use computer algebra software like Maple to complete writing projects of increasing complexity. In chemistry education, the department is moving to reinforce the use of graphing calculators with experiments using CBL units for hands-on experiments. The new institution-wide Teaching Learning Technology roundtable and many other University programs and offices offer workshops and funds for faculty development in instructional technology. Programs and facilities like the New Media Center and the Teaching and Learning Center offer a range of services that support faculty development in instruction. Our changing faculty culture is beginning to value the development of math and science education as highly as faculty research. For example, this year the Chemistry and Physics departments hired faculty whose scholarly expertise is in education and pedagogical research. We plan to reconfigure the faculty reward structure to allow a more flexible distribution of faculty effort, and greater rewards for effective teaching to underscore the university's commitment to undergraduate education.

Technology use. UNL's goal is to be a national leader in multimedia and other instructional technologies in the delivery of undergraduate instruction. Several facilities were renovated to enable a multimedia approach to instruction. These facilities are all in heavy use. UNL is planning a state-of-the-art instructional classroom building that integrates instructional technologies with library information technology. The building will house several multimedia classrooms with voice, video and data conduits, large screen computer-video projection, electronic teaching stations, and multimedia hardware and software. It will also house multimedia classrooms with a mix of pedagogical capacities, some designed with clustered student workstations for team projects, others to enhance interactive collaborative learning.

Advances in improving student learning through new instructional technologies have been made across mathematics and the sciences. There is a growing emphasis on writing and oral communication, the use of graphing calculators, and computer algebra systems like Maple. Individual faculty are developing the World Wide Web as an instructional resource by developing interactive group and class projects. The university is funding a project to develop interactive Web-based text for a series of courses. UNL boasts the premier midwest CD-ROM database creation and management facility for physics and astronomy. The Physics InfoMall CD-ROM project staff processed, proofread, and published more than 30,000 pages of text and digitized more than 25,000 graphics. Project leaders are developing and testing innovative instructional programs using the CD-ROM materials. Many science programs redesigned their curricula to incorporate instructional technology that fosters active learning. Chemistry, for example, radically changed its introductory courses and the instructional environment to reflect state-of-the-art educational approaches. In the lab, for instance, students don't replicate experiments from manuals, they get experience recycling aluminum, making and marketing aspirin, and monitoring water quality. The introductory courses have guest presentations by faculty about their research and its effects on the public, part of an institution-wide effort to integrate faculty research and undergraduate education.

- ## University of Northern Colorado

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The University of Northern Colorado is a general baccalaureate and specialized graduate research university with a statutory mission in teacher education. The university offers a broad range of undergraduate programs in the arts, sciences, humanities, business, human sciences and teacher education. Students are required to study in the liberal arts tradition to prepare them to think and act responsibly in a dynamic, diverse global society. University curricula are designed to improve students' critical thinking, communication and problem-solving skills. The university has a campus-wide commitment to preparing teachers. As Colorado's primary institution for undergraduate and graduate teacher education, the university takes pride in its state-wide mission for leadership in professional education. The University provides services that support equal learning opportunities for all students. Full-time faculty teach small classes, and teaching is the highest priority. UNC graduate and undergraduate professors subscribe to a teacher-scholar model of excellent instruction complemented by scholarship and service activities. Support for continuously improving teaching, learning, scholarship and service comes through university programs, policies and practices. The UNC College of Arts and Sciences offers broad based baccalaureate majors and minors, a general education curriculum to all undergraduate majors, and specialized masters and doctoral programs primarily in the field of content-based teacher preparation. Innovative programs in discipline-based teaching and learning, content standards, and outcomes assessment are offered through the leadership provided by three interdisciplinary centers: the Mathematics and Science Teaching (MAST) Center, the Social Science Teaching Center, and the Institute for Multicultural Education. Via these centers, the college takes a leadership role within the university and conducts programs in collaboration with individuals from the various colleges, business and industry, and K-12. The college restructured its hiring practices, faculty rewards system, and faculty development system to complement its mission.

Reform goals. Our goal is to promote an academic environment that advances a "community of learners" philosophy for all students. Students will develop the knowledge and skills that will prepare them to face the many challenges of the 21st century. Faculty will continue to develop their skills as instructors and be rewarded for their efforts just as they continue to develop as scholars through research or other forms of scholarship. The needs of a diversity of students will be addressed. Future K-16 teachers will be prepared to meet the needs of their students.

Plan overview. The plan involves student learning, faculty development and changes in the university culture. Student learning depends on student involvement. Our plan promotes diverse opportunities for students to interact with faculty, other students, technology and course content. Through their input, students become an integral part of educational improvement. Faculty development depends on greater involvement. Several strategies encourage faculty to put more effort into assessment, reflection and innovation in the learning-teaching process. The university provides the resources and facilities for continually improving the educational process. The goal is to create enhanced student learning through enhanced teacher learning.

Institutional strategies. Greater effort is planned to implement new procedures that link student learning, program objectives, student assessment and classroom research. This will reflect the principles of national, regional and state programs in K-16 and standards-based educational reform. Assessment also will be a vehicle to link strategic planning to the budgetary process.

Curricular change. We plan to move students from *passive reception* of knowledge to *active involvement* in their learning. Innovative instructional strategies that promote minds-on and hands-on experiences will be encouraged as alternatives to traditional lecture format. Learning activities that help the students interact with the concepts and develop deeper understandings will be pursued. Innovative use of specific educational technology will model real-world phenomena and allow students to predict, experiment, observe, and interpret. Students will be engaged in activities that encourage cooperation, teamwork, and discourse to increase both comprehension of concepts and appreciation for discipline.

Faculty development. More opportunities will be available to faculty to learn and implement alternative instructional strategies that promote interactive learning in their courses. This includes release time for course revision, peer mentors, workshops on content-based pedagogy, collaboration with other campuses, seminars led by outside authorities and more support staff to implement innovative curricula.

Faculty reward structure. Effective instruction must be valued and rewarded. A balance between teaching and research must be clearly communicated to all faculty and consistently followed. Demonstrated abilities to teach effectively must play a significant role in hiring new faculty, promoting in rank, and awarding tenure.

University structure. Interaction among disciplines is promoted by establishing interdisciplinary centers. The Mathematics and Science Teaching (MAST) Center is a way to assure that key people from each science and mathematics department, the College of Education, industry and public schools are involved in undergraduate education reform.

Technology use. The technology plans for College of Arts and Sciences and the General Education Program aims to provide increased opportunities for students to use emerging technology as an integral part of their learning in all undergraduate courses where it may be appropriate; provide faculty with opportunities to learn how to incorporate emerging technologies into their teaching by providing hardware, software, training and technical support. In October, 1996, UNC and the governor's office co-sponsored a state-wide education summit to give higher education academic officers and faculty a chance to meet with K-12 leaders, business leaders, and legislators to discuss how higher education and K-12 schools can work more closely together. After the summit, regional meetings across the state will discuss content standards across K-16 and benchmarking student progress by assessing outcomes.

Student experiences. The college conducted several experiments to increase student learning and retention based on a "learning pathway" model in the Freshman Cluster and Enhanced Supplemental Instruction programs. The experiences increase opportunities for student involvement in their own learning and in the university community.

University of Puerto Rico

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The University of Puerto Rico (UPR) is the premier Hispanic university in the U.S. educational system. Founded in 1903 as a small Teacher's College, UPR is an island-wide system of 11 campuses offering associate to doctoral and professional degrees in 340 fields. In 1995-96, UPR had an enrollment of 62,780 students, with 12,952 in SME&T fields. Nation-wide, the university contributes 20 percent of Hispanic BS graduates who go on to earn Ph.D.s in SME&T fields in Puerto Rico or on the mainland. Its mission is to transmit and increase knowledge through the sciences and the arts, and put this knowledge at the community's service.

Reform goals. To increase the effectiveness and efficiency of the undergraduate educational enterprise by creating a more robust, nurturing environment for students and transforming the institutional teaching-learning culture.

Plan overview. Undergraduate SME&T education reform at UPR aims to permanently transform the university system through a systemic approach that addresses key SME&T components and focuses on every level and function—teaching-learning, curricula, research and administration—of the undergraduate level of the pipeline. Four specific metrics were pioneered and institutionalized to measure the effectiveness and efficiency of the undergraduate SME&T enterprise: graduation rates; years required to complete the BS degree; the Index of Course Efficiency (ICE), which is the average number of times it takes students to pass a course; and the number of BS graduates that complete a Ph.D. in an SME&T field. During the past four years, UPR has conducted an in-depth assessment and redesign of teaching strategies and course structures of four SME&T gatekeeper courses: introductory physics, introductory chemistry, general biology, and precalculus and calculus. Among the changes implemented through this curriculum revision are the integration of the lecture and laboratory into a single course; development of laboratory activities designed to make students active participants; incorporation of inquiry based and discovery activities that promote the development of thinking skills into the courses; emphasis on key concepts to stress depth of understanding, and the development of broad based mathematics skills. Two of the key elements used to improve the quality of the SME&T curriculum and enhance student performance have been cooperative learning and the incorporation of learning/study skills within the context of a course. A study of the results of the integration of cooperative learning, by comparing the grades of participants and non-participants indicates that participants attained 12 percent more As and Bs, and 12 percent fewer Ds, Fs and Ws than non-participants. The learning-study skills program—targeting at-risk students who need more academic support—have doubled the number of As and Bs obtained by these students, and decreased Fs to a third, when compared with similar students not participating in the program.

Institutional strategies. The following core strategies are included in the institution-wide reform plan:

- *Curriculum revision.* A systemic analysis of student performance in SME&T courses will point to courses most in need of revision due to high attrition and low grades. Up to five courses will be revised annually and pilot tested in the subsequent year. The curricular revision, based on the idea that less is more, focuses on key concepts to promote depth of understanding and teaching strategies that promote active learning based on inquiry and using interactive demonstrations. Courses are being redesigned to incorporate the emulation of the scientific process by incorporating research activities and experimental design. Precalculus and calculus courses are being revised as a continuum of mathematics ideas to gradually introduce calculus concepts into the context of real-life situations. An essential part of the curricular transformation process is the incorporation of effective assessment methods that measure higher-order thinking skills, depth of understanding, integration of knowledge and scientific inquiry skills.

- *Transforming institutional teaching-learning culture.* For educational reform to work, it is necessary to change the institutional teaching-learning culture. This requires a strategic plan and carefully planned strategies to achieve a fundamental change in attitude of administrators, faculty, and students. Key institutional players must be persuaded that reform is needed by providing evidence of weaknesses and failures through a careful assessment that measures the value current teaching-learning processes contribute to student education. Once this is achieved, a cadre of reformers will pioneer and pilot test new teaching-learning strategies, and evidence proves they are effective and efficient. A strategic plan will incorporate other faculty members to scale up the reform for systemic impact.

- *Faculty development.* Faculty development is conducted to promote changes in attitudes in line with the changes in the teaching-learning process, support faculty efforts to change their teaching practices, and train faculty in curricular revision to meet reform objectives. A traveling faculty improvement team will offer workshops and onsite assistance to faculty on developing strategies to improve SME&T education. The team will access faculty through the Internet to offer technical assistance.

- *Faculty, industry and peer mentoring.* A dynamic mentor relationship is being implemented between faculty members and advanced (junior and senior) students, and between advanced undergraduate and lower-level students (freshmen and sophomores). A special Industry Mentor Program will be established through which students are matched with industry mentors according to their career interests. Each mentor-protégé will develop an activity plan to work on the student's areas of interest while the industry mentor provides key experiences that will enhance student preparation and develop their future study and career plans.

- *Strengthening educational technology in SME&T.* At the classroom and laboratory level the plan includes using multimedia technology to enhance the teaching-learning process. Students will learn to use computers to collect, store, process, transform and manipulate data as part of experimental design activities. Students will get an Internet address and services like access to the World Wide Web so they can interact with information sources and communicate with students and faculty around the island and abroad as part of their coursework and research projects

- *Institutional research and strategic planning.* Institutional research will incorporate already-pioneered metrics and guide strategic planning to achieve an institutional culture based on effectiveness and efficiency that nurtures all students, particularly low-income and first-generation college students.

• The University of Southwestern Louisiana

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The University of Southwestern Louisiana (USL) is a public, open-admissions, Doctoral II institution with 14,500 undergraduate and 2,000 graduate students. Undergraduate degrees are awarded in many disciplines, including traditional sciences and liberal arts, architecture, business administration, education, engineering and nursing.

Reform goals. The College of Sciences has a strong record of participation in successful projects designed to bring about reforms in undergraduate mathematics and science education, especially with regard to the pre- and in-service preparation of K-12 teachers and to the calculus sequence. The college now seeks to expand the scope of these activities to include the core courses in sciences and mathematics required of all non-technical majors.

Plan overview. The Louisiana Board of Regents established general education requirements for all undergraduate degrees. Core course requirements include six semester hours in mathematics (beginning at the level of college algebra), and nine semester hours of science (biological and physical, with at least two sequential courses in the same scientific discipline). Students satisfy the science requirement by choosing from several departmentally-based introductory courses in biology, chemistry, geology and physics (including astronomy). The faculty of sciences now proposes to design an innovative two-course science sequence to fulfill part of the core requirement. This sequence will follow a developmental theme (from the beginnings of the universe to concepts of populations and ecology with emphasis on Earth's physical, chemical and biological histories) and will depart from traditional lecture and laboratory formats by using a presentation-discussion-exploration approach with participation by SME&T faculty members and guests. Student success in the core freshman college algebra course is disappointingly low. The plan to improve the outcomes has three components: expanding a remarkably effective mathematical study skills program, enhancing the pedagogical skills of graduate assistants and adjunct faculty, and improving the mathematical preparation of students who enter the course.

Curricular change. The structure of the proposed new science sequence evolved from considering basic questions of USL expectations of students—what they should know about science and how to measure student progress. Existing introductory courses answer departmental questions for particular disciplines, but this is the first attempt to consider the issues from a broader perspective.

- *Student experiences*. The science and mathematics courses taken by most university undergraduates are given in traditional lecture and laboratory formats. Each department has had good results in one or more courses using the techniques associated with the national reform movements (participatory and collaborative learning, use of technology, exploration-discovery activities). Target audiences for these reform efforts have been teachers, prospective teachers, and students taking calculus or precalculus courses. It is time to give all students these kinds of learning experiences.
- *Faculty development*. Among the continuing faculty members of the College of Sciences, interest in the reform of undergraduate education continues to grow, largely as a result of positive reports by and encouragement from colleagues. The anticipated success of this pilot project is expected to accelerate this growth. At USL, graduate assistants and adjunct faculty play a significant role in laboratory instruction and in teaching the college algebra and remedial mathematics courses; their other activities and sometimes marginal contact with their departments can be disincentives to trying new course

designs and pedagogical techniques. Their inclusion as full participants in the project, along with special training and mentoring are important parts of the reform plan.

- *Faculty reward structure*. A university should certainly recognize and reward innovation and excellence in undergraduate teaching as well as in research and graduate-level education. The Dean of the College of Sciences proposed that faculty activities related to educational reforms be given more weight in personnel decisions, provided that the merits of such activities are established by the publication and informed review of materials and results.
- *Administrative support*. The president, vice president for academic affairs, and the vice president for research are informed about the plan throughout its development. They are enthusiastic about trying the new approaches and support institutionalizing the ones that work. The dean of the College of Sciences was a planning group member and will help design and teach the new course sequence.

- **The University of Texas - Austin**

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The University of Texas - Austin (UT-A) is a large, first-class national university. Our mission is to achieve excellence in undergraduate education, graduate education, research and public service.

Reform goals. Our goal is to give students the best undergraduate education of any U.S. college or university. UT-A has devised mechanisms for comprehensive improvement that builds innovation and accountability into the system. At UT-A, science, mathematics, engineering and technology (SME&T) education reform must be inextricably linked with comprehensive institution-wide reforms that affect the university mission. UT-A's continuous improvement strategy, Compact Texas, is a comprehensive agreement that affects the university and state. Three components of Compact Texas directly relate to SME&T undergraduate education reform:

- annual Compact 2000 agreements between the Provost's Office and each UT college and school that describe performance goals and expectations in all areas of college life. Compact 2000 refers to expectations about the college responding to NSF and NRC initiatives and suggestions;
- the Performance-Based Instruction System (PBIS) specifies departmental performance standards and expectations in education, including curricular review and development;
- the Total Quality Business and Education Partnership between the Ford Motor Co. and UT-Austin promotes the development of strategies for fundamental, systemic institutional reform.

UT-A's upper administration is committed to supporting and promoting systemic improvement in undergraduate education. This enthusiasm for change is in contrast to the conservative role administration often plays to preserve the status quo. All executive officers, including the president, the provost, the vice presidents for student affairs, research and graduate studies are conspicuous supporters of improved undergraduate education. This is crucial to making excellence in UT-A's undergraduate education, research, and service missions mutually supportive goals.

Plan overview. Our plan is to focus our strengths—large student body and strong research faculty—on providing superior undergraduate education. We use imaginative methods involving multimedia technology to shape our instructional program to suit student needs and faculty expertise. These mechanisms can systematically bring research-level advances to undergraduate students. UT-A is undertaking a major Freshman Experience initiative that will make an institution-wide, systemic response to the challenges involved in transitioning from high school to college. We seek to ground freshmen socially and academically so they can focus on active learning.

- *Faculty development*. The Center for Teaching Effectiveness develops faculty expertise in fostering student learning through seminars, new faculty orientations, an annual conference for experienced faculty, producing teaching and learning materials and individual interventions. Our future strategy includes exploring initiatives to systematically develop our faculty as more effective teachers through regular seminars, class visits and critiques. We will investigate the possible applicability of the initiative undertaken at the University of Wisconsin, Madison College of Engineering.

- *Faculty reward structure*. Prestige of teaching accomplishment has been accented here through a new Academy for Distinguished Teachers. A program of instructional leaves for curriculum development has been instituted. A committee of administrative and faculty leaders has been composed to review the reward policies with special emphasis on whether educational contributions are appropriately recognized.

- *Barriers*. Many research-oriented faculty have an allegiance to their disciplinary scholarship that can be at odds 'with their potential involvement with fostering student learning. Our goal is to make their research interests an absolute asset to the educational enterprise. A recommendation in *Shaping the Future*—that National Science Foundation's research projects should contribute positively to the quality of undergraduate SME&T education—would be helpful. A barrier to incorporating technological advances in instruction is the need for faculty leaves to learn the tools.
- *Discovery learning*. UT-Austin has a special heritage in inquiry-based learning in the legacy of mathematician R.L. Moore. We are undertaking a project to include discovery learning as an important part of undergraduates education. A June conference and subsequent projects to develop and disseminate modules, courses and technological aids are being planned.
- *Curricular change*. UT is instituting systematic method of continuous curricular improvement through a program of regular faculty leaves for undergraduate curricular development called the Dean's Fellows program. Web-based instructional materials are being developed. Our Emerging Scholars Program in mathematics is being adapted for biology, chemistry, and geological science.
- *Facilities*. Classrooms are being remodeled following a comprehensive master plan for the university. Innovative examples include physics lecture halls in which every desk is wired to allow real-time student responses.

Technology use. The computer infrastructure is being developed dramatically including new computer laboratories, e-mail accounts for students, computerized degree audits, a multimedia production facility for instructional materials, and use of the World Wide Web for courses. A Digital Information Science and Communication (DISC) Committee will make sure the development of digital technology infrastructure is coherent. The computer structure development is funded primarily through student fees. Innovations on the World Wide Web and in multimedia materials have been funded through NSF grants.

Student experiences. Our strategy is to involve more students in research as undergraduates. Each spring we hold an undergraduate research poster session. We plan to incorporate research experience into the work-study program following the University of Michigan model.

Resource reallocation. A portion of the instructional budget is alloeated to curriculum development leaves. A new position of Associate Dean for Undergraduate Education was created in the College of Natural Sciences to oversee the continuous improvement of undergraduate science and mathematics education. Each year $7.5 million from student fees is allocated to UT-wide instructional information technology development.

• University of Texas - El Paso

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The University of Texas-El Paso (UTEP) was established in 1914 as the state School of Mines and Metallurgy. It became the University of Texas at El Paso in 1967 and has grown into a comprehensive urban university with 17,000 students in six academic colleges: business, education, science, engineering, liberal arts, and nursing and health sciences. UTEP offers 59 bachelor's degrees, 56 master's degrees, and six doctoral degrees. It is the largest majority Hispanic university in the United States, a leader in minority education, and a national research center in such interdisciplinary areas as material science and environmental science and engineering. UTEP students come from a mix of social, cultural, and economic backgrounds. They represent 47 states and 67 countries. Eighty-five percent come from El Paso County and commute daily, 64 percent are Hispanic and nearly 8 percent come from Mexico. Seventy-five percent of UTEP students work full or part time while in school; 62 percent are first-generation college students. UTEP's mission is to provide quality higher education to residents in the El Paso region. The university aspires to be a model of educational leadership in a changing economic, technological and social environment.

Reform goals. UTEP's general reform objective is to create a university that welcomes students in an environment supportive of their involvement as participants in their own education. From newly developed summer orientation and course clusters that promote cooperative, supportive approaches in the classroom, to a renewed emphasis on laboratories and experimentation in all courses, to a new focus on the skills needed for lifelong learning, UTEP intends to mold students into active learners rather than let them be passive note-takers.

Plan overview. Beginning with its undergraduate science, engineering, and math (SEM) programs, UTEP will work to achieve its goals by

- improving the campus experience of freshmen and other entering students through a mandatory summer orientation and enrichment program before enrollment;
- clustering entry-level courses, including math, communication skill development, and introduction to science and engineering content and methods;
- requiring a common freshman seminar designed to develop critical thinking skills;
- increasing SME&T students' retention and academic achievement through faculty support and peer groups that emphasize group work, cluster-based labs, mentoring and direct student involvement;
- giving every undergraduate SME&T major a research or intern experience before graduation; and
- carefully evaluating the effectiveness of all activities and interventions.

This plan for institution-wide reform involve faculty and staff throughout the UTEP campus in an effort to foster an environment that will lead to student success. Faculty will receive support to develop innovative classes, experiments and projects; staff will revitalize old and develop new support services; and the infrastructure will be installed to ensure the continued success of these innovations. Rewarding faculty for committing themselves to student learning should change the very nature of the university's culture. As successful activities and materials are developed, they will be spread across the UTEP campus and the nation.

- ## University of Wisconsin-Madison

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The University of Wisconsin-Madison is a major public research university. Its mission is to create, integrate, transfer and apply knowledge.

Reform goals. For four years the University of Wisconsin-Madison has worked to review its undergraduate general education requirements. One goal is to ensure all students have college-level training in quantitative reasoning. We also plan to change communications and natural sciences requirements. For this exercise we focus on the quantitative reasoning requirement.

Plan overview. The General Education Requirement in Quantitative Reasoning defines quantitative reasoning as the process of forming conclusions, judgments, or inferences from quantitative information. Quantitative reasoning has many aspects—recognize and build valid mathematical models that represent quantitative information; analyze and manipulate these models; draw conclusions, predictions or inferences from the analysis; and assess the reasonableness of the conclusions. Undergraduate students who first matriculate in or after summer 1996 will be have to take two courses in Quantitative Reasoning, QR-A and QR-B. To be certified QR-A, a course must give students skills in mathematics, computer science, statistics, or formal logic. The skills must be broad-based so they have a positive impact on students' readiness to take QR-B courses in several disciplines. To be certified QR-B, a course must use quantitative tools in course material, to

- recognize and build mathematical models and hypotheses that represent quantitative information;
- evaluate these models and hypotheses;
- analyze and manipulate mathematical models;
- draw logical conclusions, predictions or inferences, and assess the reasonableness of conclusions; and
- a focus on quantitative reasoning in a specific discipline.

QR-A courses involve either mathematics or philosophy; QR-B courses are in the social sciences and natural sciences.

Institutional strategies. Any institution-wide reform that involves changing the curriculum at UW-Madison must be approved by the faculty senate. Changes in general education requirements were recommended by a faculty committee and approved by the faculty senate. Modifications in quantitative reasoning requirements use the same process.

Faculty development. The requirement in quantitative reasoning was taken from the planning stages to implementation by a committee of faculty and academic staff. Committee activities included working with departments and individual faculty members to develop new courses or modify existing courses to meet QR-A and QR-B course criteria. Institution-wide curricular reform has implications for institutions that send students to the university. We work with high schools and other UW system institutions to prepare students for our changing curriculum.

- **Wake Technical Community College**

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Wake Technical Community College is a public, two-year, comprehensive community college in Raleigh, North Carolina, near Research Triangle Park. Its mission is to provide education and training for the workforce by offering vocational, technical, college transfer, and basic skills programs.

Reform goals. The primary goal of institution-wide reform is requiring students who seek an associate of applied science degree (AAS) to complete a comprehensive capstone project before graduation. Student involvement in this project is structured to produce graduates who can think critically; communicate effectively; assimilate knowledge of engineering technology, mathematics and science; work effectively in teams; and show an enthusiastic attitude.

Plan overview. Wake Tech will expand the capstone project from the current three AAS curricula to all applicable 27 A.A.S. degrees. This expanded program will integrate general education courses with core curricula courses and include alliances with technical professionals in business and industry. Students will be introduced to the capstone project requirements during their first semester. They will work in teams to complete applications-oriented capstone projects linking such general education courses as mathematics and communications with core courses. Industry involvement will assure project validity and promote the graduates' accomplishments.

Reform strategies. The expanded capstone project will better prepare students for the technological workforce. Through the project, students will show technical competency and ability to integrate mathematics, science, engineering technology and communications knowledge. To meet these objectives, we will implement major initiatives during the two-year grant period:

- Reform curricula to meet the demands of a technological society. Business-industry representatives and faculty from other departments will be consulted to develop applications-oriented assignments for required courses. As a result, first-year courses in communications, mathematics, and engineering technology will be strengthened by inclusion of up-to-date applications-oriented assignments that demonstrate the connection between these required courses. Provide designated faculty with release time to realign the curricula and expand the project. Explain realignment and reform to other instructors at faculty development sessions and request feedback.
- Expand the capstone project from three A.A.S. curricula to all applicable 27 A.A.S. programs. To prepare students for the capstone project, show them a videotape of past projects during first-quarter enrollment so they recognize the competencies they must acquire during their education. Seeing the types of projects former students developed will help them set similar goals.
- Develop or strengthen alliances with business and industry representatives through professional societies and advisory committees to identify potential projects. By including business and industry leaders, the college ensures that instruction is relevant to workplace challenges.
- Establish yearly presentation days to demonstrate the hands-on, applications-oriented approach Wake Tech offers students through the capstone project. Invite high school students, business-industry representatives, and faculty from other community colleges to presentations of their choice.
- Document the projects and process in a brochure and a video that other colleges can use. Demonstrate the capstone process on state and national levels.

- Evaluate each step in the process using new or revised evaluation instruments. We will ask faculty, students, graduates, and employers to complete evaluations of the projects, process, and education at Wake Tech.

• APPENDIX C •

Directory of Exhibitors

COMPANY/INSTITUTION	TOPIC OF EXHIBIT
Addison Wesley Interactive Chip Price and Denise Descoteaux One Jacob Way Reading, MA 01867 Phone: 617-944-3700 x 2665 Fax: 617-438-5911 Email: chipp@aw.com	*Multimedia products for college-level courses in the physical sciences*
Arizona State University James Collins Department of Zoology Tempe, AZ 85287-1501 Phone: 602-965-3571 Fax: 602-965-2519	*Examples of undergraduate education reform at ASU*
Beloit College Brock Spencer 700 College Street Beloit, WI 53511 Phone: 608-363-2249 Fax: 608-363-2718 Email: spencer@beloit.edu	*Inter-institutional collaborations*
The Boeing Company P.O. Box 3703, M/S 6H-PR Seattle, WA 98124 Phone: 206-237-3639 Fax: 206-234-2568 Email: suzsuz@kgv2.bems.boeing.com	*Continuing leadership in the design and manufacture of the world's jetliners*
California Institute of Technology Carolyn Merkel 1201 E. California Blvd. Pasadena, CA 91125 Phone: 818-395-2885 Fax: 818-449-9649 Email: merkelc@starbase1.caltech.edu	*Institute-wide Integration of Computer-Based Instructional Aids into the Science and Technology Curriculum at Caltech*

California State University, Fullerton
Kolf O. Jayaweera
School of Natural Science and Mathematics
800 N. State College Blvd.
Fullerton, CA 92634
Phone: 714-773-2638
Fax: 714-449-5390
Email: kjayaweera@fullerton.edu

(1) *Individualized Electronic Homework in Chemistry*

(2) *CSUF Undergraduate Reform Institute*

Chemeketa Community College
Susie Kelly
Northwest Center for Sustainable Resources
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Phone: 503-315-4583
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Northwest Center for Sustainable Resources (NCSR)

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The Role of Computer Simulations and Design Projects in Undergraduate Engineering and Science Courses

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Clark Atlanta University Innovative Education

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Community College of Philadelphia Curricula Reform

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Instructional Reform at Drexel University

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Enhancing the Core Curriculum Through Problem-Based Cooperative Learning

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The New Science Project: A New Introductory Science Reform Effort

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Collaborative Student Learning

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Preserving the Legacy

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Comprehensive symbolic, numerical, and graphical mathematical software

Miami University, Oxford, Ohio
John A. Czaja
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Creating a Research-Rich Curriculum

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One Goal—Many Paths

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Transforming Grassroots Beginnings to changes that Last

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A Large-Scale Science Core Program for Nonscience Students

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The ACE Program: A New Integrative Model for Undergraduate Education

Northwest Center for Emerging Technologies
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NorthWest Center for Emerging Technologies

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A Team Approach to the Reform and Standardization of Core Courses in Science and Mathematics

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Panola College Interdisciplinary Technology Center

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Comprehensive Curriculum Reform at Rensselaer

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Environment in the Tribal College Curriculum

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New Vistas for Education: Interactive Learning Environments

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The Parallel College

Spelman College
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Interdisciplinary Science course for Non-majors at Spelman College

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Making the Connection: Science, Math, and the Public Interest

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Science-Mathematics-Engineering Core for Nonscientist

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Science Across the Curriculum: A Strategy to Enhance Science Education in the Undergraduate Curriculum

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Southwest Center for Advanced Technological Education

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Shaping the Future: Revitalizing Undergraduate Education

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The Use of Interactive Multimedia to foster Active Learning and to Address Diverse Learning Styles

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Undergraduate Research Opportunities and Undergraduate Curriculum Development Testbed

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Developing and Enhancing Instructional Technology, Undergraduate Research Experiences and Applying Mathematics/Science Across the Curriculum

University of Northern Colorado
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UTEP—A Model for Excellence

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The CAPSTONE Project

• APPENDIX D •
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