Recommendations for Action

in support of
Undergraduate Science, Technology,
Engineering, and Mathematics

Project Kaleidoscope
Report on Reports
2002

PKAL asserts that the most important attribute of strong undergraduate programs is a thriving "natural science" community, an environment where:

- *learning is experiential and steeped in investigation from the very first courses for all students through capstone courses for students majoring in science, technology, engineering and mathematics.*
- *learning is personally meaningful for students and faculty, makes connections to other fields of inquiry, is embedded in the context of its own history and rationale, and suggests practical applications related to the experience of students.*
- *learning takes place in a community where faculty are committed equally to undergraduate teaching and to their own intellectual vitality, where faculty see students as partners in learning, where students collaborate with one another and gain confidence that they can succeed, and where institutions support such communities of learners.*

— What Works: Building Natural Science Communities–Project Kaleidoscope, 1991.

September 2002

Friends and colleagues:

For the past several years, we have prepared an annual report on activities within Project Kaleidoscope. Through those reports we shared lessons learned from the experiences of leaders and participants involved in PKAL activities directed toward strengthening learning for undergraduate students in science, technology, engineering, and mathematics (STEM). This year we take a different tack. Rather than a summary of outcomes from the PKAL Summer Institute or activities engaging the PKAL Faculty for the 21st Century network, we have prepared a ***report on reports.***

Here you will find an analysis of and recommendations from a selection of influential reports since the mid-1980's that have set the stage for and shaped efforts to transform undergraduate STEM. We hope in reviewing these pages you will note what has become clear to us in assembling this document:

- the rationale for strengthening undergraduate STEM programs has been extensively, elegantly, and persuasively argued
- what needs to be done has been clearly articulated, with recommendations that are convincing in their specificity and feasibility
- what has been accomplished to date sets the stage for concerted action, now and into the future
- there are many challenges and opportunities yet to be addressed.

Our intent in submitting this *report on reports* to the community is to initiate a more intentional look at the future of undergraduate STEM. Our hope is that it serve as a catalyst for discussions within departments and across institutions and as a checklist at the national level about immediate priorities for action.

There are many more reports– just as significant– on our shelves and yours. Over the years, many of these reports have spurred thoughtful reflection that led to creative action on campuses and within the larger community of stakeholders. The challenge now is to consolidate our advances. We must collaborate more effectively in moving toward sustainable transformation of the STEM learning environment for our nation's 14 million undergraduate students. Perhaps the elegant words of the NSTC report say it best, *…it is a fundamental responsibility of a modern nation to develop the talent of all its citizens.*

The efforts of Project Kaleidoscope in the coming months and years will continue to focus on leadership for institutional transformation. We look forward to working with you toward that end.

Sincerely,

Jeanne L. Narum, Director
Project Kaleidoscope

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FOREWORD

This *report on reports* presents valuable perspectives on the past, present, and future of undergraduate programs in mathematics, technology, and the various fields of science and engineering.

For one we see a remarkable consistency of vision in these seventeen years of reports– one that is not modest and that calls for more than tinkering around the edges. The vision is of an environment in which all American undergraduates have access to learning experiences that motivate them to persist in their studies and consider careers in these fields; it is of an environment that brings undergraduates to an understanding of the role of science and technology in their world. It is a vision that calls for attention to practices and policies that affect shaping the curriculum and building the human and physical infrastructure to sustain strong programs. It is a vision that calls for collective action.

The consistency of vision is notable, in part, because of the diversity of sponsors– from government agencies and formal task forces of national associations to informal working groups such as those convened by PKAL. Certainly, the similarities derive from a common conviction of the authors that current and anticipated national needs can be addressed only by strengthening the learning of students– at all levels. The consistency also proceeds from the fact that these reports were shaped by the experiences of visionary leaders in the trenches– persons actively exploring how educational programs might serve 21st century students, science and society more creatively.

Another perspective we gain from reading these reports is of the progress made toward reform in the past decades. Campuses across the country are shaping and reshaping faculty roles, curricula, and spaces for science with an understanding of what inquiry-based, research-rich learning for <u>all</u> students means for that particular community in the context of 21st century challenges and opportunities.

These visions, recommendations, and the current momentum toward reform are only a foundation for the future. They provide a perspective both on what yet needs to be done and how to proceed. The process by which these reports were developed is one example of how to proceed: gathering leading agents of change to ask *what if* and *why not* about policies and practices within their spheres of influence and to define a vision to drive their planning and work. In looking at campuses effectively implementing the recommendations cited here, we see a similar approach: identifying and supporting a leadership cadre to explore and implement visionary plans that makes sense for their circumstance, mission and identity.

The literature on leadership speaks to the essential role that vision plays in the capacity of leaders to make a difference. The vision presented in these pages can be a resource for present and future generations of leaders. The recommendations cited here can become part of a leadership tool kit of ways and means to realize a vision. It is now time for all of us to take responsibility for leadership.

Everyone suffers when efforts for reform are piecemeal, faddish, and inconsistent; when such efforts address single segments of the community or one aspect of the scientific enterprise; when "big" science is in conflict with "little" science, and when research is in conflict with teaching. The challenge in strengthening undergraduate science and mathematics education is for all of the partners to join together on a commonly-agreed strategic plan and then to move quickly from analysis to action.
– *What Works: Building Natural Science Communities-Volume I*. Project Kaleidoscope, 1991.

THE NATIONAL SCIENCE BOARD

THE "NEAL REPORT"...1986

One lesson I have learned is that one must constantly educate administrators and non-science faculty about the special resource needs of scientific research. This is an on-going educational process that cannot cease. These needs include physical plant needs, computer and network needs and library needs.

A second lesson that I have learned is that the sciences have to stay visible in the life of the college and in the political arena of the faculty. Although the narrow world of our classroom and research lab can be all-absorbing, it is imperative that we interact formally and informally with faculty from other departments and with administrators. We must work at giving these colleagues a vivid picture of what we do, how we do it and the satisfactions and frustrations of doing it. If we do not have a strong presence on campus, resources will be spent elsewhere.

A third lesson is that changes cannot be expected to happen overnight, and that they require continued, respectful, but persistent pressure. A long-term commitment to effecting change and a long-term investment of effort in change is essential.
– PKAL F21 Statement, 2000.

BACKGROUND

The first major report in this series, commonly known as the "Neal Report," came from the National Science Board in 1986. The report outlined a *Role for the National Science Foundation and Recommendations for Action by Other Sectors to Strengthen Collegiate Education and Pursue Excellence in the Next Generation of U. S. Leadership in Science and Technology.* It emphasized that a strong undergraduate sector is critical if our nation is to:

...keep new ideas flowing through research; to have the best technically trained, most inventive and adaptable workforce of any nation; and to have a citizenry able to make intelligent judgments about technically-based issues.

The authors and sponsors of this report can be pleased at the responses from the community over the past fifteen years. Many of their recommendations (including those listed on the next page) have been or are being addressed, and there is now broader awareness that:

...undergraduate education occupies a strategically critical position in U. S. education, and [that a] resurgence of quality throughout higher education is essential to the well-being of all U. S. citizens.

But the continuing flood of reports, many of which outline similar recommendations based on a similar vision, is an unsettling sign of the work yet before us.

RECOMMENDATIONS

THE "NEAL REPORT"...1986

To the states

- Establish undergraduate STEM as a high priority, recognizing its essential importance to the economic, social, and cultural well-being of their citizens.
- Undertake responsive planning for the renewal of facilities, equipment, and other physical resources.
- Create commissions or task forces to determine conditions and needs of undergraduate STEM; set goals and recommend ways and means to achieve those goals.

To academic institutions

- Develop short- and long-range plans for the renewal of facilities, equipment, and faculties.
- Provide strong support for faculty updating and upgrading courses and curricula to meet needs of both majors and non-majors.
- Engage all faculty, including research faculty, in the instruction of undergraduates.
- Build collaborations with other educational institutions, including K-12, and with industry.

To the private sector

- Provide greater and more stable support to undergraduate STEM, including support for expanded partnerships.
- Increase corporate efforts to improve the public understanding of science and technology.

To federal agencies

- Involve undergraduate faculty and students in research activities, including providing incentives to contractors to include appropriate undergraduate research in their work.
- Develop a process of collecting and analyzing data that reveals national trends in undergraduate student achievement.

To the National Science Foundation or funding agencies

- Provide a forum for leaders from the public and private sector to consider current efforts to increase the investment in undergraduate STEM.
- Stimulate creative and productive activity in teaching and learning (and research on them) just as it does in basic disciplinary research.

The undergraduate years are critical for strengthening our nation's science and mathematics capacity. It is in college where future scientists and college faculty are recruited and prepared for graduate study; where our nation's elementary and secondary teachers, educators of America's youth, are equipped; and where tomorrow's leaders gain the background with which to make critical decisions in a world permeated by vital issues of science and technology. It is also at the undergraduate level where many able young people – particularly minorities and women – decide to discontinue their study of science and mathematics. The result is a serious loss of talent to the service of the nation, a loss that we cannot afford if we are to remain competitive in a global economy.
– *What Works: Building Natural Science Communities-Volume I.* Project Kaleidoscope, 1991.

SIGMA XI

AN EXPLORATION OF THE NATURE & QUALITY...1989

The success of the current national efforts to revitalize engineering, mathematics, and science instruction depends on the commitment and collaboration of a number of communities, including industry, schools, colleges, universities, government at all levels, and the public. Mostly, however, it depends on the faculty in our nation's schools, colleges and universities. The faculty...are the curriculum personified. The faculty, both individually and collectively, have considerable latitude in the curriculum content and in the instructional approaches used. Superior faculty motivate students to broaden and deepen their intellect, and aspire to higher achievements. Mediocre faculty dampen the enthusiasm of good students and stifle development of potential talents in others.

– *America's Academic Future: A Report of the Presidential Young Investigators*. National Science Foundation, 1992.

BACKGROUND

Sigma Xi, the Scientific Research Society convened a national advisory group to identify fundamental topics to chart policies for reshaping undergraduate STEM. Their 1989 report, *An Exploration of the Nature and Quality of Undergraduate Education in Science, Mathematics and Engineering*, is a direct and compelling statement:

Undergraduate programs exist in order to provide environments that encourage and enable students to accomplish something. These "somethings" are the missions of the programs. Just exactly what these missions are depends upon the perceptions of academic administrators and departmental faculty members of factors such as 1) the needs and goals of students, and 2) the needs and goals of society.

This focus on getting the mission in place is threaded throughout reports that emerged in the 1990's. Many also echo the Sigma Xi call for departments to set learning goals that reflect clearly the understanding of the nature of science, of engineering and of mathematics, the nature of knowing in these fields, and the symbiosis of science, engineering and mathematics. This report is explicit on the goals that should be set to ensure a quality undergraduate education, one that provides students access to:

- *instruction that generates enthusiasm and fosters long-term learning*
- *a curriculum that is relevant, flexible and within their capabilities*
- *a human environment that is intellectually stimulating and emotionally supportive*
- *a physical environment that supports the other three dimensions.*

That more and more departments have set goals for student learning, and that institutional leaders call for and support the development, implementation, and assessment of such goals is one valuable legacy of this report.

RECOMMENDATIONS

To Congress and the National Science Foundation

- Facilitate an open and forthright discussion and evaluation of the factors that make the reward system for excellence in undergraduate teaching noncompetitive with the reward systems for excellence in other professional activities.
- Facilitate entry and sustained professional development of women, underrepresented minorities and physically disabled individuals in the study and practice of STEM.
- Facilitate exchange of information among those developing innovative undergraduate curricula.

WHAT WORKS: BUILDING NATURAL SCIENCE COMMUNITIES...1991

After eighteen months of work, the first Project Kaleidoscope leadership cadre published a report in 1991. Entitled *What Works: Building Natural Science Communities*, it outlined a rationale for an action agenda based on their experience with what works. This early PKAL vision was of an environment in which learning is active, investigative and experiential, where the curriculum connects to the world beyond the campus and is steeped in the methods of research as practiced by professionals.

The report focused on four critical initiatives, relevant both then and now.

RECOMMENDATIONS

- Reform introductory courses in undergraduate STEM.

  A significant body of research and our own experience confirms that the first year of college is a critical drop-off point in the number of students in science and mathematics courses. Introductory courses can give first-year students the pleasure of discovery and the opportunity to construct a personal understanding of science and mathematics at a critical stage in their academic career.

- Support the integrated teacher/scholar role of undergraduate STEM faculty.

  Hands-on, discovery-based, laboratory-rich approaches require that teaching faculty be actively engaged in scholarship. Such faculty foster a culture that enhances the community of learners. They are often the most productive leaders in curriculum reform and laboratory improvement efforts, locally and nationally. Faculty active in scholarship are the most effective role models for students.

- Make disciplinary content and active learning central to the education of K-12 teachers in science and mathematics.

  The single most important determinant of what elementary and secondary students learn in science and math is how much their teachers know. Teacher preparation must include substantial, deep exposure to the content of subjects they will eventually teach.

- Develop partnerships focused on strengthening undergraduate STEM.

  Each sector of the science and mathematics community has a unique contribution to make in addressing national goals. We can accomplish more by working together than by working alone.

The health of the academic research enterprise rests on several factors that are mutually dependent and reinforcing. State-of-the-art facilities and equipment influence what research will be done and how productive it will be. And the environment in which scientists work is critical to recruiting new faculty and retaining them, thus ensuring the availability of sufficient numbers of future scientists and engineers.

Inadequate facilities, when combined with other pressures on investigators, such as increased difficulty in finding support for their research, are discouraging many young people from beginning careers in science and engineering. This failure to meet the nation's need for highly trained people will have potentially disastrous consequences for the U.S. economy and national security. The nation simply cannot continue to allow the academic infrastructure to erode. It is inextricably linked to our most precious resource– human capital.

– *Financing and Managing Academic Research Facilities*. GUIRR, 1990.

AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE

INVESTING IN HUMAN POTENTIAL...1993

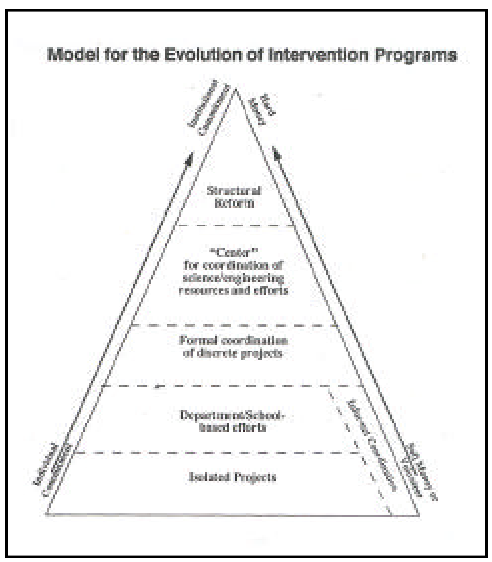
With the day coming in which white Americans of non-Hispanic origin will no longer be a majority of this country's population, the United States cannot hope to maintain its worldwide scientific and mathematical leadership if we continue to discard so much of our talent. If more STEM departments would take to heart the notion that their job is not just to create science, but also scientists, and that they need to be drawing from all segments of society if they are to have an adequate pool to sustain their disciplines in the new century, then those efforts could go a long way toward addressing the problem. Pre-college intervention projects, in which college and university faculty work directly with pre-college students in programs designed to fan the students' interest in careers in science- and mathematically-based disciplines, can help feed the pipeline.
–PKAL F21 Statement, 2002.

BACKGROUND

Reviewing the 1993 report, *Investing in Human Potential*, is frustrating, a reminder of the ineffectiveness of efforts to increase the participation of women and underrepresented minorities in the study and practice of science & technology. It is especially disheartening because today the opportunities to be a contributing citizen and to have interesting productive careers increasingly depends on a person's scientific, technological, and quantitative literacy. Further, failure to attract underrepresented populations to the study of STEM leads to significant loss of talent in the service of the nation.

This report includes recommendations directed at the wide range of individuals and agencies that must take responsibility to intervene at appropriate stages. None of this will be inexpensive, but several of the recommendations directed toward institutions can be undertaken with existing resources, to set the stage for more extensive reforms. The editors point out:

> *...creating an atmosphere which promotes diversity among the science and engineering faculty and student body requires a focus on many aspects of both academic and social life on campus. [This] study suggests that the approach an institution takes toward creating an atmosphere for diversity may differ by institutional type. Regardless of the specific strategies to be used however, institutional commitment is the required first step.*



RECOMMENDATIONS

To academic institutions and departments

- Examine both the amount and type of financial aid received by science and engineering students by racial/ethnic group, by sex, and by physical disability. In addition, special consideration should be given to students who carry a heavy load of laboratory course work which requires more in- and out-of-class laboratory time. The nature of the science/engineering curriculum may make it difficult for students to put in adequate paid-work hours to supplement their financial aid.
- Reduce the rigidity of the science and engineering curriculum to allow "undecided" students, or those in other major areas of study, to switch into science or engineering studies.
- Undertake surveys of the accessibility and climate of your campus. Those institutions that have already conducted general access studies should initiate specific studies to examine access to science/engineering classrooms, laboratories, and equipment and intervention programs.
- Mount aggressive efforts to recruit and develop female and minority graduate students and postdoctoral students, and provide mentoring programs and general support for new female and minority faculty.
- Monitor carefully the progress of students, especially female and minority students and those with physical disabilities, to determine where attrition is occurring. Further, careful analysis may be warranted to determine the causes of those losses.

...careful reading of recent reports finds that the special needs of a growing population of students for whom English is a second language are not addressed. Perhaps the absence of discussion of this issue is just an oversight or that these proposals are broad in scope and cannot include detailed attention to 'special interest' groups. Whatever the reasons, this situation must be remedied if the goal of reform is to improve science instruction for all students and to increase minority participation in the sciences.

The role of language in the institutional process–and related issues such as culture and learning styles–must be taken into consideration with an increasingly multilingual and multicultural student population. And ways to address such matters in the sciences do not have to be invented de novo. In others words, considerable information is already available which deals with appropriate science instruction for college students who are still learning English; however, it is not found in places where college science faculty or science education 'reformers' normally look.

– *Teaching Science to Language Minority Students.* Judith W. Rosenthal, 1996.

NATIONAL RESEARCH COUNCIL

FROM ANALYSIS TO ACTION...1996

Undergraduate education is faced with the challenge of teaching students the integrated relationship of disciplines across the curriculum.

...The functional connections among disciplines also can be powerfully illustrated by incorporating experiential learning opportunities into the classroom. Projects that apply skills and information being learned in class help students make connections with the real world around them. Collaborations with businesses, industry and the community through class projects, internships and field trips broaden student understanding of the material and the variety of areas for which it is important.

...In order for dramatic curricular change of this nature to occur on an institutional level, a commitment from the institution is necessary, not just from the faculty or students.
– PKAL F21 Statement, 2002.

BACKGROUND

The 1996 report *Analysis to Action* resulted from an extended study by the Committee on Education at the National Research Council. Their goal was to identify key questions and explore all facets of the undergraduate STEM community toward the end of establishing...*a common vision of what undergraduate preparation in these vital subjects should be, and how higher education can achieve that vision*. A convocation at the National Academy of Sciences was the culmination of the year-long effort; 300 reformers and supporters of reform gathered to distill from that study recommendations that would spur the larger community.

This PKAL *report on reports* is intended to be a resource for communities moving from analysis to action. Thus, in addition to presenting for your consideration key recommendations included in the NRC report, we also include a question and comments about one of the pressing issues now facing our society: preparing graduates for careers in an increasingly technological workplace.

Question: What are the best avenues for professional development for faculty who are involved with educating future members of the technical workforce?

Comment: Advisory councils from industry can help shape educational programs in colleges and universities. The education of future technicians highlights a major challenge facing higher education: placing content in context. Student and faculty internships in industry, industrial involvement in designing and teaching college courses, and cooperative projects in undergraduate education all promote continuous interaction between educational and industrial partners. An emphasis on flexibility and core competencies would help ensure that institutions of higher education balance broad education with specific training. Hands-on learning, project-oriented courses, distance learning, and the delivery of courses at industrial sites would tie learning to the application of knowledge. Inquiry capabilities, including problem solving, critical thinking, communication, and teamwork, are all basic to lifelong technical careers.

Faculty members and departments are responding to the new needs of the workplace with a variety of innovations. Close links between the offerings of different departments are enhancing understanding of the connections among subjects. Majors in some departments are doing senior projects grounded in real-world problems that instill skills they will need in their careers.

RECOMMENDATIONS

FROM ANALYSIS TO ACTION...1996

One recommendation emerged from all the others as conveying a fundamental conviction of the assembled group:

- All students should have access to supportive, excellent programs in STEM, and all students should acquire literacy in these subjects by direct experience with the methods and processes of inquiry.

This recommendation, though simply stated, is audacious in its implications. It looks to a future in which STEM education incorporates open-ended investigations in which students are fully engaged with the ideas and methodologies of the disciplines they are studying. It looks to a future in which many undergraduates get degrees [in these fields] not because they necessarily want to work in those fields but because those subjects are superb training for whatever it is they want to do. It looks to a future in which English majors, for example, emerge from college not fearful and distrustful of science and technology but familiar with their basic principles and outlooks– and in which science majors can express themselves fluently, both orally and in writing, as a result of the experiences they have in college.

Colleges and universities have been presented with a unique opportunity to remake undergraduate education in STEM. The reassessment of national goals set in motion by the end of the Cold War, the demographic changes occurring in the country, the financial constraints affecting many institutions, and the rapidly growing influence of new technologies have contributed to an environment in which fundamental principles are being reexamined. This reexamination will inevitably change higher education. Toward what end depends on the decisions that colleges and universities make today and on the support they get to carry out those decisions in the future.

What makes some colleges and universities more "transforming" than others? We identified four factors that shaped the successful course of change:

- *Transforming institutions had propitious external environments and internal conditions. ...these institutions also had the freedom to respond creatively and to remain in control of their futures.*
- *Change leaders...recognized the importance of anchoring change in cherished academic values, created a climate of trust, shared the credit, and looked at change from a long-term perspective.*
- *Leaders helped people develop new ways of thinking...as well as different practices, structures, and politics. They provided opportunities for people to reflect on the assumptions, values, and habits that supported the status quo.*
- *Leaders paid attention to the change process and adjusted their actions in response to what they learned. They thought about who was involved and why, and what changes made sense to whom. Instead of discounting dissent, they listened to and learned from it.*

–*On Change V*. American Council on Education, 2001.

NATIONAL SCIENCE FOUNDATION

SHAPING THE FUTURE...1996

The year is 2009.

STEM education has been changing and is continuing to change. Relative to the year 1999, many of these changes are ones that were mostly expected, and a few are ones that were mostly unexpected. As expected by most, technology plays a larger role in education than a decade ago.

As expected by only a few, a rather large share of undergraduate STEM education has come to have an ethical, or value–based, component. Basic and especially applied science is no longer viewed as being value–free. As science educators, we are now also beginning to think about how to get those who are not scientifically literate to be a part of the solutions to problems facing our society. This is leading us to push for the integration of the sciences more visibly into the general liberal arts curriculum, which might just be the biggest change we see in undergraduate STEM education in the next decade.
– PKAL F21 Statement, 1999.

BACKGROUND

...we can no longer be satisfied with incremental improvement in a world of exponential change...

This was the call to action that concluded *Shaping the Future: New Expectations for Undergraduate Education in Science, Mathematics, Engineering, and Technology*, a 1996 report from the National Science Foundation. The review committee analyzed several points of exponential change, from the perspective of new challenges within science and society since the time of the "Neal Report." This analysis served as a foundation for the wide-ranging recommendations made to the broad stakeholder community for immediate action.

Of particular note for our consideration here, *Shaping...*is one of the earliest of the major reports to carefully connect the dots between the quality of undergraduate STEM programs and the strength of the economy within an increasingly global community. It anticipates 21st century concerns about how to ensure that college graduates have the sophisticated skills– are literate scientifically, technologically, and quantitatively– necessary to be contributing citizens with satisfying careers.

Presciently, this report also speaks about the pressures on higher education because of rising expenditures and growing financial constraints, and that:

...these financial restraints present major challenges and reduced opportunities in many institutions to try innovative approaches to undergraduate instruction while placing a premium on productivity-enhancing changes.

But, as illustrated by the recommendations from *Shaping...*presented on the opposite page, there are many incremental improvements that can be made at minimal cost, as a first step in strengthening learning in undergraduate STEM for all students– for example, setting measurable departmental goals for student learning.

RECOMMENDATIONS

To faculty

- Believe and affirm that every student can learn; recognize that different students may learn in different ways and with differing levels of ability; and create an environment in each class that both challenges and supports.
- Be familiar with and use the results of professional scholarship on learning and teaching.
- Build into every course inquiry, the processes of science (STEM), a knowledge of what STEM practitioners do, and the excitement of cutting-edge research.
- Devise and use pedagogy that develops communication skills, teamwork, critical thinking, and lifelong learning in each student.
- Build bridges to other departments, seeking ways to reinforce and integrate learning.

To departments

- Set measurable departmental goals in collaboration with other departments and with prospective employers for undergraduate learning that include clear expectations about what all students should learn in STEM courses.
- Provide a curriculum that engages and motivates the broadest spectrum of students, enabling every student to learn and providing reasonable flexibility for students to move onto or off various career-preparation paths without undue penalty.
- Create and support learning communities for students and faculty.
- Use instructional technology effectively.

To institutions

- Re-examine mission in light of needs in undergraduate STEM education.
- Hold accountable and develop reward systems for departments and programs, not just individuals, so that the group is responsible for effective student learning.
- Support faculty who effectively help students learn in hospitable environments that recognize student differences and that provide reasonable opportunities to address those differences.
- Ensure that there is a supportive climate across the campus for student learning, including sound academic advising and effective career development services.

The necessity for strengthening science education in the United States has been widely acknowledged. Although the most powerful argument for improving the science education of all students may be its role in liberating the human intellect, much of the public discussion has centered on more concrete, utilitarian, and immediate justifications. Ultimately, reform is more about people than it is about policies, institutions, and processes. And most people– not only educators–tend to change slowly when it comes to attitudes, beliefs, and ways of doing things. Sensible professionals do not replace their strongly held views and behavior patterns in response to fiat or the latest vogue; instead, they respond to developing sentiment among respected colleagues, to incentives that reward serious efforts to explore new possibilities, and to the positive feedback that may come from trying out new ideas from time to time–all of which can take years.

– *Science for All Americans*. American Association for the Advancement of Science, 1990.

REINVENTING UNDERGRADUATE EDUCATION...1998

From administration on down, institutions of higher education must recognize the roles that scholarship and research play in attracting high quality enthusiastic students. I have witnessed the positive effects associated with engaging undergraduates in independent research projects. For example, students develop an authentic passion for scientific discovery and realize that scientific thought truly does not require loads of memorization, but an understanding of major themes. And, yes, we need to make scholarship part of the tenure process at all institutions of higher education…the engagement of students in the process is vital to satisfying inquiring minds and must become integral to a student's education.
–PKAL F21 Statement, 2002.

BACKGROUND

The roles and responsibilities of research universities are outlined in one of the most significant reports emerging from and directed toward that sector of the academic community: *Reinventing Undergraduate Education: A Blueprint for America's Research Universities.* Published in 1998, this report is the work of the National Commission on Educating Undergraduates in the Research University, whose efforts are continuing through the Reinvention Center at SUNY-Stony Brook. Although the report speaks to research universities, their recommendations will resonate on campuses of all types. Moreover, the arguments and rationale for research universities to proceed from a clear vision of mission and identity are also a reminder that this is the fundamental first step in "…reinvention," at research universities and beyond.

Their recommendations are built around a concept of integrated education, which is introduced by discussion about the process of change. The report makes a compelling call for the redirecting of resources that will be required, including the redefinition of the teaching load:

…if guided research becomes an important component of undergraduate education, the professor may well conduct research and class simultaneously but in a very different format. The old definitions of workload will have to be replaced. Time-worn assumptions and practices cannot be allowed to prevent needed change in undergraduate education.

One valuable contribution of this report is the brief descriptions of "signs of change," those programs at research universities that can be adapted by their peers and the larger community as well.

RECOMMENDATIONS

Make research-based learning the standard

- Beginning in the freshman year, students should be able to engage in research in as many courses as possible.
- Beginning in the freshman year, students must learn how to convey the results of their work effectively both orally and in writing.
- Undergraduate must explore diverse fields to complement and contrast with their major fields; the freshman and sophomore years need to open intellectual avenues that will stimulate original thought and independent effort, and reveal the relationships among sciences, social sciences and humanities.

Remove barriers to interdisciplinary education

- Lower division courses should introduce students to interdisciplinary study.
- Academic majors must reflect students' needs rather than departmental interests or convenience.
- Customizing interdisciplinary majors should be not only possible but also readily achievable.

Use information technology creatively

- Planning for academic units, such as block-scheduled courses for freshman or required courses for individual majors, should include conscientious preparations for exercises that expand computer skills.
- Active exchange between units on campus and through professional meetings should encourage and inspire faculty to create new computer technologies for teaching and to share ideas about effective computer-based learning.

REINVENTING UNDERGRADUATE EDUCATION…1998

Two- and four-year colleges and universities should:

- *Eliminate the barriers of course transferability by articulating transfer agreements between two-year colleges and four-year institutions that are mutually established through open communication concerning specific course content and expectations.*
- *Reduce the cultural barriers and misconceptions between two-year colleges and four-year institutions by encouraging the exchange of faculty and facilitating STEM topical workshops.*
- *Increase the number of partnerships between two-year colleges and four-year institutions.*
- *Develop collaboratively a teaching track for M.S. and Ph.D. STEM students whose career goal is to teach at two-year colleges.*
- *Increase sustainable joint STEM professional development opportunities (co-teaching, teacher exchange, and others) by preK-12 institutions and two- and four-year colleges for full-time and adjunct faculty.*
  –*Investing in Tomorrow's Teachers: The Integral Role of Two-Year Colleges*. Report from an NSF Workshop, 1998.

GOVERNMENT-UNIVERSITY-INDUSTRY RESEARCH ROUNDTABLE

STRESSES ON RESEARCH...1998

BACKGROUND

The Government-University-Industry-Research Roundtable (GUIRR) at the National Research Council (NRC) initiated a series of meetings in the mid-1990's to illuminate the major sources of stress affecting the academic research and education community, and to identify possible remedies to specific concerns. One outcome from these meetings was the report, *Stresses on Research and Education at Colleges and Universities– Phase II of a Grass Roots Inquiry*, published in 1998.

One notable difference in this report from others cited here is that it followed a multi-year series of meetings and discussions on campuses across the country, and of convocations in Washington, DC. From these meetings there were many messages, including the recognition of a new urgency for restructuring institutional, state, and federal reward systems to recognize teaching in a manner more in balance with rewards for research excellence.

In reflecting on how insights from this inquiry can inform the work of those now shaping departmental and institutional visions, the following report excerpts are instructive.

...as a consequence of the changes taking place in society broadly, there is a need to rethink the way we are preparing a generation of students whose career paths likely will look very different from those of their mentors. A constructive approach to this issue is to provide students with a wider range of research experiences– perhaps by offering a research practicum in corporate or national labs, or by creating multi-authored dissertation tracks to the Ph.D.

...discussion revealed new vigor and heightened interest in the pervasive impact of information and communication technology, and of interactive media, on the role and the physical realities of universities, classroom instruction, and publication. [All] agreed that coming changes that are being driven by the information and communications revolution will be rapid, fundamental, pervasive and unpredictable. Some even emphasized that these technologies will change the very essence of the academic enterprise. If the university is envisioned as an information generating and information disseminating system– if everything we do, from scholarship to information storage and retrieval in libraries to teaching, has to do with the creation, transmission, or storage of information– then it follows that new technologies that redefine the nature of the research record, and the avenues for creating and modifying it, will change fundamentally the very essence of universities themselves.

The most important challenge for undergraduate education in the life sciences is to integrate a culture of research into the curriculum. As the pace of discovery continues to accelerate, teaching approaches that present a static pool of information are increasingly limited. In contrast, students who learn the logic of experimental design and data analysis are better prepared to assimilate new information and are more likely to be active participants.
–PKAL F21 Statement, 2002.

BACKGROUND

BEFORE IT'S TOO LATE...2000

Before It's Too Late was published in September 2000 by the National Commission on Mathematics and Science Teaching for the 21st Century, otherwise knows as the "Glenn Commission" after its chair, astronaut and former Senator, John Glenn. *Before It's Too Late* is the most recent of major national reports that call for action to transform K-12 science and mathematics education. This call is grounded in data from recent assessment efforts that reveal U.S. students are not succeeding in their study of science. In assessing the performance of students from forty-one countries, the 1995 *Third International Mathematics and Science Study* (TIMSS) reported that U.S. children were among the leaders in the fourth-grade assessment, but by high school graduation, they were almost last.

The TIMMS study identified characteristics of school systems in high-performing countries as having: i) a coherent vision of what all students in each successive grade should learn; ii) instruction delivered by teachers well-prepared in the subject and who have ready access to faculty development opportunities; and iii) an alignment between what is expected, taught, tested, and rewarded for students, teachers and schools.

The "Glenn Commission" made specific suggestions on how to reach these goals, and how to make the teaching profession more attractive for K-12 mathematics and science teachers. Their recommendations target the entire community– school boards, school administration, teachers, government, parents, higher education institutions, and business– recognizing that the reform of K-12 education cannot occur without the commitment of everyone.

Many of the challenges that face STEM leaders focus on pre-service teacher education.

...With the intention of...improving K-12 student achievement, policy reports regularly recommend a different approach to teacher preparation, because it has become increasingly apparent that no isolated college, department, or school district can provide the necessary depth of preparation that beginning teachers need. These reports argue that partnerships among colleges of education, colleges of arts and sciences, and public schools are needed for excellence in teacher preparation.
–PKAL F21 Statement, 2002.

RECOMMENDATIONS

To higher education institutions

- Work closely with area schools to identify existing and future needs for highly qualified K-12 mathematics and science teachers.
- Ensure that your program meets criteria for exemplary math and science teacher preparation and actively contributes to the knowledge base in support of these criteria.
- Collaborate with area school districts to ensure a quality induction process for new mathematics and science teachers.
- Emphasize recruitment strategies and provide incentives for eligible students to become science and mathematics teachers.
- Evaluate and track teacher performance following graduation and use this information to improve your mathematics and science teacher preparation programs.

NATIONAL RESEARCH COUNCIL

HOW PEOPLE LEARN…1999

I advocate incorporating the "essence" of science, along with whatever content is necessary in the context, into courses across the curriculum. Some subjects already provide logical opportunities for exposing students to scientific thinking: medical ethics or environmental economics, for example. But there are many more. In a political science course, an understanding of the nature of science would help students understand the frequent conflicts between scientists and policymakers. For journalism students, an exposure to the process of science would help them report and interpret scientific issues more accurately. And what about a literature course? Would an exposure to a biological understanding of the world enhance one's appreciation for literary treatments of the same world? I think so. What's more, this process would also bring benefits for science students and instructors as well. As we work to incorporate an appreciation for scientific thinking into other disciplines, we will also improve our understanding of the social context in which science is done, and that should make us better scientists and better teachers.
–PKAL F21 Statement, 2002.

BACKGROUND

How People Learn, a report published in 1999 by a committee established by the National Research Council, has a single focus: bringing research from advances in cognitive science into the work of shaping effective learning environments. It might be that, among all the documents reviewed here, this publication alone could drive decisions of reformers in the next decade in the most productive ways. Although, in the end, it speaks to each of the stakeholder communities, the value of this report is that its starting point is the process of learning, and all discussions, conclusions, and recommendations are derived therefrom.

Most faculty understand what works for student learning primarily by analyzing their own experiences– from when they were students and from the achievements or lack thereof of students in their classrooms and labs. This is the case even as educators from John Dewey on have called for attention to how people learn. This NRC publication builds a 21st century educational philosophy on a foundation of solid research, documenting that there are more effective approaches than diligent drill and practice. In the past 30 years, research has generated new conceptions of learning in five areas:

1. memory and structure of knowledge
2. analysis of problem solving and reasoning
3. early foundations
4. metacognitive processes and self-regulatory capabilities
5. cultural experiences and community participation.

If the integration of research and education is one of the goals of 21st century reformers, *How People Learn* is an essential roadmap to make that happen. It will also be a valuable resource for colleges and universities wrestling to use the tools of technology most creatively in the service of student learning. It shows how decisions made at each stage of shaping the learning environment– including incorporating technologies– will be more felicitous over the long term when they are based on scientific research that has *implications for the design of formal institutional environments* and is designed to *explore the possibility of helping all individuals achieve their full potential.*

Build learning environments with tools of technology

- Bring real-world problems into classrooms through the use of videos, demonstrations, simulations and Internet connections to concrete data and working scientists
- Provide "scaffolding" support to augment what learners can do and reason about on their path to understanding. Scaffolding allows learners to participate in complex cognitive performances, such as scientific visualization and model-based learning, that are more difficult or impossible without technical support.
- Increase opportunities for learners to receive feedback from software tutors, teachers, and peers; to engage in reflection on their own learning processes; and to receive guidance toward progressive revisions that improve their learning and reasoning.
- Build local and global communities of teachers, administrators, students, parents, and others interested in learning.
- Expand opportunities for teachers' learning.
- Conduct extensive evaluation research through both small-scale studies and large-scale evaluations, to determine the goals, assumptions, and uses of technologies in classrooms and the match or mismatch of these uses with the principles of learning and the transfer of learning.

EPILOGUE: Developments from a diverse array of sciences have altered conceptions of learning in fundamental ways. The cumulative knowledge from these sciences delineates the factors that contribute to competencies in reasoning and thinking. The new developments are ready to take learning science another step and focus on processes that promote learning with understanding.

There is a common fallacy of educational thinking that asserts that a liberal education is synonymous with the humanities. Nothing could be further from the truth. A liberally educated mind is precisely one that has composed itself sufficiently to experience the thrill, the deeply satisfying, rousing excitement, of seeing a mathematical solution move to the same kind of inevitable, economical fulfillment of itself as does a great sonnet; one that can derive the same pleasure from discerning and absorbing the nature of a pattern in matter as in a painting or in market behavior; that can find the same satisfaction in applying the results of technological experimentation as in applying any other kind of knowledge, for the betterment of humankind. The imagination, the capacity to discover or impose a new shape with the mind, is the province of science as much as of any other form of human investigation. And the power of the imagination is finally the energy tapped and transformed by an education.

– *A Free and Ordered Space: The Real World of the University.* Bartlett A. Giamatti, 1988.

ENSURING A STRONG U.S. …2000

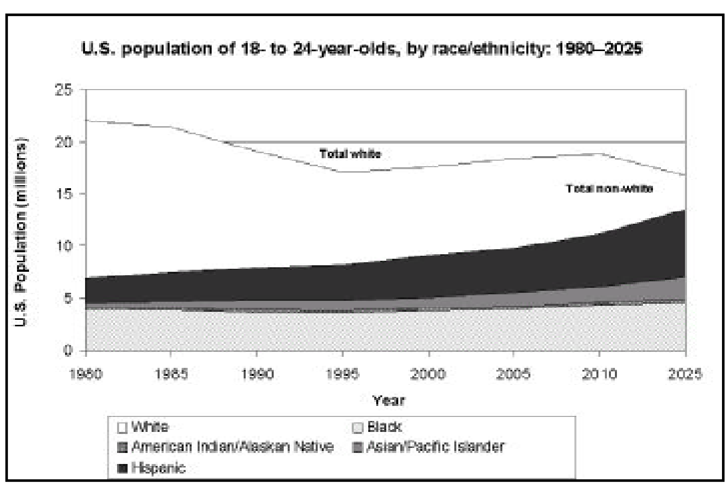
BACKGROUND

Ensuring a Strong U.S. Scientific, Technical, and Engineering Workforce in the 21st Century is the 2000 report of a multi-agency working group developed in 1998 under the auspices of the National Science and Technology Council (NSTC) Committee on Science. The task of this interagency working group was to assess the ST&E workforce in light of demographic and socioeconomic changes and to examine agency programs designed to increase the participation of women, minorities and persons with disabilities in the ST&E workforce. A major workshop in 1998, held in conjunction with the National Science Foundation, helped form the basis for the final report.

The working group agreed that ST&E workers are essential contributors to both the private and public sectors and that it is prudent to examine, to the extent possible, what actions will ensure that the nation has an adequate ST&E workforce in the 21st century.

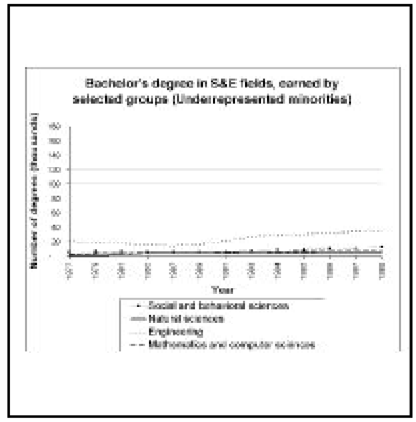
Historically, non-Hispanic white males have made up a large fraction of US scientists and engineers. However, it is projected that this portion of the US population will decrease significantly this century. Hispanic and African-American population groups form a much smaller part of the ST&E workforce, but their populations are expected to increase markedly in the next 50 years. This implies that the ST&E fraction of the total workforce may decline if the relative participation rates of these different groups remain at their present values. If a strong ST&E workforce is to be ensured, it is imperative that members of all groups participate at increasing rates.

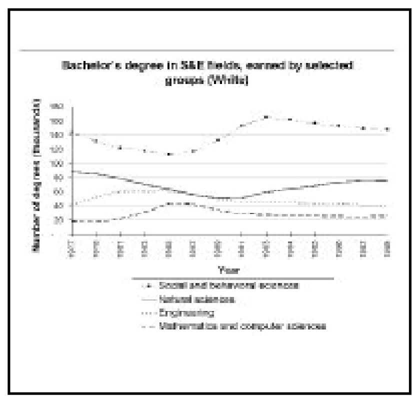
We need to actively reach out to our communities and let them know that we are here. We need to advertise and promote science as a critical commodity in our society and that we need people to practice it as a craft. We may do such simple things as volunteer in local K-12 schools, host teacher workshops, and present summer science camps for students. We can also provide expertise to our community and be a valuable resource for demonstrating how cutting edge scientific technology is helping to change the world. We must network to build scientific communities with broad representation and energetic participants. We want our scientific role models to portray a positive attitude toward science and for their excitement to be contagious. Indeed, the future of science lies in the hands of these leaders who are committed to finding progressive solutions to problems and who can lead with a strong, positive presence.
–PKAL F21 Statement, 2002.



To federal agencies

- Evaluate how the wide range of federal programs can enlarge the ST&E talent pool by encouraging greater participation of all ethnic and gender groups. Consistent with the Government Performance and Results Act, an important criterion for support of these programs should be their effectiveness in promoting a strong 21st century ST&E workforce. Agencies should expand or add programs that effectively overcome barriers such as the transition from one educational level to the next and that address student requirements for financial resources. Where appropriate they should work in concert with the private sector.
- Support research on barriers to full participation of underrepresented ethnic and gender groups. The federal government should take the lead in fully understanding the dimensions of the ST&E human resources challenge and in raising the results of research to the attention of all stakeholders to promote future action.
- Enhance the dialogue on integration of research and education, and develop a national dialogue on barriers to participation with private industry, academe, local government, and community leaders, as well as women, minorities, and persons with disabilities.
- Establish and oversee the maintenance of an Internet site that provides information on ST&E workforce-related programs.
- Foster cooperation among institutions, such as partnerships and networks. Examples include partnerships between minority serving institutions and research universities to enrich the research experiences of staff and students; public-private partnerships; and networks or partnerships in a state or region.
- Reward exemplary efforts to increase inclusiveness and provide workforce opportunities.
- Increase diversity within an agency's own scientific and technical workforce and encourage grantees and contractors to promote diversity.





* Note: Graph data from *Science & Engineering Indicators–2002*. National Science Foundation, 2002.

U.S. COMMISSION ON NATIONAL SECURITY

ROAD MAP FOR NATIONAL SECURITY…2001

One of the most profound changes we have seen during the 20th century is the formation of a global community. In a time when communication and travel is so easy, countries are uniting, and corporations are becoming global, it makes sense that we should incorporate in our curricula the practice of collaboration with other institutes.
…This [collaboration] could take the form of joint research projects,…or laboratories designed to receive and pass on information. Students would gain experience in relating many different concepts to solve a single problem. With technological ability increasing while financial resources dwindle at many undergraduate institutions, the ability to give our undergraduates a meaningful educational experience will require the efficient use of institutional resources as well as an innovative approach to teaching.
–PKAL F21 Statement, 1999.

BACKGROUND

The U.S. Commission on National Security/21st Century, otherwise known as the "Hart/Rudman Commission" was established in 1998. *Road Map for National Security*, their 2001 report, is a blueprint for reorganizing the national security structure so to achieve organizational competence to creatively and effectively address such new and serious issues as globalization, information technology, and the rapid ascendance of free-market economies and democracies. The report concludes that, despite the end of the Cold War threat, *America faces distinctly new dangers, particularly to the homeland and to our scientific and educational base.*

The earlier "Sputnik" days of space exploration galvanized attention on the need for a strong undergraduate STEM community to serve the national interest. The current position of the United States in an increasingly interconnected, technologically dependent global community once again challenges us to examine the strength of our educational system.

…the inadequacies of our systems of research and education pose a greater threat to U.S. national security over the next quarter century than any potential conventional war that we might imagine. American national leadership must understand these deficiencies as threats to national security. If we do not invest heavily and wisely in rebuilding these two core strengths, America will be incapable of maintaining its global position long into the 21 st century.

The report closely links educational goals to national goals.

Educational goals

- *The American educational system needs to produce significantly more scientists and engineers, including four times the current number of computer scientists, to meet anticipated demand.*
- *More than 240,000 new and qualified science and mathematics teachers are needed in our K-12 classrooms over the next decade (out of an estimated 2.2 million new teachers).*
- *Levels of math, science, and technology literacy, need to be raised throughout our society. Core secondary school curricula should be heavier in science and mathematics, and should require higher levels of proficiency for all high school students.*
- *More rigorous achievement goals in science and math are making both American teachers and students accountable for improvements. Science curricula, in particular, must be better designed to teach science for what it is: a way of thinking and not just a body of facts. If testing and evaluation methods for science education better reflect the reality of science as a discovery-based rather than as a fact-based activity, it would be easier to reform curricula in an appropriate fashion as well.*

To federal agencies

- Adopt a new National Security Science and Technology Education Act to fund a comprehensive program to produce the needed numbers of science and engineering professionals as well as qualified teachers in science and math. This act should provide loan forgiveness incentives to attract those who have graduated and scholarships for those still in school and should provide these incentives in exchange for a period of K-12 teaching in science and math, or of military or government service. Additional measures should provide resources to modernize laboratories in science education, and expand existing programs aimed at helping economically-depressed school districts.

- Establish and fund a National Math & Science Project to provide additional support for continuing professional development. All fifty states should also fund professional enrichment sabbaticals of various durations for science teachers and should do so wherever possible in concert with local universities, science museums, and other research institutions.

- The President should direct the Department of Education to work with the states to devise a comprehensive plan to avert a looming shortage of quality teachers. This plan should emphasize raising teacher compensation, improving infrastructure support, reforming the certification process, and expanding existing programs targeted at districts with especially acute problems.

- Devise a targeted program to strengthen the historically black colleges and universities in our country.

…fifteenth in the series of biennial Science Indicators reports, Science and Engineering Indicators–2002 was designed to provide a broad base of quantitative information …on the scope, quality, and vitality of the nation's science and engineering enterprise [including] public attitudes and understanding of science and engineering…

In general, most Americans feel that they are not well informed about S&T issues. In fact, for all issues included in the…survey, the level of feeling well informed was considerably lower than the level of expressed interest. For example,… nearly half of the respondents said they were very interested in new developments in science and technology. Yet fewer than 15 percent of respondents described themselves as very well informed about new scientific discoveries and the use of new inventions and technologies; approximately 30 percent considered themselves poorly informed. The NSF survey shows that people are feeling less informed than they used to.

Science and Engineering Indicators–2002. National Science Foundation, 2002.

ACCREDITATION BOARD FOR ENGINEERING & TECHNOLOGY

ACCREDITATION CRITERIA...2001

With the increased attention being paid to assessment of educational reforms and the increased political need for accountability, it is clear that assessment tools may soon become part of the requisite skill set for the practicing STEM educator/reformer. [Thus]...it is imperative that leaders within the STEM community extend their bridge-building efforts beyond the scope of the STEM community. As we build teams to create and develop interdisciplinary and multidisciplinary projects, we should also incorporate members whose strengths lie within the arena of educational assessment. In addition to strengthening the assessment of what we do, the validation of what we do to an audience outside of the STEM community also serves to strengthen our validity with the general populace.
–PKAL F21 Statement, 2002.

BACKGROUND

There are several welcome signs that current efforts toward reform are sustainable. This includes recent efforts of professional societies in setting formal criteria against which programs in their disciplines can be reviewed and in setting guidelines for the development of curriculum. Because these criteria and guidelines are developed by and for the community, there is a greater sense of ownership. With the society behind their consideration and adaptation, there is also an increased urgency that these criteria and guidelines are taken seriously. We have chosen to highlight the work of the Accreditation Board for Engineering & Technology in these pages, as one of the catalytic initiatives from a professional society toward the end of changing the culture for undergraduate learning.

It is important to point out however, the remarkable congruence in this generation of reports and recommendations in regard to issues such as faculty review and tenure policies, discovery-rich curriculum, etc. In formal statements from societies ranging from the American Psychological Society to the Society for Computer Science Education to those from ABET, we find agreement on goals for student learning, as well as on the departmental and institutional conditions needed to ensure that those goals are attained. One value of this growing agreement between and among disciplinary communities is the potential for collective action at the campus level. When different departments understand how similar are their goals for program outcomes and of their plans for assessing progress toward those goals, everyone's work will proceed more efficiently and productively.

Materials from ABET suggest criteria that could be generalized and/or that provide a platform from which broader campus conversations about visions for student learning could proceed.

The ABET materials are also explicit in regard to assessment processes that lead to documented results, requiring evidence that the results of that assessment be applied to the further development and improvement of the program. The assessment process must demonstrate that the outcomes important to the mission of the institution and the objectives of the program, including those listed above, are being measured.

RECOMMENDATIONS

ACCREDITATION CRITERIA...2001

Each engineering program for which an institution seeks accreditation or reaccreditation must have in place:

- detailed published educational objectives that are consistent with the mission of the institution and these criteria
- a process based on the needs of the program's various constituencies in which the objectives are determined and periodically evaluated
- a curriculum and processes that ensure the achievement of these objectives
- a system of ongoing evaluation that demonstrates achievement of these objectives and uses the results to improve the effectiveness of the program.

Engineering programs must demonstrate that their graduates have (selected):

- an ability to apply knowledge of mathematics, science, and engineering
- an ability to design and conduct experiments, as well as to analyze and interpret data
- an ability to function on multidisciplinary teams
- an understanding of professional and ethical responsibility
- an ability to communicate effectively
- the broad education necessary to understand the impact of engineering solutions in a global and societal context
- a recognition of the need for and an ability to engage in lifelong learning
- a knowledge of contemporary issues.

- *Students will demonstrate familiarity with the major concepts, theoretical perspectives, empirical findings and historical trends in psychology.*
- *Students will understand and apply basic research methods in psychology, including research design, data analysis, and interpretation.*
- *Students will respect and use critical and creative thinking, skeptical inquiry, and, when possible, the scientific approach to solve problems related to behavior and mental processes.*
- *Students will be able to weigh evidence, tolerate ambiguity, act ethically, and reflect other values that are the underpinning of psychology as a discipline.*
- *Students will be able to communicate effectively in a variety of formats.*
- *Students will recognize, understand and respect the complexity of sociocultural and international diversity.*
- *Students will develop insights into their own and others' behavior and mental processes and apply effective strategies for self-management and self-improvement.*

–*Undergraduate Psychology Major Learning Goals and Outcomes.* American Psychological Association, 2002.

AFTERWORD

This *report on reports* has several purposes, to:

- remind those familiar with these visions and recommendations of their continued applicability to the work of leading agents of change
- alert emerging leaders within stakeholder communities to the richness of visions and the relevance of recommendations already on the table
- provide a set of benchmarks against which individuals, institutions, associations, and agencies can determine the clarity of their vision and the credibility of their agendas for action
- set the stage for the next generation of reports that capture both the experiences of those taking these recommendations seriously and– perhaps more important– the work of those identifying and addressing new challenges facing our society.

We hope people read this report with pencil in hand, marking the themes and issues already being addressed within their community and those that might need more concerted action, short- or long-term. We hope also that this publication sparks much dialogue within departments and at the institutional level, in disciplinary societies and educational associations, and perhaps in national or regional gatherings of educators, policy makers, and/or other supporters.

A persistent theme in this diverse set of reports is the call for collective action. Dialogue with colleagues and peers is one step toward that end. But collective action is more than talking together; it is taking responsibility for the active sharing of ideas and materials– building on, connecting to, and enhancing the work of others. We must find a better balance between the need for individuals to "own" a new approach (from a nascent idea through final implementation) and the need for more expedient action that comes from learning about and adapting the work of others. The time is too short and the task too great for individuals or institutions to work in isolation.

We must also find a way to identify and bring new voices into the dialogue. There are faculty and institutions exploring at the edges, leading the undergraduate STEM community into a world that is more interdisciplinary, more global, more technologically-connected, more dependent on the scientific and quantitative literacy of citizens. There are also individual and institutional leaders developing models of effective practices that serve the increasing diversity of backgrounds and aspirations of students coming to our campuses, as well as the growing demands of our nation's high-tech workforce. Perhaps most important, we need to capture the experiences of campuses that have established programs that reflect a specific vision: that the richest educational experience for undergraduate students is one that connects the study of science and mathematics to learning in all disciplines, an essential part of the 21st century experience of learning. We need mechanisms to provide a public forum for these emerging agents of change so their visions and experiences drive the next generation of recommendations.

The PKAL Faculty for the 21st Century is a network of faculty in undergraduate STEM, identified by a senior administrator on their campus because of their leadership capacity. From the first Class of 1994, there are now over 1200 PKAL F21 members, many now in positions of leadership on their campus and in national professionals associations. Each year, F21 members are invited to submit a personal statement on leadership in the work of reform; the F21 sidebars presented in this publication are excerpts from that collection of statements.

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**Note: Reports unavailable on-line or through the publisher can be found by contacting the PKAL office.*

**Note: PKAL welcomes background information and recommendations from reports not mentioned in Recommendations for Action. Materials can be sent to the PKAL office and will be added to an ongoing Report collection available on the PKAL website.*

**Note: All report recommendations are direct quotes with minor edits for spacing considerations.*

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ABOUT PKAL

Project Kaleidoscope began in 1989 with support from the National Science Foundation to outline an agenda for reform of undergraduate programs in science and mathematics. From the beginning, Project Kaleidoscope (PKAL) has taken a kaleidoscopic perspective, giving attention to all facets of the undergraduate learning environment– what is learned, how it is learned and where it is learned. PKAL's initial report, *What Works: Building Natural Science Communities*, was presented at the first PKAL colloquium at the National Academy of Sciences in 1991. Since that time, nearly 4,500 individuals from over 850 colleges, universities and professional organizations have participated in one or more PKAL activity, primarily workshops that continue to be supported by NSF. A significant focus of PKAL is fostering leadership within undergraduate STEM. With support from the ExxonMobil Foundation, PKAL is identifying and supporting faculty who, at an early career stage, are taking responsibility for leadership on their home campus and at the national level. There are over 1200 PKAL Faculty for the 21st Century, representing campuses across the country. Support for local leadership teams also comes through a consultant program supported by the W.M. Keck Foundation, which provides advice to campuses implementing an agenda for action developed at a PKAL event. With support from FIPSE, PKAL is building local, regional, and virtual networks which advance efforts in developing cadres of leaders at the institutional and national levels. Increasingly, the PKAL web site is a significant vehicle for dissemination about the work of PKAL and others dedicated to building and sustaining a strong undergraduate STEM community.

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