TRANSFORMING AMERICA'S SCIENTIFIC AND TECHNOLOGICAL INFRASTRUCTURE

Recommendations for Urgent Action

Project Kaleidoscope ◆ 2006
Report on Reports II

PROJECT KALEIDOSCOPE

Suite 803
1730 RHODE ISLAND AVENUE, NW
WASHINGTON, DC 20036

Phone: 202-232-1300
Fax: 202-331-1283
Email: pkal@pkal.org
http://www.pkal.org

PROJECT KALEIDOSCOPE PHASE IV
is supported by grants from

The National Science Foundation
Directorate for Education and Human Resources
Directorates for Biological Sciences and for Mathematical and Physical Sciences
Directorate for Social, Behavioral & Economic Sciences— Office of International Science & Engineering

The ExxonMobil Foundation

The W.M. Keck Foundation

PROJECT KALEIDOSCOPE (PKAL) is an informal national alliance dedicated to: exploring and defining what works in undergraduate science, technology, engineering and mathematics (STEM); disseminating effective practices through workshops, institutes, publications, real and virtual networks; and supporting their widespread adaptation.

January 2006

Dear Friends and Colleagues:

In 2002, PKAL presented its first *Report on Reports*, analyzing a selection of influential reports issued from the mid-1980's that had shaped efforts to strengthen undergraduate learning environments in science, technology, engineering, and mathematics (STEM) over a seventeen year period. The audience for that 2002 publication was primarily leaders taking responsibility for the quality of STEM learning in the nation's colleges and universities; the intent was to provide ideas and recommendations to inform and advance their work, and to spotlight the potential for collective action.

This 2006 PKAL *Report on Reports II* is modeled after its predecessor, with some significant differences:

- all of the nearly 20 reports cited, briefly or at length, have been issued in the last 36 months, reflecting an increasing concern at the national level and within academe about America's present and future capacity to be a world leader in innovating and applying scientific and technological advances to address critical societal problems. An array of groups that represent a broad spectrum of American society has expressed concern about this situation, including business and government groups, professional societies, foundations, academics, and private-public partnerships operating at the national level.

- the arguments and recommendations presented are "in their own voice," with short background statements to establish the context.

- the intended audience is the entire community of stakeholders: those responsible for budgets, policies and programs that affect research and education in STEM fields at the national, state and local level; those responsible for the quality of STEM research and education in America's educational institutions; those potential employers of STEM graduates; and all citizens in a society in which science and technology have a significant impact on most aspects of our lives.

PKAL's *raison d'etre* is strengthening undergraduate STEM. Yet from the reports cited here (and from the others that seem to be issued daily) what is urgently needed is fundamental change of the entire system. Short-term, piece-meal, sector by sector, underfunded and uncoordinated efforts will not move America confidently and creatively forward in the next, challenging decades of the 21st century.

We hope this publication helps to spark and inform such fundamental change.

Sincerely,

Jeanne L. Narum
Director

TABLE OF CONTENTS

RECOMMENDATIONS FOR URGENT ACTION

Focus on students now in the pipeline

- support those students demonstrating promise for success in the study of science and mathematics as they enter into and pursue undergraduate studies
- give each undergraduate the opportunity for personal experience with inquiry-based learning that brings him or her to a deep understanding of the nature of science, the language of mathematics, the tools of technology
- extend research opportunities beyond the classroom and campus
- capitalize on and celebrate the growing diversity of students in American classrooms.

◄
Ownership of student achievement must be community property, with wide involvement of all stakeholders. To cultivate ownership and accountability is to cultivate for the long-term.

—American Association for the Advancement of Science. *A System of Solutions: Every School, Every Student*. 2005

Focus on the future workforce

- connect student learning in STEM fields to the world beyond the campus, so students appreciate the relevance of their studies and consider careers that use the skills and understandings gained from study in these fields
- build regional collaborations of academe, business, and civic groups working to ensure a steady stream of graduates well-prepared for the 21st century workplace, as well as to be responsible citizens in our "flat world"
- respond to contemporary calls for interdisciplinarity by nurturing and rewarding faculty who make the kind of cross-discipline connections they hope their students will make.

◄
At the heart of interdisciplinarity is communication— the conversations, connections, and combinations that bring new insights to virtually every kind of scientist and engineer.

—National Academy of Sciences. *Facilitating Interdisciplinary Research*. 2004

Focus on innovation for the future

- be adventurous in exploring opportunities to strengthen student learning in the STEM fields and in piloting new ideas, tools, and approaches to keep the work of transforming student learning at the cutting edge
- set benchmarks (2010, 2015, 2020) against which action plans can be shaped and progress measured, at the local, regional, and national levels.

◄
Higher education must redesign itself.... Education must be engaging, flexible, and interactive. Forward-thinking institutions that can lead the way must pioneer innovative new efforts and become champions of redesign and learning.

—Business Higher Education Forum. *A Commitment to America's Future: Responding to the Crisis in Mathematics and Science Education.* 2005.

INTRODUCTION

Barriers and challenges to changing the system:

- insufficient investment of resources to foster the professional training and education necessary to maintain a sustainable workforce that adapts to changing national dynamics
- organizational barriers that create competitive instead of cooperative environments among departments and organizations
- cultural differences between disciplines and agencies
- lack of innovative approaches in education
- scientific disciplines are too compartmentalized and tend to focus research on disciplinary interests
- hostility to 'disruptive' change to the status quo...can inhibit acceptance and support of new approaches.

—*Adapted from* National Institutes of Health, National Science Foundation, et al. *Conference on Research at the Interface of the Life and Physical Sciences: Bridging the Sciences.* 2005

The reports cited in these pages present specific recommendations for immediate action by one or many of the stakeholder communities: educational and business leaders, politicians and parents, staff of public and private funding agencies. The highlighted "calls to action" are one beginning point from which individuals and institutions can respond to the challenges expressed so clearly, particularly in the national reports in Part I. Some short-term benefits surely would accrue to students, science and society if the individual recommendations were adopted and implemented in 2006 by individuals, organizations, and institutions.

But the need for a transformation of the system that will be sustainable over the long-term is the real message of these reports. Collectively they press the point that the challenges are so pressing they require a direct, coordinated, and coherent response from the community of stakeholders. What they call for is the transformation of systems, whether the system is:

- a single STEM disciplinary department at a college or university looking to achieve a robust learning environment that ensures the persistence and success of all students
- institutional and national policies undergirding efforts to develop a strong and innovative cadre of 21st century S&T professionals in schools, academe, and the workplace
- institutional and national policies focusing on students: who they are, how they learn, and what their preparation is for leadership in an increasingly technological, global, competitive society
- networks of citizens working with public officials, business and educational leaders to ensure a robust pre-K-16 science/mathematics (STEM) learning experience for all students— no matter their background or career aspiration
- regional partnerships of academic scientists and industrial partners introducing students to the world of the scientist/engineer as a means to motivate students to consider careers in an S&T field
- networks of leading scientists and engineers, across disciplinary or geographic boundaries, bringing 21st century science and technology into the undergraduate learning environment.

To achieve such transformed systems, we can begin by spotlighting, scaling-up and institutionalizing practices having documented success in building robust STEM learning environments for 21st century students, preK-20. Many examples of such programs and practices are described in the full body of these cited reports; other exemplars can be found in the work of pioneering agents of change around the country. That we do not have to begin with a blank slate is good news; the time is too short and the task too monumental to do otherwise. There are significant lessons learned from relevant reform efforts undertaken since the mid-1980's that offer direction as we respond to calls to build a nation of learners, a nation of innovators.

But building on what has worked yesterday and what is working today is not enough, if we are convinced that the authors of these reports are on target. The world of tomorrow they describe is already here. It is one in which the context of changing demographics, global competitiveness, scientific and technological advances (and more) calls for risk-taking initiatives to break systems apart and to put them together in ways that better serve students, science, and society over the next decade.

It is critical for each of us responsible for some small part of the larger system to understand how what we do affects the entire enterprise. Indeed, all of us making decisions— stakeholders with responsibility for individual parts of the system— about allocation and reallocation of public and private resources should be asking:

- does this initiative fit into America's emerging agenda to build a nation of learners, a nation of innovators, and a world-class science and technology workforce, and if so, how?
- can we evaluate the impact of this initiative, and thus, the return on our investment?

The broader vision of America's future presented in these pages is compelling, not only in responding to current challenges of an increasingly "flat world" in economic terms. Although the vision encompasses the character of the workforce and our relationship to global partners, at its core it speaks about "people." The vision is about the people needed to lead America with confidence into a future that, although uncertain, requires the same spirit of adventure, openness to discovery, and the agility and flexibility to deal with uncertainty as did past generations of leaders. How we respond to this 21st century economic and technological "Sputnik" will determine America's future.

The need is for structural change, from the schoolhouse to the statehouse…. Fundamental change. Structural change. The educational system must not only be better. It must be different.

—Business Higher Education Forum. *A Commitment to America's Future: Responding to the Crisis in Mathematics and Science Education.* 2005.

Effective programs never stop asking basic questions about processes and outcomes: 'Are we doing the job?'

—Building Engineering & Science Talent. *The Talent Imperative: Meeting America's Challenge in Science & Engineering,* ASAP. 2004

CALLS TO ACTION

▶ We (all stakeholders) must plan and invest for the long-term, recognize the multifaceted nature of this problem, and come together across all sectors to form a new social and economic compact to promote a national innovation-oriented culture.

COUNCIL ON COMPETITIVENESS

National Innovation Initiative Summit and Report: Thriving in a World of Challenge and Change. 2005

1. "The world is becoming dramatically more interconnected and competitive...
2. Where, how and why innovation occurs are in flux— across geography and industries, in speed and scope of impact, and even in terms of who is innovating.

The way forward is not to retreat or to re-trench. The way forward is to become more open, more experimental, and to embrace the unknown. We cannot turn inward, nor can we allow our institutions to become overly centralized, calcified and risk-averse.

... [T]he bar for innovation is rising. And simply running in place will not be enough to sustain America's leadership in the 21st century. Innovation itself— where it comes from and how it creates value— is changing." *(Pages 8 & 37)*

▶ We must focus, as quickly as possible, on...areas that affect the choices made by students now in the pipeline.

BUSINESS ROUNDTABLE, ET AL.

Tapping America's Potential: The Education for Innovation Initiative. 2005

"...Although numerous policy initiatives and programs are under way, none matches the coordinated vision, concentrated energy, attention and investment that emerged from the shock Americans faced when the Soviet Union beat the United States into space with Sputnik in 1957. We need a 21st century version of the post-Sputnik national commitment to strengthen [STEM] education. We need a public/private partnership to promote, fund and execute a new National Education for Innovation Initiative. It must be broader than the 1958 National Defense Education Act because federal legislation is only one component of a larger, more comprehensive agenda.

...If we take our scientific and technological supremacy for granted, we risk losing it. What we are lacking at the moment is not so much the wherewithal to meet the challenge, but the will. Together, we must ensure that U.S. students and workers have the grounding in math and science that they need to succeed and that mathematicians, scientists and engineers do not become an endangered species in the United States." *(Pages 7 & 14)*

THE NATIONAL ACADEMIES

Rising Above the Gathering Storm: Energizing and Employing America for a Brighter Economic Future. 2005

"[S]hort-term responses to perceived problems can give the appearance of gain but often bring real long-term losses. It is useful to return to the implications of a flat world and of the exportation of the nation's jobs. [Our] report emphasizes the need for world-class science and engineering— not simply as an end in itself but a principal means to creating new jobs for our citizenry as a whole in this global marketplace of the 21st century." *(Page 1-16)*

◄
We must increase our investment in the talent pool that serves America's S&T workforce: scholarships for potential K-12 teachers; competitive scholarships for citizens who are undergraduate STEM majors on U.S. campuses; increased support for outstanding early career researchers.

BUILDING ENGINEERING AND SCIENCE TALENT

The Talent Imperative: Meeting America's Challenge in Science and Engineering. 2004

"The message is clear. Today's relentless search for global talent will reduce our national capacity to innovate unless we develop a science and engineering workforce that is second to none….

The barriers that stand in the way of broadening the participation of the underrepresented majority are built into our homes, schools, workplaces, communities, and psyches. Most would have fallen decades ago if they were not deeply embedded in our institutions and our behavior. The challenge of removing them goes beyond the reach of any group, organization, or economic sector. It is a shared task for which there is no single point of accountability. The piecemeal efforts upon which we have relied have opened up opportunities for thousands, but have not produced change on the scale that is required." *(Page 3)*

◄
We must scale-up practices recognized as succeeding in nurturing, deploying and retaining the talent of under-represented groups in STEM fields.

BUSINESS HIGHER EDUCATION FORUM

Building a Nation of Learners: The Need for Changes in Teaching and Learning to Meet Global Challenges. 2003

"In the future, the livelihood of the individual will be even more dependent on skills and education with the increased need for all members of the workforce to be better skilled, better educated, lifelong learners…. 60 percent of future jobs will require training that only 20 percent of today's workers possess.

The lifelong learning skills and attributes…leadership, teamwork, problem solving, time management, self-management, adaptability, analytical thinking, global consciousness, and communications need to be firmly embedded in teaching at colleges, including community colleges, and universities. When evaluating courses, programs, and styles of teaching, educators need to address questions such as: How do programs improve student leadership abilities? What kinds of multidisciplinary courses enhance analytical thinking? What learning experiences can help students become aware of global concerns and responsibilities? How can course requirements and exams enhance communications skills, both oral and written?" *(Pages 13 & 15)*

◄
We must immediately support activities, that by 2010, give two generations of students the benefit of a higher education system that is more attuned to giving students the analytical skills, the learning abilities, and the other life-long learning skills and attributes needed to adapt to 21st century workplace realities.

COUNCIL ON COMPETITIVENESS

NATIONAL INNOVATION INITIATIVE SUMMIT AND REPORT. 2005

BACKGROUND

The Council on Competitiveness is a forum that sets an action agenda to drive economic growth, and for elevating national competitiveness to the forefront of national consciousness. In 2005, it convened a National Innovation Summit exploring the relationship between our nation's ability to compete in the global economy of the 21st century and to "unleash its innovation capacity."

The Summit's report significantly informs and advances discussions of key issues. Its most valuable contributions are: 1) to set "a nation of innovators" as the vision toward which efforts of all stakeholders can aspire; 2) to outline approaches for addressing the entire innovation "system," from the earliest educational opportunities to the range of public policies that lead to greater tangible support for students, for workers, and for the "entrepreneurial" community.

"Today, America finds itself at a unique and delicate historical juncture, shaped by two unprecedented shifts— one in the nature of global competition, the other in the nature of innovation itself:

- The world is becoming dramatically more interconnected and competitive. At the same time that economic interdependencies are growing, America is in the unfamiliar position of the world's sole superpower. It is important to recognize how novel this situation is historically, and what opportunities and dangers it holds— from rivals or potential rivals, to be sure, but perhaps even more from how we ourselves choose to handle this geopolitical reality.

- Where, how and why innovation occurs are in flux— across geography and industries, in speed and scope of impact, and even in terms of who is innovating. In many ways, the playing field is leveling, and the barriers to innovation are falling. Whenever such a shift occurs, there are always changes in how economies and societies work— including new ways of creating value and measuring success, and realignments of competitive advantage. In the 21st century, the pace of these changes will accelerate. To thrive in this new world, it will not be enough— indeed, it will be counterproductive— simply to intensify current stimuli, policies, management strategies and to make incremental improvements to organizational structures and curricula.

What will America do? Will we plan and invest for the long term, rather than just the next quarter, putting in place the talent pool, innovation capital and infrastructure necessary for continuing success throughout the 21st century? Will we recognize the multifaceted nature of this problem and come together across all sectors— business, government, labor and academia— to form a new social and economic compact?" *(Page 8)*

RECOMMENDATIONS

- "Universities should promote an innovation-oriented culture while maintaining a commitment to creating new knowledge at the frontiers of research. This culture should seed traditional technical studies with new exposure to methods for creative thinking and translating ideas into commercial applications. Tenure and promotion policies should give weight to teaching creativity, inventiveness and innovation. These changes may require reassessments of organizational structures and learning environments.

- Academic institutions should develop curricula specifically designed to teach innovation skills and support major changes in innovation learning. They should expand the use of experiential learning.

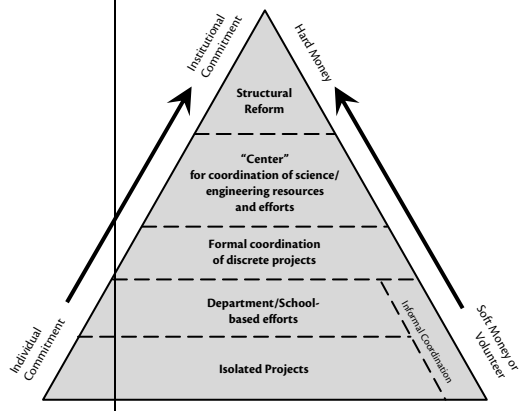
- Innovation Partnerships need to be created to bridge the traditional gap that has existed between the long-term discovery process and commercialization. These new partnerships would involve academia, business and government, and they would be tailored to capture regional interests and economic clusters.

- States and universities should fund internships for innovation-oriented students interested in experiencing local startup and small business environments.

- Universities and colleges— including community colleges— should establish curricula to teach innovation management skills to middle and senior managers from small businesses. States should create local and regional innovation synergies by providing incentives for interaction between small businesses and educational institutions and resources.

- The National Science Foundation should take a significant role in funding pilot efforts to create innovation-oriented learning environments in K-12 and higher education. It should also sponsor research into the processes involved in teaching creativity, inventiveness and commercialization in technical environments." *(Page 27)*

Figure A: Model for the Evolution of Intervention Programs



Source: American Association for the Advancement of Science. *Investing in Human Potential: Science and Engineering at the Crossroads.* Ed. Marsha Lakes Matyas, Shirley M. Malcom. Washington, DC.1991.

BUSINESS ROUNDTABLE, ET AL.

TAPPING AMERICA'S POTENTIAL: THE EDUCATION FOR INNOVATION INITIATIVE. 2005

BACKGROUND

▶ Our goal is to double the number of science, technology, engineering and mathematics graduates by 2015. (Note: Therefore, the goal, by 2015, is 400,000 bachelor's degrees earned annually by U.S. citizens and permanent residents.)

This report is a letter to "leaders who care about America's future." It is from fifteen of our country's most prominent business organizations that came together to challenge themselves and other leaders to work as partners toward a goal to double the number of science, technology and mathematics graduates from our nation's colleges and universities by 2015. As with reports from many peer groups, it suggests the challenges now facing America are similar in nature to those faced at the time of Sputnik— perhaps even more serious.

Tapping America's Potential emphasizes the need for partnerships geared for collective action, and commits the nation's business leaders to moving ahead now on this ambitious agenda for action.

"[T]o reach our goal of doubling the number of science, technology, engineering and math graduates by 2015, we must focus as quickly as possible in the years ahead on five critical areas that affect the choices made by students now in the pipeline.

- Build public support for making science, technology, engineering and math improvement a national priority.
- Motivate U.S. students and adults to study and enter science, technology, engineering and mathematics careers, with a special effort geared to those in currently underrepresented groups.
- Upgrade K–12 math and science teaching to foster higher student achievement.
- Reform visa and immigration policies to enable the United States to attract and retain the best and brightest science, technology, math and engineering students from around the world to study for advanced degrees and stay to work in the United States.
- Boost and sustain funding for basic research, especially in the physical sciences and engineering." (*Pages 10-13)*

BUSINESS ROUNDTABLE, ET AL.

TAPPING AMERICA'S POTENTIAL: THE EDUCATION FOR INNOVATION INITIATIVE. 2005

RECOMMENDATIONS

"[We] identified a core set of recommendations in a dozen recent reports that we can begin to initiate, even in this tight budget year."

- "Launch a campaign to help parents, students, employees and community leaders understand why math and science are so important to individual success and national prosperity.
- Create more scholarships and loan-forgiveness programs for students who pursue two-year, four-year and graduate degrees in science, technology, math and engineering (including students who plan to teach math and science, particularly in high-poverty schools).... Supplement Pell Grants for eligible students who successfully complete core academic courses in high school.
- Increase the retention rate of undergraduate [STEM] majors by expanding programs...that encourage college graduates to pursue fields outside of academia that combine science and/or math with industry needs.
- Encourage private sector involvement in consortia of industries and universities that establish clear metrics to increase the number of [STEM] graduates.
- Adopt curricula that include rigorous content as well as real world engineering and science experiences so that students learn what it means to do this work, what it takes to get there, and how exciting these fields are.
- Include incentives in the Higher Education Act and in state policies for colleges and universities to produce more math, science and engineering majors and to strengthen preparation programs for prospective math and science teachers.

All of these efforts should be driven by a commitment to inspire and educate a new generation of mathematically and scientifically adept Americans." *(Pages 10–13)*

2001 bachelor's degrees earned by U.S. citizens/permanent residents:

- 14,048 in physical sciences
- 4,001 in earth, atmospheric and ocean sciences
- 63,528 in biological sciences
- 11,256 in math
- 34,502 in computer sciences
- 17,986 in agriculturalsciences
- 55,003 in engineering

TOTAL: 200,324

—National Science Board. *Science and Engineering Indicators.* 2004

BUILDING ENGINEERING & SCIENCE TALENT

THE TALENT IMPERATIVE: MEETING AMERICA'S CHALLENGE IN SCIENCE & ENGINEERING, ASAP. 2004

BACKGROUND

▶

BEST is a public-private partnership dedicated to building a stronger, more diverse U.S. workforce in science, engineering and technology by increasing the participation of under-represented groups. Its efforts reflect the growing realization that, historically, America has drawn upon a small segment of its population— and imported talent— to meet most of its needs for scientific and technological talent.

Further, as this traditional segment is ever-narrowing, BEST argues that the single most important test for American higher education over the next decade will be to develop "an emerging domestic talent pool that looks different from that in decades past." Unless it can do so, the primacy of American innovation will be lost, even as employers access international technical talent or move operations offshore.

BEST has sought systemically those higher education programs that are "pockets of success where the talent of under-represented groups is being nurtured, deployed and retained."

"Our greatest untapped resource: America's under-represented majority. Consider women, for example. They have emerged as the most educated segment of our society over the past quarter century, but a large number still view technical fields as off-limits. Image the infusion of knowledge and creativity if they were to choose science or engineering at the same rate that they have opted for business, law or medicine?

Or, take our burgeoning Hispanic population. Half of California's current kindergartners are Hispanic, yet the state's Science and Technology Council reports that only five percent of Hispanics who entered ninth grade in 1996 completed high school in 2000 fully ready to start college. What if that figure were multiplied 10-fold over the next decade? What could those kids, along with their African American and Native American classmates, bring to our innovation enterprise in 2025 and beyond?

Persons with disabilities, who comprise about 20% of our population, are another case in point. Technology is often their lifeline to a full and productive life. Think of what they could contribute if they had greater opportunities.

America's Talent Imperative is to ensure we draw upon the strengths of all groups in science, engineering and technology. Innovation happens fast once all the pieces are in place." *(Page 2)*

BEST's Blue Ribbon Panel on Higher Education found common principles designed into the most successful programs it identified. They invite all stakeholders to "consider these as essential ingredients in any recipe for producing diverse talent for science and engineering:

ESSENTIAL INGREDIENTS

Institutional leadership

- Leadership matters. Although passionate commitment to diversity may exist at any level of the campus, only commitment by the campus administration and senior faculty ensures that the values, goals and paths toward increased participation are essential to everyone's success.

Targeted recruitment

- Attracting the best available students and faculty from under-represented groups is critical, but so is establishing and sustaining a feeder system from pre-K-12, undergraduate and graduate schools.

Engaged faculty

- The traditional markers of academic accomplishment, such as research productivity, do not replace ongoing commitment to diversifying successful student talent. Student outcomes are a critical measure of faculty performance.

Enriched research opportunities

- Extending research opportunities beyond the classroom, for example, by way of internships, connects students' experiences to the world of work, establishes mentors and presents career options.

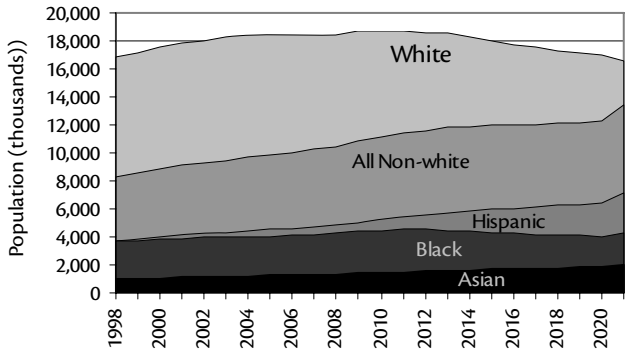
Bridging to the next level

- The path from grade school through university may be uneven for even the most privileged students. Successful programs to promote diverse student success build both the institutional relationships and the students' skills to enable them to progress through the educational system and envision career achievements.

Continuous evaluation

- Effective programs never stop asking basic questions about processes and outcomes: 'Are we doing the job?'" *(Page 7)*

Figure B: U.S. population 18-24 years old: July 1998 and projections to 2025



Sources: U.S. Bureau of the Census, Current Population Survey, annual series; and U.S. Bureau of the Census, Projections of the Total Resident Population by 5-Year Age Groups, and Sex With Special Age Categories: Middle Series, 1999 to 2100, NP-T3, http://www.census.gov/population/www/projections/natsum-T3.html

THE NATIONAL ACADEMIES

RISING ABOVE THE GATHERING STORM: ENERGIZING AND EMPLOYING AMERICA FOR A BRIGHTER ECONOMIC FUTURE. 2005

BACKGROUND

▶ The National Academies were asked by members of the U.S. Senate Committee on Energy and Natural Resources, with endorsement by Representatives of the House Committee on Science, to respond to the following questions:

- What are the top ten actions, in priority order, that federal policy-makers could take to enhance the science and technology enterprise so that the United States can successfully compete, prosper, and be secure in the global community of the 21st century?
- What strategy, with several concrete steps, could be used to implement each of those actions?

Having reviewed trends in the United States and abroad, the National Academies committee is deeply concerned that the scientific and technical building blocks of our economic leadership are eroding at a time when many other nations are gathering strength. They strongly believe that a worldwide strengthening will benefit the world's economy— particularly in the creation of jobs in countries that are far less well-off than the United States.

"History is the story of a people mobilizing intellectual and practical talents to meet demanding challenges. World War II saw us rise to the military challenge, quickly developing nuclear weapons and other military capabilities. After the launch of Sputnik in 1957, we accepted the challenge of the space race and landed twelve Americans on the moon and fortified our science and technology capacity.

Today's challenge is economic— no Pearl Harbor, Sputnik, or 9/11 will stir quick action. It is time to shore up the basics, the 'blocking and tackling' without which our leadership will surely decline. For a century, many in the United States took for granted that most great inventions were homegrown— electric power, the telephone, the automobile, the airplane— and were commercialized here as well.

We are less certain today who will create the next generation of innovations, or even what they will be. We know that we need a more secure Internet, more efficient transportation, new cures for disease, and clean, affordable, and reliable sources of energy. But who will dream them up, who will get the jobs they create, and who will profit from them? If our children and grandchildren are to enjoy the prosperity that our forebears earned for us, our nation must quickly invigorate the knowledge institutions that have served it so well in the past and create new ones to serve in the future.

The committee identified two key challenges that are tightly coupled to scientific and engineering prowess: creating high quality jobs for Americans and responding to the nation's need for clear, affordable and reliable energy." *(Pages 1-15 & 1-16)*

RECOMMENDATIONS

Talent Pool

- "Increase America's talent pool by vastly improving K-12 science and mathematics education." *(Page 4-2)*

Long-term Research

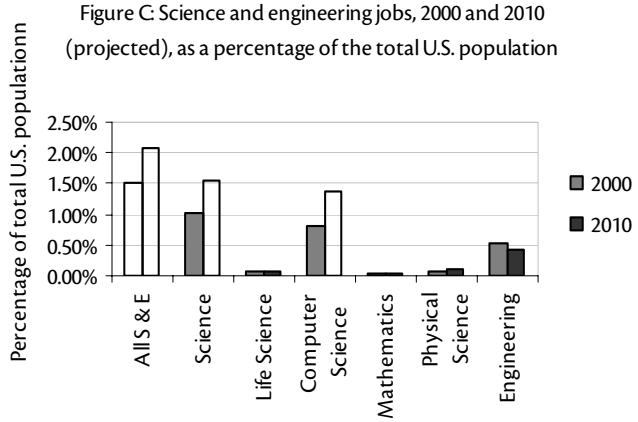
- "Sustain and strengthen the nation's traditional commitment to long-term basic research that has the potential to be transformational [in order] to maintain the flow of new ideas that fuel the economy, provide security, and enhance the quality of life." *(Page 4-2)*

Attracting Students

- "Make the United States the most attractive setting in which to study and perform research so that we can develop, recruit, and retain the best and brightest students, scientists, and engineers from within the United States and throughout the world." *(Page 4-3)*

"Although the committee was asked only to recommend actions that can be taken by the federal government, it is clear that related actions at the state and local levels are equally important for U.S. prosperity, as are actions taken by each American family." *(Page ES-7)*

Figure C: Science and engineering jobs, 2000 and 2010 (projected), as a percentage of the total U.S. population



Sources: Research and Policy Committee of the Committee for Economic Development. Learning for the Future: Changing the Culture of Math & Science Education to Ensure a Competitive Workforce: A Statement on National Policy. Washington, DC: Committee for Economic Development. Table 3. *and* U.S. Census Bureau, 2004, "U.S. Interim Projections by Age, Sex,

BUSINESS HIGHER EDUCATION FORUM

BUILDING A NATION OF LEARNERS. 2003

BACKGROUND

A nation of learners is one that effectively and efficiently helps students achieve proficiency in those basic, lifelong learning skills that transcend specific job categories. There is also a need to provide ongoing education and training tailored both to individual needs and workplace demands.

To increase the effectiveness of learning, educators must provide more engaging, relevant content targeted to individual styles of learning and needs. Although some institutions of higher learning are doing this, as illustrated in other reports cited throughout, solutions must be scaled to a wider range of learning environments.

To achieve change on the scale needed, BHEF, a coalition of leaders from American businesses, colleges, and universities, recommends a bold new commitment to the nation's learning future— the creation of a Presidential Commission on Learning, comprised of representatives from Congress, the private sector, education, state and local government, and the relevant agencies in the executive branch.

"Higher education must redesign itself to meet the learning standards of today's world. Education must be engaging, flexible, and interactive. Forward-thinking institutions that can lead the way must pioneer innovative new efforts and become champions of redesign and learning….

The Challenge by 2010:

- Every campus will have redesigned its coursework.
- Every student will have access to individualized and customized strategies for his or her specific education needs.
- Every classroom on every campus will have access to the online and off-line tools that students need.
- Every graduate will be assessed not only on his or her academic achievement, but also on his or her skills….

Lastly, this effort requires a massive new investment in technology infrastructure that will allow U.S. colleges and universities to scale these learning solutions to a broad expanse of learning environments..

[We propose] that Congress create new regional centers of learning excellence that can specifically focus on improving and redesigning learning by:

- pushing the frontiers of learning science with new research
- exploring the role that the latest technology advancements can play in providing more effective learning techniques...
- disseminating the best models and methods to higher education and other institutions to put them into practice….

[T]hese centers would bring together the brightest minds from academia, the private sector, and government to search for new ways to further increase the effectiveness of learning. The centers will need to constantly look for and work with the most innovative learning models that pioneering institutions are developing." *(Pages 27 & 30)*

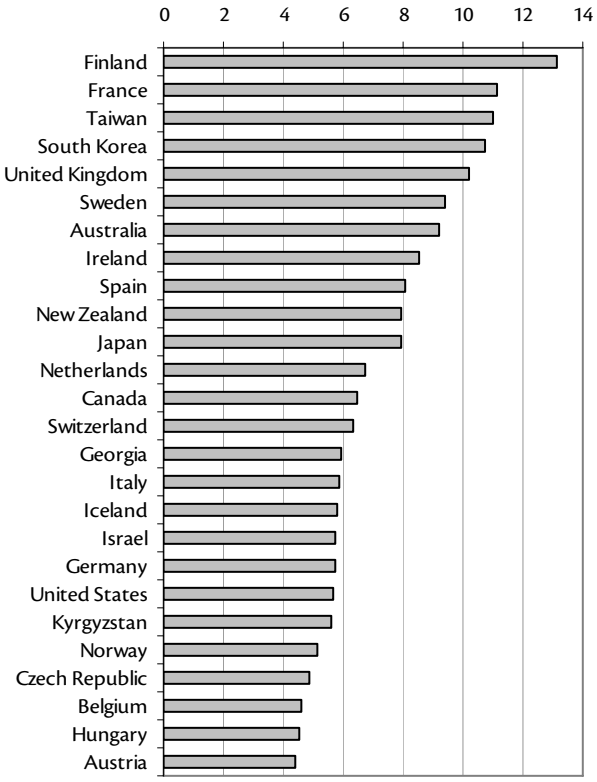
KEY CHANGES

BHEF has identified five key changes that can help redesign education to produce graduates prepared for the 21st century. These include:

- "focusing education on the lifelong learning skills and attributes needed for a nation of learners
- creating content that is challenging, motivating, and relevant
- encouraging learning through more interaction and individualization
- increasing opportunities and access to education
- adapting objectives to specific outcomes and certifiable job-related skills.

Change cannot happen in a vacuum. An undertaking of this magnitude can happen only through committed leadership at the highest level. To meet these goals by 2010, federal leaders must rise to this challenge, refocusing existing education and training efforts, and creating the new policies, priorities, and programs that will transform the United States into a nation of learners." *(Pages 15 & 29)*

Figure D: Percentage of 24-year-olds with first university degrees in natural sciences or engineering, 2000 or most recent year



Source: National Science Board, 2004. *Science and Engineering Indicators 2004.* Two volumes. Arlington, VA: National Science Foundation (volume 1, NSB 04-1; volume 2: NSB 04-1A). Appendix Table 2-35.

ASSOCIATION OF AMERICAN COLLEGES AND UNIVERSITIES

LIBERAL EDUCATION OUTCOMES: A PRELIMINARY REPORT ON STUDENT ACHIEVEMENT IN COLLEGE. 2005

INTRODUCTION

"For the future, the nation will need a workforce equipped with more than literacy in reading, math, and science. We need a whole generation with the capacities for creative thinking and for thriving in a collaborative culture. We need a class of workers who see problems as opportunities and understand that solutions are built from a range of ideas, skills and resources.

People are not born with inherent innovation skills, but they can learn them. They can acquire the social skills to work in diverse, multidisciplinary teams, and learn adaptability and leadership. They can develop communication skills to describe their innovation. They can learn to be comfortable with ambiguity, to recognize new patterns within disparate data, and to be inquisitive and analytical. They can learn to translate challenges in opportunities and understand how to complete solutions from a range of resources.

These skills are best acquired by experiencing innovation first-hand, building the confidence that underpins future success. To quote Benjamin Franklin: 'You tell me, I forget; you teach me, I remember; you involve me, I learn.'"

—Council on Competitiveness. *National Innovation Initiative Summit and Report: Thriving in a World of Challenge and Change.* 2005

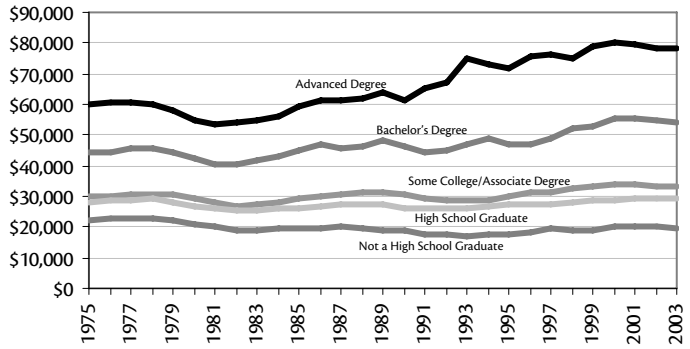
Part I of this *Report on Reports* captures insights and recommendations from reports shaped primarily by perspectives of national policy makers and corporate leaders, representing groups with a real stake in and concern about America's continued competitiveness in a changing world.

As a transition to Part II, in which reports from the educational and disciplinary community are captured, we present ideas and insights from a working group of the Association of American Colleges and Universities (AAC&U). Their preliminary report is the opening salvo of an extended focus within AAC&U on what Americans might expect as outcomes of a robust and transformed undergraduate learning environment, one that serves all citizens.

The value of AAC&U's preliminary findings is their stress on the enduring goals that have guided American higher education in the context of setting a vision that can drive our collective responses to 21st century challenges. After enunciating "recommended outcomes" in regard to knowledge, intellectual and practical skills, and individual and social responsibility, AAC&U sought responses and reflections from business and government leaders to reinforce how generic "liberal education outcomes" could serve to strengthen America's public life and its economy into the future (see facing page).

The sidebar from the Council on Competitiveness further illustrates the larger impact of focusing on learning outcomes as we respond to current pressures. Finally, the data below make clear how investing in American higher education will have long-term economic benefit to society in many ways, including how U.S. citizens can contribute to and benefit from a robust work environment, nationally and internationally.

Figure E: Mean earnings by degree level
(adjusted to 2005 dollars)



Source: U.S. Census Bureau, Current Population Survey (noninstitutionalized population, excluding members of the Armed Forces living in barracks). Table A-3. Mean Earnings of Workers 18 Years and Over, by Educational Attainment, Race, Hispanic Origin, and Sex: 1975 to 2003. http://www.census.gov/population/www/socdemo/educ-attn.html

ASSOCIATION OF AMERICAN COLLEGES AND UNIVERSITIES

LIBERAL EDUCATION OUTCOMES: A PRELIMINARY REPORT ON STUDENT ACHIEVEMENT IN COLLEGE. 2005

RECOMMENDED OUTCOMES

Knowledge	
Science Social Studies Mathematics Humanities Arts	"Executives will need a broad understanding of other cultures, other languages, history, science and the arts, if they are to successfully navigate a rapidly changing future business environment."
Intellectual and Practical Skills	
Written and oral communication	"Good writing skills and good public speaking are crucial to business success."
Inquiry, critical and creative thinking	"We are reminded that the real challenge of today's economy is not in making things but in producing creative ideas."
Quantitative literacy	"Business wants new employees from the educational system who can do mathematics accurately...in the world of work it means dealing with real, unpredictable, and unorganized situations where the first task is to organize the information and only then calculate to find an answer."
Information literacy	"Workers are expected to identify, assimilate, and integrate information from diverse sources; they prepare, main, and interpret quantitative and qualitative records; they convert information from one form to another...."
Teamwork	"Extracurricular activities and college projects that require teamwork can help students learn to value diversity and deal with ambiguity."
Integration of learning	"Reading, writing, and basic arithmetic are not enough. These skills must be integrated with other kinds of competency to make them fully operational."
Individual and social responsibility	
Civic responsibility and engagement	"Educating youth for citizenship should be the job of all teachers, not just those who teach history, social studies, and civics."
Ethical reasoning	"Study of the liberal arts can lead to moral understandings that are invaluable to success in whatever one attempts in life."
Intercultural knowledge and actions	"The improved ability to think critically, to understand issues from different points of view, and to collaborate harmoniously with co-workers from a range of cultural backgrounds all enhance a graduate's ability to contribute to his or her company's growth and productivity."
Propensity for lifelong learning	"So the industry requires a workforce that can keep pace with technology—people who have the fundamental skills and an ability to continue learning.... [T]hey will need employees that can adapt, continue to learn, and keep pace with rapid developments."

(Page 3)

AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE

A SYSTEM OF SOLUTIONS: EVERY SCHOOL, EVERY STUDENT. 2005

BACKGROUND

"[T]he committee identified a number of science learning goals that have been attributed to laboratory experiences, including:

- enhancing mastery of subject matter
- developing scientific reasoning
- understanding the complexity and ambiguity of empirical work
- developing practical skills
- understanding the nature of science
- cultivating interest in science and interest in learning science
- developing teamwork abilities.

Helping all high school students achieve these science learning goals is critical to improving national scientific literacy and preparing the next generation of scientists and engineers.

—National Research Council. *America's Lab Report: Investigations in High School Science*. 2005

This AAAS report details precise strategies for transforming a "system," based on an analysis of the experiences of a select group of Urban Systemic Initiatives (USI) funded by NSF in the 1990's.

The charge to the AAAS study group was to provide guidance to those responsible for the quality of America's K-12 system of public education— in densely-populated complex systems serving largely minority students living in poverty.

However, their findings inform the work of all stakeholders seeking to "re-imagine" our country's educational infrastructure. The AAAS authors ask themselves, "is there a pattern to the successes observed?" and they answer, "we think so."

In particular, they are clear about the value of and need for the right data, collected in the right way, if the system is to be transformed over the long-term.

In their words:

- "There remains the need to document how well any models are working. Within any initiative there are decisions that have to be made about what models to import or, if inappropriate to the specific circumstances, what models need to be invented. Invention carries with it the additional responsibility for research to determine whether the practices are effective in producing the desired changes, consistent with the overall strategic vision. An opportunity to re-evaluate one's adoption in light of changing circumstances or altered demands must exist." *(Page 15)*

AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE

A SYSTEM OF SOLUTIONS: EVERY SCHOOL, EVERY STUDENT. 2005

RECOMMENDATIONS

Ownership & Accountability

- "Ownership of student achievement must be 'community property.' [There is a] need to promote wide stakeholder involvement ('buy-in') in any and all education reform efforts.... Having plans broadly understood and widely accepted means that a district will likely be given the time needed to enact meaningful system-wide reform."

Resources, Notably Time

- "Longer periods of planning (up to a year or more) [are required] to ensure effective implementation that is faithful to vision and maps system (re)design to action.... The timetable for sustainable reform— policies and practices institutionalized throughout the school district— is more like a decade than a few years."

Data & Research-based Practices

- "It takes time to develop a culture (both habits and skills) of using data for decision-making.... There is a difference between 'knowing better' and 'doing better.'"

High Expectations & High Standards

- "Simply declaring 'high expectations' as a goal does not change hearts, minds or behaviors. Data are essential elements to support dialogue and professional development aimed at identifying resources and developing skills to promote learning to high standards for all students."

Management & System Capacity

- "Regardless of where management responsibilities for the reform initiative might reside, all stakeholders need to be clear about their roles within it and accountability to the partnership."

Implementation

- "We must accept that roles and responsibilities are distributed widely across communities. While there must be shared accountability to each other, there is also a requirement to provide the know-how and resources that change school culture, developing learning communities of practice for all."

(Pages 5-17)

"[B]asic steps of strategic planning:

- *Establishing clear goals and objectives.* Higher education institutions (HEI) must be able to justify their race- and ethnicity-conscious programs with compelling interests, which are clearly defined and central to the achievement of the institutions' educational mission.

- *Devising appropriate strategies.* HEI must be able to demonstrate that the means used to achieve their compelling ends are in fact designed and implemented in ways that materially advance those goals.

- *Reviewing and evaluating results.* HEI must periodically evaluate their programs to ensure continued compelling interests and the implementation of appropriate strategies advancing those interests; and they must make changes when necessary....

Indeed...process matters— and it matters a lot." *(Page 17)*

—College Board. *Federal Law and Recruitment, Outreach, and Retention: A Framework for Evaluating Diversity-Related Programs.* 2005

NATIONAL RESEARCH COUNCIL

BIO 2010: TRANSFORMING UNDERGRADUATE EDUCATION FOR FUTURE RESEARCH BIOLOGISTS. 2003

RECOMMENDATIONS

BACKGROUND

In the brief time since its publication, *Bio2010* has become one of the most influential of the many reports on undergraduate science education issued in the past decade by the National Academies of Science. The announced intent of *Bio2010* was to address issues relating to the preparation of biomedical researchers of the future, yet the scope of its analysis and keenness of its recommendations have had a ripple-effect across many disciplines and communities.

Central to its recommendations is the conviction that, increasingly, potential biomedical researchers (as with students in all biological sciences) must be comfortable applying diverse aspects of mathematics and the physical sciences in their pursuit of biological understanding. Indeed, it calls for a renewed discussion of how engineering and computer science, as well as chemistry, physics, and mathematics are presented to students in the life sciences.

Several recommendations made in *Bio2010* call for action at the campus level, including attention to understanding barriers to the kind of interdisciplinary education the committee seeks to promote, including:

Barrier: "[F]aculty who teach within a discipline often are not able to make the kind of connections they hope their students can grasp. Even very bright students often fail to transfer what they learn in one course to another, or to applications outside the classroom."

- *Recommendation*: "Recent research on student learning has identified some of the key characteristics promoting learning and transfer…. Departments and faculty need to utilize this educational research to guide curricular and pedagogical reform so that transfer between disciplines is promoted."

Barrier: "In almost all institutions, systemic change in the curriculum lies beyond the reach of individual faculty members. In addition, sustaining change requires the creation of an institutional culture in which faculty receive appropriate support from their colleagues, department chairs, and those in control of the university budget."

- *Recommendation*: "Administrators need to recognize the time and effort required by encouraging faculty to take advantage of campus resources (such as teaching and learning centers and computer services)…. For interdisciplinary education to become a reality, colleges and universities must provide incentives and help eliminate disincentives to interdepartmental collaborations."

Barrier: "The science teaching spaces on most campuses today are typically located in buildings constructed in the immediate post-Sputnik era…. These old spaces reflect the strong influence of the inflexible, discipline-oriented laboratory spaces of that era and are ill-suited for new pedagogical approaches."

- *Recommendation*: "Teaching and research facilities must be designed and developed to work synergistically with new, interdisciplinary pedagogical approaches and to emulate the physical environments in which students will ultimately work."

(Pages 102-105)

NATIONAL ACADEMY OF SCIENCES

FACILITATING INTERDISCIPLINARY RESEARCH. 2004

KEY CONDITIONS

Key Conditions for Effective Interdisciplinary Research

"Initial Stages

- common problems to solve.

Building Bridges

- leadership
- environment that encourages faculty/researcher collaboration
- establishing a team philosophy
- seed/glue money
- seminars to foster bridges...at the same institution
- workshops to foster bridges between investigators at other institutions
- frequent meetings among team members
- think of the end at the beginning.

Supporting the Project

- science and engineering PhDs trained in research administration
- support [for] project initiation and team building
- seamless and flexible funding
- willingness to take risks
- recognize potential for high impact
- involvement of funding organizations.

Facilities

- physical co-location of researchers
- shared instrumentation
- enhanced chance meetings between researchers.

Organization/administration

- matrix organization
- rewards for academic leaders who foster IDR
- tenure/promotion policies for interdisciplinary work
- utilize experts with breadth and IDR experience for assessment
- professional recognition of successful practitioners of IDR."
  (Page 21)

BACKGROUND

This report is from another *National Academies* committee. It provides a useful definition of "interdisciplinary research" (IDR) to inform the work of all stakeholders (students, postdoctoral scholars, researchers, institutions, funding organizations, professional societies, and those who evaluate research) to help IDR to reach its full potential.

"Four powerful 'drivers' of IDR are:

- the inherent complexity of nature and society
- the drive to explore basic research problems at the interfaces of disciplines
- the need to solve societal problems
- the stimulus of generative technologies.

At the heart of interdisciplinarity is communication— the conversations, connections, and combinations that bring new insights to virtually every kind of scientist and engineer."
(Pages 2 & 19)

Those making decisions about funding IDR should support efforts aimed at ensuring "key conditions" are in place.

AMERICAN ASSOCIATION OF PHYSICS TEACHERS

STRATEGIC PROGRAMS FOR INNOVATIONS IN UNDERGRADUATE PHYSICS (SPIN-UP): PROJECT REPORT. 2003

CHARACTERISTICS

BACKGROUND

Although reports from various of the academic groups present analyses of "what works," this report is the result of one of the most comprehensive evaluation of departments within a specific discipline in recent years. It reinforces what is known intuitively, that regardless of differences (mission, diversity, etc.) between participating schools, essentially the same practices were being implemented in all of the thriving physics departments. The SPIN-UP effort parallels that presented in reports from BEST, MAA and other organizations.

The value to the broader community of stakeholders of their carefully documented research is on several levels:

- for departmental leaders it provides benchmarks from which to measure how "thriving" their program is, and to establish strategies for building such a program
- for policy leaders it reinforces the premise that the most immediate, sustained and systemic impact of limited funds would be to focus on supporting transformation at the "system" level, rather than "project" level.

Characteristics of a Thriving Department

- "have a reputation as being first rate in the types of academic programs offered, in the pedagogical skills of faculty, and in the nurturing environment established by the faculty"
- "offer students both research opportunities and personal involvement with professors"
- "have professors who serve, formally or informally, as advisors"
- "have goals that are clearly stated, well-known, understood by faculty and staff [and are] consistent with the goals of each respective university"
- "actively recruit majors"
- "have departmentalized the practices that have been implemented to attract students"
- "foster environments where personal involvement of the faculty with individual students is the rule"
- "have flexibility in the physics curriculum"
- "have strong institutional support both financially and academically"
- "have strong leadership."

(Pages 80-84)

MATHEMATICAL ASSOCIATION OF AMERICA

UNDERGRADUATE PROGRAMS AND COURSES IN THE MATHEMATICAL SCIENCES: COMMITTEE ON THE UNDERGRADUATE PROGRAM IN MATHEMATICS CURRICULUM GUIDE 2004

RECOMMENDATIONS

General Education

"All students meeting general education or introductory requirements...should be enrolled in courses designed to:

- ...increase quantitative and logical reasoning abilities needed for informed citizenship and in the workplace
- strengthen quantitative and mathematical abilities that will be useful to students in other disciplines
- improve every student's ability to communicate quantitative ideas orally and in writing."

Partner Disciplines

"Courses that primarily serve students in partner disciplines should incorporate activities designed to advance students' progress in:

- creating, solving, and interpreting basic mathematical models
- making sound arguments based on mathematical reasoning and/or careful analysis of data
- effectively communicating the substance and meaning of mathematical problems and solutions."

Education Majors

"Mathematical sciences departments should create programs of study for [K-8] teachers that help students develop

- mathematical thinking and communication skills…
- an understanding of and experience with the uses of mathematics...."

Mathematics Majors

"Courses for students majoring in mathematics should ensure they:

- ...gain experience in careful analysis of data
- become skilled at conveying their mathematical knowledge in a variety of settings, both orally and in writing."

(Pages 92-94)

BACKGROUND

This "once-in-a-decade" report from the MAA arrives at much the same conclusions about the shape of the (math) department of the future as do *SPIN-UP*, *Bio2010*, *Engineering 2020*, and a host of other reports. As with those efforts of peers, recommendations from *CUPM 2004* evolved from a careful examination of departments recognized as "models that work." This CUPM guide contributes significantly to collective efforts to shape the future of science/mathematics education by putting the "student" at the center of its discussions and recommendations.

Their emphasis on the quality of the introductory and general education courses suggests one response to the calls for action issued in reports such as *A Nation of Learners* and *National Innovation Initiative Summit Report.*

Encouraging greater student understanding of the value and power of mathematics reinforces their recommendation for working with "partner disciplines" in strengthening the math courses that serve those disciplines.

NATIONAL RESEARCH COUNCIL

BEYOND THE MOLECULAR FRONTIER: CHALLENGES FOR CHEMISTRY AND CHEMICAL ENGINEERING. 2003

RECOMMENDATIONS

BACKGROUND

The pool of chemists and engineers must be expanded by attracting more women and minorities to the fields that chemical scientists find so rewarding and exciting. We must examine our current practices and beliefs to see how to fully tap the talents of all members of our society. U.S. chemistry and chemical engineering benefit from the immigration of individuals with the needed skills who have been trained both here and in other countries. However, the challenges are so great, and the demand for talent so large, that it is important to attract more of the brightest American students into these fields.

This report of a National Academies committee makes it clear that chemists and chemical engineers will need to be active ambassadors for their fields by recruiting new students and describing the satisfaction and rewards of a life on the frontier. This will require visits to schools to talk about the careers and opportunities. It is critical that such visits include students in the entire range from kindergarten through high school. Students need to learn early that there are exciting things to do in creative science, and that they could play a role in inventing solutions to the challenges that humanity faces.

"Educators should take advantage of the availability of professional chemists and chemical engineers, who can speak to the students.... Contact with practicing scientists can help students put a human face on a possible future career. It is especially important that women and minority scientists also play a role in such outreach to students, to show that indeed the profession welcomes all with the talent to contribute.... The future of the chemical sciences may depend on the ability of educators to convince young students that 'it's cool to be excited by chemistry.'" *(Page 184)*

The core of *Beyond the Molecular Frontier* is the discussion of opportunities and challenges in specific areas of fundamental or applied chemistry and chemical engineering— from "the interface with biology and medicine" to "energy: providing for the future" and "national and personal security."

Valuable ideas and insights are presented in the "why this is important" paragraph that concludes each of the nine central chapters, particularly in articulating new questions for exploration in the chemical sciences.

This report is the most recent of a periodic examination of the status of the chemical sciences. It reflects and responds to ways the field of chemical sciences are evolving in the 21st century, opportunities and challenges in both research and education.

Woven throughout the analyses of research fields are themes in tune with those in other reports. For example:

- "We conclude that chemists and chemical engineers need to be prepared to work increasingly in multidisciplinary teams, and that this will change the way we educate future chemical scientists." *(Page 5)*
- "We urge that students get into research as soon as possible, so they can learn what it is that scientists find so exciting." *(Page 6)*

NATIONAL ACADEMY OF ENGINEERING

EDUCATING THE ENGINEER OF 2020: ADAPTING ENGINEERING EDUCATION TO THE NEW CENTURY. 2005

RECOMMENDATIONS

Among the recommendations in *Educating the Engineer of 2020,* several reflect those presented in reports of peer organizations, and thus suggest approaches to collective action in changing the educational system in which the scientists and technologists, as well as the engineers, of 2020 will be prepared.

"Curricular approaches that engage students...in courses that connect engineering design and solutions to real-world problems…appear to be successful in retaining students. However, the designs of such approaches and assessment of their effectiveness…are still not well-rooted in rigorous investigation…. Thus, we recommend that:

- The engineering education establishment…should endorse research in engineering education as a valued and rewarded activity for engineering faculty as a means to enhance and personalize the connection to undergraduate students [and] to understand how they learn….

Departments need to more closely examine the mix of skills and experiences possessed across their cadre of faculty to determine how best to provide students with the knowledge and experiences necessary to engineering practice. Thus, we recommend that:

- Colleges and universities should develop new standards for faculty qualifications, appointments, and expectations, for example, to require experience as a practicing engineer, and should create or adapt development programs to support the professional growth of engineering faculty.

Real world problems are rarely defined along narrow disciplinary lines. Undergraduate students would benefit from at least cursory learning about the interplay between disciplines embodied in such problems. Thus, we recommend that:

- Engineering schools should introduce interdisciplinary learning in the undergraduate environment, rather than having it as an exclusive feature of the graduate programs.

Community colleges provide a vital pathway for an engineering education for lower income students, from both majority and underrepresented groups…. Thus, we recommend that:

- Four-year engineering schools must accept it as their responsibility to work with their local community colleges to ensure effective articulation, as seamless as possible, with their two-year programs."

(Pages 54-56)

BACKGROUND

This is the second publication in a multi-year NAE effort to first "envision the future and to use that knowledge to attempt to predict the roles that engineers will play in that future, and then to position engineering education in the United States for what lies ahead, rather than waiting to time to pass and then trying to respond."

In their first report, they outlined the essential characteristics of the engineer of 2020, as a starting point from which to reshaping the system. They recommend:

[It is] imperative for engineers to be lifelong learners. They will need this not only because technology will change quickly but also because the career trajectories of engineers will take on many more directions - directions that include different parts of the world and different types of challenges and that engage different types of people and objectives. Hence, to be individually/ personally successful, the engineer of 2020 will learn continuously throughout his or her career, not just about engineering but also about history, politics, business, and so forth."

(Pages 56-57)

—National Academy of Engineering. *The Engineer of 2020: Visions of Engineering in the New Century.* 2004

NATIONAL RESEARCH COUNCIL

EVALUATING AND IMPROVING UNDERGRADUATE TEACHING IN SCIENCE, TECHNOLOGY, ENGINEERING, AND MATHEMATICS. 2003

BACKGROUND

The report tackles one of the big "how can the system be transformed" questions, as it focuses on what colleges and universities need to do in order to ensure their faculty are prepared to face daunting, 21st century challenges. These include:

- "the need to apply principles of…research in cognitive science to the assessment of learning outcomes…
- to teach and advise large numbers of students with diverse interests and varying reasons for enrolling…."

Its recommendations about evaluating and strengthening faculty echo the "accountability" theme that resonates across a wide range of recent reports. In doing so, it calls for institution-wide clarity about expectations on two levels: first, what students should be learning; and second, how faculty should be evaluated for their influence on the quality of learning of students in their classrooms and labs.

Achieving clarity on those two points would be a major step for an academic community to respond to contemporary calls for transforming the educational system.

RECOMMENDATIONS

- "Teaching effectiveness should be judged by the quality of student learning.

  Reaching institution-wide consensus on this principle is a critical step that will require consideration of such questions as what different kinds of students (STEM majors, pre-professionals, and non-majors) should be learning in each discipline and how that learning can best be fostered. Definitions of effective teaching in STEM courses in the institution should take into account what is known about student learning and academic achievement.

- Departments and institutions of higher education should reinforce the importance of…professional development for faculty through the establishment and support of campus resources and through personnel policies that recognize and reward such efforts.

  When evaluating teaching, it is critical to recognize the different emphases and approaches among disciplines. For example, departments that stress laboratory-based teaching and learning as integral components of their curriculum will have different approaches to teaching (and learning) than departments in which laboratory and field work are not typically part of the curriculum.

- Quality teaching and effective learning should be highly ranked institutional priorities. University (and college) leaders should clearly assert high expectations for quality teaching to newly hired and current faculty….

  [All faculty] should be given opportunities for ongoing professional development in teaching and recognized and rewarded for taking advantage of those opportunities. Support also should be given for long-term, ongoing research projects that enable effective teaching and learning practices on campus to be analyzed and applied to additional courses and programs.

- Faculty should be encouraged to develop curricula that transcend disciplinary boundaries, through a combination of incentives, expectations of accountability, and development of standards for disciplinary and interdisciplinary teaching."

(Pages 118-124)

- What are the characteristics of a successful innovator?
- What are the characteristics of a life-long learner?
- What are the characteristics of a contributing and productive participant in the 21st century workforce?

These questions need to be on the table as we move toward realizing the visions described in these several reports, as they direct our continuing attention to the student, to the people affected by the systems we are attempting to transform. These reports also suggest how to answer those questions, as they talk about ensuring that students have access to the kind of learning experiences that give them the ability to self-educate over a lifetime, the skills of defining and solving problems, an understanding of intellectual depth, the capacity to work in and lead teams, and the willingness to take on and the knowledge to manage risks.

This *Project Kaleidoscope Report on Reports II, 2006* can be one tool for advancing and informing discussions within schools, colleges and universities, within disciplinary societies and educational associations, and in national, regional, and local gatherings of citizens, policy makers, and business leaders. It is intended to remind those already committed of the continued urgency of this work, and to alert emerging leaders about the critical challenges and opportunities facing our society. This PKAL publication also provides a set of benchmarks against which each of us can measure our progress— if, how, and where we are making a difference.

The 2002 *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.

—Project Kaleidoscope. *Recommendations for Urgent Action in Support of Undergraduate Science, Technology, Engineering, and Mathematics*. 2002

BIBLIOGRAPHY

Featured Reports

Pages 18-19. American Association for the Advancement of Science. *A System of Solutions: Every School, Every Student.* Washington DC: AAAS, 2005. http://www.aaas.org/programs/centers/capacity/documents/GELongReport.pdf.

Page 22. American Association of Physics Teachers. *Strategic Programs for Innovations in Undergraduate Physics: Project Report.* College Park, MD: AAPT, 2003. http://www.aapt.org/Projects/upload/SPIN-UP-Final-Report.pdf

Pages 16-17. Association of American Colleges & Universities. *Liberal Education Outcomes: A Preliminary Report on Student Achievement in College.* Washington DC: AAC&U, 2005. http://www.aacu.org/advocacy/pdfs/LEAP_Report_FINAL.pdf

Pages 10-11. Building Engineering & Science Talent. *The Talent Imperative: Meeting America's Challenge in Science & Engineering ASAP.* San Diego: BEST, 2003. http://www.bestworkforce.org/PDFdocs/BESTTalentImperativeFINAL.pdf

Pages 14-15. Business-Higher Education Forum. *Building a Nation of Learners.* Washington DC: BHEF, 2003. http://www.bhef.com/includes/pdf/2003_build_nation.pdf

Pages 8-9. Business Roundtable et al.[1] *Tapping America's Potential: The Education for Innovation Initiative.* Washington DC: Business Roundtable, 2005. http://www.businessroundtable.org/pdf/20050803001TAPfinalnb.pdf

Pages 6-7. Council on Competitiveness. *Innovate America: Thriving in a World of Challenge and Change.* Washington DC: Council on Competitiveness, 2005. http://innovateamerica.org/webscr/report.asp

Page 23. Mathematical Association of America. Undergraduate Programs and Courses in the Mathematical Sciences: CUPM Curriculum Guide. Washington DC: MAA, 2004. http://www.maa.org/cupm/cupm2004.pdf

Page 25. National Academy of Engineering. *Educating the Engineer of 2020: Adapting Engineering Education to the New Century.* Washington DC: National Academies Press, 2005.http://www.nap.edu/catalog/11338.html

Pages 12-13. National Academy of Sciences, National Academy of Engineering, and Institute of Medicine. *Rising Above the Gathering Storm: Energizing and Employing America for a Brighter Economic Future.* Washington DC: National Academies Press, 2005. http://books.nap.edu/catalog/11463.html

Page 21. National Academy of Sciences. *Facilitating Interdisciplinary Research.* Washington DC: National Academies Press, 2004. http://books.nap.edu/catalog/11153.html

Page 24. National Research Council. *Beyond the Molecular Frontier: Challenges for Chemistry and Chemical Engineering.* Washington DC: National Academies Press, 2003. http://www.nap.edu/catalog/10633.html

Page 20. National Research Council. *Bio 2010: Transforming Undergraduate Education for Future Research Biologists.* Washington DC: National Academies Press, 2003. http://www.nap.edu/catalog/10497.html?onpi_newsdoc09102002

Page 26. National Research Council. *Evaluating and Improving Undergraduate Teaching in Science, Technology, Engineering, and Mathematics.* Washington DC: National Academies Press, 2003. http://books.nap.edu/catalog/10711.html

Consulted Reports

American Association for the Advancement of Science. *Vision 2033: Linking Science and Policy to Tomorrow's World.* Washington DC: AAAS, 2003. http://Fellowships.aaas.org/08_Events/08_30th/Vision_2033.shtml

American Association of Physics Teachers. *Strategic Programs for Innovations in Undergraduate Physics at Two-Year Colleges: Best Practices of Physics Programs.* Washington DC: AAPT, 2005. http://www.aapt.org/Projects/upload/SPIN-UP-TYC-Booklet.pdf

Building Engineering & Science Talent. *A Bridge for All: Higher Education Design Principles to Broaden Participation in Science, Technology, Engineering, and Mathematics.* San Diego: BEST, 2004. http://www.bestworkforce.org/PDFdocs/BEST_BridgeforAll_HighEdDesignPrincipals.pdf

Business-Higher Education Forum. *A Commitment to America's Future: Responding to the Crisis in Mathematics and Science Education.* Washington DC: BHEF, 2005. http://www.bhef.com/MathEduReport-press.pdf

Business-Higher Education Forum. *Public Accountability for Student Learning in Higher Education: Issues and Options.* Washington DC: BHEF, 2004. http://www.bhef.com/includes/pdf/2004_public_accountability.pdf

Education Commission of the States. *Keeping America Competitive: Five Strategies to Improve Mathematics and Science Education.* Denver: ECS, 2005. http://www.ecs.org/clearinghouse/62/19/6219.pdf

Howard Hughes Medical Institute. *Mentoring, Interdisciplinary Curricula, and Assessment: Resources and Recommendations from HHMI Professors and Undergraduate Program Directors.* Chevy Chase, MD: HHMI, 2004.

[1] *Tapping America's Potential* is a collaboration between the following prominent business organizations: AeA, Business Roundtable, Business-Higher Education Forum, Computer Systems Policy Project, Council on Competitiveness, Information Technology Association of America, Information Technology Industry Council, Minority Business RoundTable, National Association of Manufacturers, National Defense Industrial Association, Semiconductor Industry Association, Software and Information Industry Association, TechNet, Telecommunications Industry Association, U.S. Chamber of Commerce

BIBLIOGRAPHY

Mathematical Association of America. *Achieving Quantitative Literacy: An Urgent Challenge for Higher Education.* Washington DC: MAA, 2004. https://enterprise.maa.org/ecomtpro/Timssnet/products/TNT_products.cfm

Mathematical Association of America. *Math & Bio 2010: Linking Undergraduate Disciplines.* Washington DC: MAA, 2005. https://enterprise.maa.org/ecomtpro/Timssnet/products/TNT_products.cfm

National Academy of Engineering. *The Engineer of 2020.* Washington DC: National Academies Press, 2004. http://books.nap.edu/catalog/10999.html

National Center for Higher Education Management Systems. *As America Becomes More Diverse: The Impact of State Higher Education Inequality.* Boulder, CO: NCHEMS, 2005. www.higheredinfo.org/raceethnicity/InequalityPaperNov2005.pdf

National Institutes of Health and National Science Foundation. *Conference on Research at the Interface of the Life and Physical Sciences: Bridging the Sciences.* Proc. of Conference on Research at the Interface of the Life and Physical Sciences: Bridging the Sciences, February 2005. http://www.nibib.nih.gov/nibib/File/News%20and%20Events/Previous%20Symposia%20and%20Workshops/9Nov2004/interfacereport20405.pdf

National Research Council. *Advancing Scientific Research in Education.* Washington DC: National Academies Press, 2005. http://www.nap.edu/catalog/11112.html

National Research Council. America's Lab Report: Investigations in High School Science. Washington DC: National Academies Press, 2006. http://darwin.nap.edu/books/0309096715/html/

National Research Council. *Knowing What Students Know: The Science and Design of Educational Assessment.* Washington DC: National Academies Press, 2001. http://books.nap.edu/catalog/10019.html

National Research Council. *Learning and Understanding: Improving Advanced Study of Mathematics and Science in U.S. High Schools.* Washington DC: National Academies Press, 2002. http://books.nap.edu/catalog/10129.html

National Research Council. *National Laboratories and Universities: Building New Ways to Work Together – Report of a Workshop.* Washington DC: National Academies Press, 2005. http://www.nap.edu/catalog/11190.html

National Science Board. *Broadening Participation in Science and Engineering Research and Education: Workshop Proceedings.* Washington DC: NSB, 2003. http://nsf.gov/pubs/2004/nsb0472/start.htm

National Science Board, 2004. *Science and Engineering Indicators 2004.* Two volumes. Arlington, VA: National Science Foundation (volume 1, NSB 04-1; volume 2: NSB 04-1A).

Pfirman, S., and the NSF Advisory Committee for Environmental Research and Education. *Complex Environmental Systems: Synthesis for Earth, Life, and Society in the 21st Century.* Washington DC: NSF, 2003. http://nsf.gov/geo/ere/ereweb/ac-ere/acere_synthesis_rpt_full.pdf

Research and Policy Committee of the Committee for Economic Development. *Learning for the Future: Changing the Culture of Math & Science Education to Ensure a Competitive Workforce: A Statement on National Policy.* Washington, DC: Committee for Economic Development.

Task Force on the Future of American Innovation. *The Knowledge Economy: Is the United States Losing Its Competitive Edge?* Washington DC: 2005. www.futureof innovation.org/PDF/Benchmarks.pdf

Figures

Figure A: American Association for the Advancement of Science. *Investing in Human Potential: Science and Engineering at the Crossroads.* Ed. Marsha Lakes Matyas, Shirley M. Malcom. Washington, DC.1991.

Figure B: U.S. Bureau of the Census, Current Population Survey, annual series; and U.S. Bureau of the Census, Projections of the Total Resident Population by 5-Year Age Groups, and Sex With Special Age Categories: Middle Series, 1999 to 2100, NP-T3, http://www.census.gov/population/www/projections/natsum-T3.html

Figure C: Research and Policy Committee of the Committee for Economic Development. Learning for the Future: Changing the Culture of Math & Science Education to Ensure a Competitive Workforce: A Statement on National Policy. Washington, DC: Committee for Economic Development. Table 3. *and* U.S. Census Bureau, 2004, "U.S. Interim Projections by Age, Sex, Race, and Hispanic Origin," http://www.census.gov/ipc/www/usinterimproj/

Figure D: National Science Board, 2004. *Science and Engineering Indicators 2004.* Two volumes. Arlington, VA: National Science Foundation (volume 1, NSB 04-1; volume 2: NSB 04-1A). Appendix Table 2-35.

Figure E: U.S. Census Bureau, Current Population Survey (noninstitutionalized population, excluding members of the Armed Forces living in barracks). Table A-3. Mean Earnings of Workers 18 Years and Over, by Educational Attainment, Race, Hispanic Origin, and Sex: 1975 to 2003. http://www.census.gov/population/www/socdemo/educ-attn.html

ACKNOWLEDGEMENTS

Project Kaleidoscope Staff

Jeanne L. Narum, Director

Jennifer Luebbert
Christopher Mueller
Christina Shute
Stefanie Turner
Mark Wold

Contact Information

Project Kaleidoscope
Suite 803
1730 Rhode Island Avenue, NW
Washington, DC 20036

Phone: 202-232-1300
Fax: 202-331-1283
Email: pkal@pkal.org
http://www.pkal.org

Project Kaleidoscope is supported, in part, by the National Science Foundation under Grants #0314006, #0341516, and #0532090. Any opinions, findings, conclusions or recommendations expressed are those of the grantee and do not necessarily reflect the views of the National Science Foundation.
http://www.nsf.gov/

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 of PKAL's NSF-supported workshops or other PKAL activities. A significant focus of PKAL is fostering leadership within undergraduate STEM. With support from the ExxonMobil Foundation, PKAL is identifying and supporting faculty with 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. The PKAL web site is a significant vehicle for dissemination about the work of all dedicated to building and sustaining a strong undergraduate STEM community in the service of students, science, and society.

Special thanks to: David F. Brakke, Dean of the College of Science & Mathematics— James Madison University; Judith A. Dilts, Associate Dean of the College of Science & Mathematics, Professor of Biology— James Madison University; James R. Gentile, President—Research Corporation; Melvin D. George, President Emeritus— University of Missouri; Daniel L. Goroff, Vice President, Dean of Faculty— Harvey Mudd College; Ishrat M. Kahn, Professor of Chemistry— Clark Atlanta University; C. Gary Reiness, Dean of Mathematical & Natural Sciences, Professor of Biology— Lewis and Clark College; Frank G. Rothman, Provost and Professor Emeritus— Brown University; J. B. Sharma, Professor of Physics— Gainesville College; Susan R. Singer, Professor of Biology— Carleton College; and Daniel F. Sullivan, President— St. Lawrence University.

Thanks to: PKAL DSEA* colleagues James Brown, American Chemical Society; Amy Chang, American Society for Microbiology; Ida Chow, Society for Developmental Biology; Carla B. Howery, American Sociological Association; Mary M. Kirchhoff, American Chemical Society; Jay B. Labov, National Research Council; Susan Musante, American Institute of Biological Sciences; Abraham Parker, American Institute of Biological Sciences; Irelene P. Ricks, American Society for Cell Biology; Tina H. Straley, Mathematical Association of America; and Jodi Wesemann, American Chemical Society.
**DSEA is the Disciplinary Society and Educational Association Alliance*

And to:

- **The National Science Foundation**— *Directorate for Education and Human Resources—Division of Undergraduate Education, Directorates for Biological Sciences and for Mathematical and Physical Sciences, and Directorate of Social, Behavioral, & Economic Sciences— Office of International Science & Engineering.*
- **The ExxonMobil Foundation**
- **The W.M. Keck Foundation**

Project Kaleidoscope
Suite 803
1730 Rhode Island Avenue, NW
Washington, DC 20036
◆
Phone: 202-232-1300 ◆ Fax: 202-331-1283 ◆ Email: pkal@pkal.org
http://www.pkal.org
◆
Copyright © 2006 by Project Kaleidoscope. All Rights Reserved.