U.S. HOUSE OF REPRESENTATIVES
SUBCOMMITTEE ON RESEARCH
COMMITTEE ON SCIENCE
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John Burris, President
Beloit College

Chairman Inglis and distinguished members of the Subcommittee.

My name is John Burris and I am the president of Beloit College. I appreciate the opportunity to present testimony today and am honored to do so. I extend my thanks to Chairman Inglis and the other members of the subcommittee for holding a hearing on "Undergraduate Science, Technology, Engineering, and Mathematics Education: What's Working?" I present this testimony from the perspective of a president of a liberal arts college with a long and distinguished record in science and math education. My convictions have been influenced also by my eight years as the director of the Marine Biological Laboratory (MBL)in Woods Hole, Massachusetts, an institution dedicated to research and graduate education.

In recent years there has been considerable apprehension and concern expressed regarding the ability of the United States to compete in a world economy increasingly driven by science and technology. These concerns have been reflected in particular in the last several years when over twenty reports have been issued that state concerns about the United States and its future leadership ability to address critical needs of our society through the applications of science and technology. [1]

Although I share many of the concerns expressed in these reports and agree with a number of solutions proposed, I am not going to tackle all the problems they identify. Instead I will address specifically the questions posed to the panel, focusing on science, technology, engineering and mathematics (STEM) education at the undergraduate level. My remarks will conclude with a specific recommendation:

> That as the overall budget of the National Science Foundation (NSF) is doubled in the next ten years, doubled dollars be intentionally targeted for programs that strengthen and sustain the capacity of America's undergraduate institutions to serve the national interest by preparing students to be the innovators, the life-long learners and civic leaders, and the participants in the 21st century workplace needed for our country to prosper in these challenging days.

This is a timely hearing. As our country seeks to respond to new challenges and opportunities and shape the recently announced 'America's Competitive Initiative,' I welcome the opportunity to make the case for undergraduate STEM as a critical link in America's scientific and technological infrastructure.

To have a well-trained workforce, we must educate undergraduates in STEM fields, preparing them as K-12 math/science teachers, for graduate education that leads to a professional career as an academic or research scientist, or for the increasing number of jobs that require scientific and technological expertise. To have a functioning democracy, we must prepare all undergraduates to understand the nature of the scientific process, whether or not they choose to major in a STEM field. An educated public is critical to providing the resources and encouragement the United States will need to maintain its role as a world leader in science and technology.

Your first question was: *What obstacles have we encountered in recruiting and retaining STEM majors….and how are we measuring the effectiveness of our actions?*

Responding to this question is an opportunity to talk about successes at Beloit, successes common to the larger liberal arts college community for which I speak today, successes which have more than a twenty-year history. In the mid-1980's it was painfully apparent America was not doing a good job of educating undergraduates in STEM, a circumstance having a ripple-effect up and down the scientific pipeline. The famous "champagne glass" image of that time graphically illustrated that the point of serious attrition in science enrollments was during the first two college years. This reality triggered a careful review of science education by the National Science Board, which became a catalyst for national reform efforts led by groups such as Project Kaleidoscope (PKAL), with leadership funding from the NSF.

Much of our knowledge of what does and does not work was summarized in reports such as *What Works: Building Natural Science Communities* (PKAL, 1991). Over many years of direct observation it had become clear that students learn science best in small classes with extensive hands-on experience in a so-called inquiry-based approach. They learn best in settings in which lectures and laboratory experiences are merged, with ample opportunity for collaborative work in posing, exploring and solving problems, rather than everything being tackled on an individual basis. It was clear that participation in research and open-ended problem solving captured the attention and intellect of the students.

One of the primary reasons I came to Beloit College was my firsthand interactions at the MBL with students from small liberal arts colleges, such as Beloit, and others within the Associated Colleges of the Midwest and the Independent Colleges Office, two consortia of which we are a part. At the MBL, we had established a "Semester in Environmental Sciences" program where students from small liberal arts colleges took courses and did independent research. I was incredibly impressed with the preparation of those young men and women. They had clearly been taught to think independently and critically at these schools and were able to conduct graduate level research while in Woods Hole.

Beloit College is a private, national liberal arts college enrolling 1250 students. A recent national study by the Higher Education Data Sharing (HEDS) consortium has identified Beloit College as one of the leading producers of doctoral degree recipients in the nation, placing Beloit 20th out of roughly 2,000 U.S. baccalaureate degree-granting institutions in the proportion of its graduates continuing on to receive a Ph.D. degree, and 11th among 165 national liberal arts colleges. Beloit is a member of the Science 50 group of liberal arts colleges noted for its Ph.D. productivity in the sciences. One of our goals is to continue to be a significant source of students who receive science Ph.D. degrees.[2]

Beloit College is remarkable as the home site for two major, NSF-funded national efforts, the BioQUEST Curriculum Consortium and the ChemLinks Coalition. In addition to the BioQUEST Consortium and ChemLinks Coalition, Beloit has been a major contributor to NSF-supported efforts to bring solid state chemistry and materials science into the undergraduate curriculum, with the development and class testing of many of the labs and demonstrations published in *Teaching General Chemistry: A Materials Science Companion* and a decade of subsequent articles in the *Journal of Chemical Education*. As a founding member and the second host campus for the Keck Geology Consortium of a dozen leading liberal arts colleges, Beloit has contributed to and benefited from this collaborative student/faculty research network for 18 years with its summer field research projects, shared research equipment, annual research symposium, and community of science scholars and teachers. *The UMAP Journal*, published by the Consortium for Mathematics and its Applications to focus on mathematical modeling and applications of mathematics at the undergraduate level, has been housed at Beloit College since its inception in 1995. As part of the NSF-supported calculus reform effort, a Beloit faculty member published *Applications of Calculus* in conjunction with other liberal arts college mathematicians.

For our students at Beloit, we have developed and tested inquiry-based, collaborative, and research-rich experiences at the introductory and intermediate levels, based on the emerging understanding of how students learn best through intensive engagement, as recently summarized in the National Research Council's *How People Learn.*

We are currently in the process of building a new Center for the Sciences whose design and technology reflects the experience we have developed over the past decade through our national leadership role in developing and disseminating new models and materials for undergraduate science education. Planning has followed the Project Kaleidoscope (PKAL) model of starting with goals for students, pedagogy, and curriculum, and working outward to the design of the physical spaces needed to accomplish them. But the present successes of Beloit, although repeated at many institutions, are not universal. This leads me to respond to your next question.

What are the obstacles to implementing similar improvements at other institutions of higher education?

Here the answers are easy, from my perspective as a college president educated as a research scientist: the rapid pace of change; the cost of responding to that pace of change; and the lack of a long-range, comprehensive plan to do so.

I emphasized above the strength of Beloit's undergraduate STEM programs. In large part our excellence and the capacity of our faculty pioneers to design, develop, and then disseminate their work and findings to the broader undergraduate community is due to informed support from the NSF. In responding twenty years ago to the "champagne glass" signal about problems in the scientific pipeline, NSF supported undergraduate faculty pedagogical pioneers, those building and sustaining undergraduate STEM learning environments in ways that reflected research on how people learn, made the best use of emerging technologies, and emphasized "doing science" in the process of "learning science."

So, a real obstacle today is the lack of a similar national effort, most visible in the continued decline in support for precisely the kind of efforts like BioQuest and ChemLinks, efforts that were ignited, piloted, sustained and disseminated because of visible and persistent support from the National Science Foundation. This is a costly effort, but the greatest cost will be the loss of talent in the service of our nation.

We may not be preparing the numbers of students in STEM fields the United States needs to ensure a vital economy, although I must emphasize that the quality of students we produce may be a more important benchmark than purely numbers. It is, however, important to think about numbers in thinking about obstacles to ensuring that all college graduates are scientifically literate. I have examined data and information from the 2006 NSB Indicators about real increases in undergraduate enrollments (expected to grow from 18.5 million in 2000 to 21.7 million in 2015).[3] These numbers become even more daunting in the context of thinking about the changing student demographics, as well as about the need for all 21st century students to become scientifically, quantitatively, and technologically literate as one outcome of their undergraduate learning experience.

Yet, it is of national concern that on many campuses, students still drop out of these majors during their early college years. Why is this happening? When science is not presented as science is done, when faculty see it as their responsibility to use introductory course to eliminate students rather than to encourage them, when classes are too large and laboratories are neither interesting nor challenging, students will demonstrate displeasure by changing majors. If this problem is not attacked with a national effort, the current legislation making its way through the House and the Senate for providing increased numbers of scholarships for students preparing to be a K-12 science or math teachers will be a bad investment. Just having a scholarship might not be enough to keep a student interested in persisting in the study of mathematics and science.

We do have an idea of how to correct this problem, for at liberal arts colleges such as Beloit, it is not unusual to have 80% of students entering as prospective science/math majors graduate as majors in those fields. But even the Beloits of the world cannot rest on our laurels, anymore then a research scientist stops studying and investigating after a successful experiment. Instead we need to continue to refine the way our students learn, to continue to experiment with what works, to disseminate what works and to continue to examine what does not work for the 21st century students coming on to our campuses. Students are changing, and science is changing.

This brings me to a further point about the nature of change. Over ten years ago, Albert Gore, then U.S. Senator, said:

> "We could seat children in rows and talk at them when we were going to expect them to stand in rows in factories and mills. If they are to be prepared to be the workers and thinkers of the 21st century, they must be experiencing the world directly, guided by teachers who act as coaches in helping them to formulate and answer difficult questions. Now we must give our children the opportunity to use and strengthen every creative and inquiring instinct they possess. We know that they must learn to work cooperatively, to write intelligently, to speak persuasively, and to acquire a fundamental level of competence in math and science."

If we examine these words from the perspective of preparing coming generations of K-12 math/science teachers, it tells us what their undergraduate experience should be; if we examine them from the perspective of preparing new entrants in the workplace, it is equally clear that the character and quality of the undergraduate STEM learning environment is a critical factor.

The changing nature of science is clearly reflected in the NSF Budget Request to Congress from the research directorates. The current and new programs they outline are explicitly focused on the future. What they now fund and propose to fund will be keeping my community of biologists at the cutting-edge of exploration, discovery, and application. [4]

As a biologist, I am compelled by this careful analysis of how biology is changing and where biology is growing, and welcome the new NSF programs in the research directorates that support the future of the field about which I am still passionate. But as a biologist now wearing the hat of a college president, I am frustrated by the lack of a similar vision of the future for the undergraduate learning environment and of NSF's role in shaping that future.

Thus, I suggest at least three obstacles that we will have to address as a nation: how to serve the increased numbers and increasing diversity of undergraduates; how to keep the 21st century STEM learning community at the leading edge in integrating research and education; and incorporating insights from research on how people learn in shaping the learning environment for all students.

Neither NSF's current budget figures or program analyses reflect an awareness (and here I speak as a biologist) that the systems are interconnected, interrelated, and interdependent. The strength of Beloit's programs are in direct relationship to the opportunity to benefit from and leverage grants from NSF programs twenty years ago that responded to the growing awareness that each link in the nation's scientific and educational infrastructure has to be strong if the system is to function effectively.

I conclude with my recommendation in responding to your final question: *what can the Federal Government do to help in identifying, assessing and disseminating what works at the undergraduate level that serves to strengthen the entire system of America's scientific, technological and educational enterprise?*

RECOMMENDATION: That as the overall budget of the National Science Foundation (NSF) is doubled in the next ten years, doubled dollars be intentionally targeted for programs that strengthen and sustain the capacity of America's undergraduate institutions to serve the national interest by preparing students to be the innovators, the life-long learners and civic leaders, and the participants in the 21st century workplace needed for our country to prosper in these challenging days.

This recommendation has implications for all the stakeholders, not just for NSF. My presidential colleagues (within the select liberal arts community and beyond) are concerned about the continued shrinking of budgets for the kind of undergraduate programs that stimulated a generation of pioneering pedagogies like BioQuest and ChemLinks.

I mentioned earlier that this was a timely hearing. For the first time in twenty years, our nation is wrestling with hard questions about our future and America's capacity to face an uncertain future with confidence. Congressional response to these reports has been welcome, but merely increasing the number of scholarships available to undergraduates exploring STEM careers is not enough. Our Beloit experience with 'what works' offers specific ideas for use of a doubled budget for undergraduate programs at NSF. We do know what works. There is a solid base from which to expand and enhance NSF programs in the coming decade; it is not necessary to start from scratch.

Significant parts of what works are: i) attention to how students learn; ii) an institutional culture that has a common vision about the value of building research-rich learning environments; and iii) faculty who are eager to remain engaged within their disciplinary community, and who have the resources of time and instrumentation to do so. The value of dissemination networks, collaborations and partnerships has been highlighted in many recent reports, as well as signaled by the work of PKAL and other NSF-funded dissemination networks.

To determine how best to program the doubling of NSF undergraduate funds over the next ten years, I propose a NSB taskforce be established. Its charge would be to outline NSF undergraduate priorities and budgets in ways that respond to recommendations in the many recent national calls for action.

We would like on the table for their consideration programs that support institution-wide initiatives and an expansion of programs that give faculty from predominantly-undergraduate institutions opportunity to engage in cutting-edge research appropriate for research teams that include undergraduates. Further, we ask for continued and expanded programs for the kind of course, curriculum and laboratory improvements that have enabled colleges like Beloit to be at the cutting-edge in shaping 21st century learning environments for 21st century students. Much of this is already happening at NSF, and we are glad for programs such as Research in Undergraduate Institutions (RUI), the Research Opportunities Award (ROA) and the Major Research Instrumentation (MRI) and other programs within the research directorates that provide critical opportunities for undergraduate faculty to be a contributing part of their scholarly disciplinary community. But most successes are isolated, piecemeal, and underfunded. They do not lead collectively to the kind of interdisciplinary, interdependent world in which most 21st century scientists and citizens will be working and living.

The 2003 Business Higher Education Forum report, *Building a Nation of Learners: The Need for Changes in Teaching and Learning to Meet Global Challenges*, challenges us all.

> "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."

1. EXHIBIT A: PROJECT KALEIDOSCOPE REPORT ON REPORTS II: RECOMMENDATIONS FOR URGENT ACTION, EXECUTIVE SUMMARY AND CALLS TO ACTION
2. EXHIBIT B: REPORT ON NATURAL SCIENCES AND MATHEMATICS AT BELOIT COLLEGE
3. EXHIBIT C: *NSB SCIENCE AND ENGINEERING INDICATORS, 2006: VOLUME 1*
4. EXHIBIT D: NSF FY 07 REQUEST (SELECTED PROGRAMS RE: UNDERGRADUATE STEM)

Representing the Associated Colleges of the Midwest and the Independent Colleges Office: Allegheny College (PA); Augsburg College (MN); Augustana College (IL); Beloit College (WI); Birmingham-Southern College (AL); Bowdoin College (ME); Bucknell University (PA); Calvin College (MI); Carleton College (MN); Claremont McKenna College (CA); Coe College (IA); Colby College (ME); Colgate University (NY); College of the Holy Cross (MA); College of Wooster (OH); Cornell College (IA); Dickinson College (PA); Grinnell College (IA); Harvey Mudd College (CA); Hope College (MI); Illinois Wesleyan University (IL); Kalamazoo College (MI); Knox College (IL); Lake Forest College (IL); Lawrence University (WI); Macalester College (MN); Monmouth College (IL); Oberlin College (OH); Pomona College (CA); Reed College (OR); Ripon College (WI); Skidmore College (NY); St. John's University (MN); St. Lawrence University (NY); St. Olaf College (MN); The Colorado College (CO); Union College (NY); University of Redlands (CA); University of Richmond (VA); Wheaton College (MA)

EXECUTIVE SUMMARY

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.

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.

EXHIBIT B
REPORT ON NATURAL SCIENCES & MATHEMATICS
BELOIT COLLEGE
BELOIT, WI

Beloit College is a private, national liberal arts college in southern Wisconsin, enrolling 1250 students. A recent national study by the Higher Education Data Sharing (HEDS) consortium[1] has identified Beloit College as one of the leading producers of doctoral degree recipients in the nation, placing Beloit 20th out of roughly 2,000 U.S. baccalaureate degree-granting institutions in the proportion of its graduates continuing on to receive a Ph.D. degree, and 11th among 165 national liberal arts colleges. Beloit is a member of the Science 50 group of liberal arts colleges noted for its Ph.D. productivity in the sciences. One of our goals is to continue to be a significant source of students who receive science Ph.D. degrees.

MISSION: At Beloit College science teaching and learning is of central importance. The Division of Natural Sciences and Mathematics at Beloit adopted a Mission Statement that placed significant weight on educating all students to understand the processes as well as the concepts of science in order to make informed decisions in their lives. Our vision is that all students understand how to choose questions to study scientifically and why those questions are important, as well as the practical applications and their social and ethical consequences of the answers to those questions. They should gain that understanding through inquiry-based courses and through laboratory and field experiences that model how science is done.

VISION: Additionally, our vision is that students majoring in one of the sciences at Beloit College should be prepared for and encouraged to participate in research in and out of formal courses, and should be able to begin to practice their craft and to function as professionals in their chosen scientific field. This includes, but is not limited to, asking appropriate questions, seeking solutions to their questions, communicating their results to specific and general audiences, and understanding their responsibility to engage in each of these activities. All students majoring in the sciences should be prepared to practice science in this way regardless of whether they anticipate a career in science.

PROGRAM: For all students, we have developed and tested inquiry-based, collaborative, and research-rich experiences at the introductory and intermediate levels, based on the emerging understanding of how students learn best through intensive engagement, as recently summarized in the National Research Council's *How People Learn.* [2] In this national science education reform effort, Beloit College has been in the vanguard. As highlighted by Priscilla Laws in her 1999 *Daedalus* article[3], liberal arts colleges have been leaders in science education reform, and Beloit College is remarkable in hosting two of those national efforts, the BioQUEST Curriculum Consortium and the ChemLinks Coalition. Both of these projects were also highlighted in a 2001 *Science* feature "Getting More Out of the Classroom" in an article "Reintroducing the Intro Course." [4] The ChemLinks project and its Beloit connections were also featured in the American Chemical Society's *Chemical and Engineering News* in a 2002 feature "Focusing on Reform." [5] Quite recently, a Policy Forum in *Science* on "Scientific Teaching" [6] includes references to teaching materials from BioQUEST, ChemLinks, and a Materials Science project that was partially authored and class-tested at Beloit.

For more than a decade, the hallmark at Beloit has been the "workshop" or "studio" format courses that combine inquiry-based classroom and laboratory activities; these have spread from introductory chemistry and biology courses into intermediate courses in both of those departments, and more recently into physics, geology, and computer science courses. Some examples:

- "Concept Test" interactive response systems are now used in introductory physics courses.
- Organic Chemistry uses a guided-inquiry approach in the classroom, instead of traditional lectures, and inquiry-based labs using two new research-grade capillary gas chromatographs as well as NMR and IR spectroscopy.
- The Genetics course uses BioQUEST materials with weekly poster presentations of student projects.

Three successive Howard Hughes Medical Institute (HHMI) grants have supported interdisciplinary curricular development, and successive National Science Foundation Course, Curriculum, and Laboratory Improvement (NSF CCLI) grants have provided instruments and student/faculty research time to develop inquiry-based experiments. We have seen burgeoning enrollments in these courses as we have made them more inquiry-based and interactive, with careful attention to measuring student learning as we use these new approaches. NSF-funded ChemLinks assessment studies have shown that these new approaches provide significant increases in conceptual understanding and in scientific reasoning skills for students, while also increasing their confidence in their ability to do chemistry successfully.

Throughout the sciences, almost all majors graduate having had at least one full-time research experience, many two, and some three. In addition, many students are actively involved in academic year research at Beloit with faculty research colleagues. Similar opportunities exist for students who seek clinical or public health experience, and we are increasingly able to find overseas placements for students with a particular international interest.

FACULTY: One of our goals has been to provide support and encouragement in faculty efforts to transform the undergraduate science experience at Beloit through collaborative work regionally and nationally, as well as within the Science Division at Beloit. The early and highly successful establishment of the Pew Midstates Science and Mathematics Consortium, and its continuation since the end of the Pew Charitable Trusts funding has provided a forum for curricular change across a dozen leading liberal arts colleges, Washington University in St. Louis, and the University of Chicago. The on-going Pew Faculty Workshops and inter-campus visits, as well as the annual Undergraduate Research Symposia, have stimulated curricular reform and supported undergraduate research.

NATIONAL LEADERSHIP: In addition to the BioQUEST Consortium and ChemLinks Coalition, Beloit has been:

- a major contributor to NSF-supported efforts to bring solid state chemistry and materials science into the undergraduate curriculum, with the development and class testing of many of the labs and demonstrations published in *Teaching General Chemistry: A Materials Science Companion*[7] and a decade of subsequent articles in the *Journal of Chemical Education*.
- a founding member and host campus for the Keck Geology Consortium of a dozen leading liberal arts colleges, Beloit has contributed to and benefited from this collaborative student/faculty research network for 18 years with its summer field research projects, shared research equipment, annual research symposium, and community of science scholars and teachers.
- a founding member of Project Kaleidoscope (PKAL), continuing to contribute to and benefit from that collaboration as well.

- home since 1995 to *The UMAP Journal*, published by the Consortium for Mathematics and its Applications to focus on mathematical modeling and applications of mathematics at the undergraduate level.
- a part of the NSF-supported calculus reform effort; a Beloit faculty member published *Applications of Calculus*[8] in conjunction with other liberal arts college mathematicians.

INSTRUMENTATION: In 2001, Beloit replaced an aging scanning electron microscope (SEM) with a new research-grade JEOL SEM with an energy-dispersive spectrometer (EDS) for elemental analysis. This state-of-the-art system, obtained with an NSF CCLI grant to a faculty member in Geology and matching funds from an earlier Kresge Foundation challenge grant for a scientific equipment endowment, has catalyzed a number of research and course-related imaging and elemental analysis projects ranging from Geology, Biology, Chemistry, and Physics to Archaeology and Museum Studies. The ability to examine the surface of a solid sample in detail and determine the elemental composition of individual regions provides an extremely powerful tool not only for answering important research questions, but also for connecting students' visual and structural understanding with chemistry on the nanoscale. Naturally occurring minerals collected in the field, light emitting diodes (LEDs), computer circuits, CDs, nanowires and quantum dots synthesized by students, and tool marks on archaeological samples become fascinating images that draw the science major and the non-major equally into the process of asking questions and gathering and interpreting data to answer them. Our experience with this instrument has strongly reinforced our emerging view that providing research-grade instruments to students as soon as they can help them pose and answer interesting questions makes sense educationally. Having such instruments that can be used in a variety of disciplines not only is cost-effective, but it promotes the kind of interdisciplinary experience our students want and need.

FACILITIES: We are currently in the process of building a new Center for the Sciences whose design and technology reflects the experience we have developed over the past decade through our national leadership role in developing and disseminating new models and materials for undergraduate science education. Planning has followed the PKAL model of starting with goals for students, pedagogy, and curriculum, and working outward to the design of the physical spaces needed to accomplish them. The degree of spatial integration among the disciplines that we plan is highly unusual. Another indication of our long-term planning for interdisciplinary integration has been the intention from the start to bring Psychology into the sciences with the plan to build more programmatic and laboratory space links among biology, biochemistry, and psychology to reflect the direction that neurobiology, pharmacology, and physiological psychology are taking.

Since its founding in 1846, Beloit College has offered one of the nation's most rigorous and inventive science curricula. As we maintain our position as a leading, national liberal arts college, Beloit's new state-of-the-art science facility will house and match our leading-edge science program in the new millennium, empowering the education of all Beloit students.

References Cited

1. Higher Education Data Sharing (HEDS) consortium, *Baccalaureate Origins of Doctoral Recipients*, January 1998. Data drawn from NSF CASPAR database (caspar.nsf.gov).
2. National Research Council, *How People Learn: Brain, Mind, Experience, and School*, National Academy Press, Washington, D.C., 2000.
3. Priscilla W. Laws, New Approaches to Science and Mathematics Teaching at Liberal Arts Colleges, *Daedalus*, J. Am. Acad. Arts and Sciences, Vol. 128, No. 1,Winter, 1999, p. 271-240.
4. Erik Stokstad, "Reintroducing the Intro Courses," *Science*, Vol 293, 31 August 2001, p. 1608-1610.
5. Amanda Yarnell, "Focusing on Reform," *Chemical and Engineering News*, Vol. 80, Num. 43, October 28, 2002, pp. 35-36.
6. Jo Handelsman et al, "Scientific Teaching," *Science*, Vol. 304, 23 April 2004, pp. 521-522 and online supporting materials.
7. A. B. Ellis et al, *Teaching General Chemistry: A Materials Science Companion*, American Chemical Society, Washington, D.C., 1993.
8. P. D. Straffin, editor, *Applications of Calculus*, Mathematical Association of America, 1996.

EXHIBIT C
NSB SCIENCE AND ENGINEERING INDICATORS 2006 VOLUME 1

The need for greater attention at the national level to the quality and character of America's undergraduate STEM learning environment.

1. DEMOGRAPHICS & BACCALAUREATE DEGREES *(Chapter 2)*

- "The importance of higher education in science and engineering is increasingly recognized around the world for its impact on innovation and economic development."
- "In recent years, demographic trends and world events have contributed to changes in both the numbers and types of students participating in U.S. higher education."
- "...global competition in higher education is increasing. Although the United States has historically been a world leader in providing broad access to higher education..., many other countries are expanding their own higher education systems, providing comparable educational access to their own population...."
- "After declining in the 1990's, the U.S. college-age population is currently increasing and is projected to increase for the next decade. " "According to U.S. Census Bureau projects, the number of college-age (ages 20 - 24) individuals is expected to grow from 18.5 million in 2000 to 21.7 million by 2015."
- "Changes in the demographic composition of the college-age population as a whole and increased enrollment rates of some racial/ethnic groups have contributed to changes in the demographic composition of the higher education student population in the U.S." "The demographic composition of students planning S&E majors has become more diverse over time."
- "The baccalaureate is the most prevalent degree in S&E, accounting for 77% of all degrees awarded. S&E bachelor's degrees have consistently accounted for roughly one-third of all bachelor's degrees for the past decade. Except for a brief downturn in the late 1980's, the number of S&E bachelor's degrees has risen steadily, from 317,000 in 1983 to 415,000 in 2002."

2. S&E LABOR FORCE *(Chapter 3)*

- "An estimated 12.9 million workers reported needing at least a bachelor's degree level of S&E knowledge– with 9.2. million reporting a need for knowledge of the natural sciences and engineering and 5.3 million a need for knowledge of the social sciences. That the need for S&E knowledge is more than double the number in formal S&E occupations suggests the pervasiveness of technical knowledge in the modern workplace."
- "The 3.1% average annual growth rate in all S&E employment is almost triple the rate for the general workforce."
- "S&E occupations are projected to grow by 26% from 2002 to 2012, while employment in all occupations is projected to grow 15% over the same period."
- "Recent recipients of S&E bachelor's and master's degrees form an important component of the U. S. S&E workforce, accounting for almost half of the annual inflow into S&T occupations. Recent graduates' career choices and entry into the labor market affect the supply and demand for scientists and engineers throughout the United States."
- "Although it is a very subjective measure, one indicator of labor market conditions is whether recent graduates feel that they are in 'career-path' jobs."

3. S &T: PUBLIC ATTITUDES AND UNDERSTANDING *(Chapter 7)*

- "Knowledge of basic scientific facts and concepts is necessary not only for an understanding of S&T related issues but also for good citizenship."
- "Having appreciation for the scientific process may be even more important. Knowing how science works, i.e., understanding how ideas are investigated and either accepted or rejected, is valuable not only for keeping up with important science-related issues and participating meaningfully in the political process, but also in evaluating and assessing the validity of various types of claims people encounter on a daily basis."

4. ELEMENTARY AND SECONDARY EDUCATION *(Chapter 1)*

- "Strengthening the quality of teachers and teaching has been central to efforts to improve American education in recent decades. Research findings consistently point to the critical role of teachers in helping students to learn and achieve. Many believe that...changes in teaching practices will occur if teachers have consistent and high-quality professional training."

EXHIBIT D
NSF FY 2007 BUDGET REQUEST:
COMPARATIVE DATA AND PROGRAM DESCRIPTIONS, SELECTED PROGRAMS

A. EHR UNDERGRADUATE EDUCATION FUNDING: SELECTED

1. FACULTY

- *Distinguished Teaching Scholars(DTS)* — *Request:* $0.5: *Change:* N/A

DTS is emerged into the new “Excellence Awards in Science and Engineering program in EHR.... part of NSF’s efforts to promote an academic culture that values a scholarly approach to both research and education.

2. STUDENTS

- *Noyce Scholarships* — *Request:* $9.77 *Change:* 11.4 %

Goal to encourage talented STEM majors and professionals to become K-12 math/science teachers, funding institutions of higher education to support scholarships, stipends, programs for students who commit to teaching in high-need K-12 schools.

- *Research Experiences for Undergraduates (REU) Sites* — *Request:* $35.64 *Change:* 2.6%
- *REU Supplements* — *Request:* $21.28 *Change:* 0.19 %

Provides active research experiences (working with faculty researchers) through which to attract talented undergraduates and retain them in S&T careers.

- *Scholarships for Service/Cybercorps* — *Request:* $10.80 *Change:* 4.9%

Seeks to increase number of professionals in information assurance and computer security.

3. PROGRAM/INSTITUTIONAL

- *Advanced Technological Education* — *Request:* $45.92 *Change:* 2.2%

Promotes improvement in technological education at the undergraduate and secondary levels by supporting program and faculty/teacher development, focusing on the education of technicians for the high-technology fields that drive our economy.

- *Tribal Colleges and Universities Program* — *Request:* $12.42 *Change:* 34%

Support for comprehensive institutional approaches to strengthen STEM teaching and learning in ways that improve access to, retention within and graduation from STEM programs.

- *Course, Curriculum and Laboratory Improvement (CCLI)* — *Request:* $35.14 *Change:* -8.12%

Seeks to improve the quality of STEM education for all students, based on research concerning the needs and opportunities that exist and effective ways to address them. Targets activities affecting learning environments, course content, curricula, and educational practices. (“Fewer new awards will be supported in FY 2007 as the program introduces phases that help prioritize efforts in this area.”)

- *STEM Talent Expansion Program (STEP)* — *Request:* $26.07; *Change:* 1.9%

Supports colleges and universities in increasing the number of U.S. citizens and permanent residents receiving associate or baccalaureate degrees in established or emerging STEM fields, and supports educational research on student achievement in STEM fields.

B. ADDITIONAL PROGRAMS RELATED TO UNDERGRADUATE EDUCATION: SELECTED

1. STUDENTS

- *Computational Training for Undergraduates in the Mathematical Sciences* — *Request:* $1.5; *Change:* N/A

Seeks to enhance computational aspects of undergraduate mathematics majors and prepare them for careers and graduate study in relevant fields by providing REU-like experiences.

- International Research Experiences (REU) — Request: $2.0; Change: 100%

Through international cooperative research training, networking and mentoring, seeks to provide U.S. students with a global perspective and opportunities for professional growth.

- *Scholarships in STEM (S-STEM)* — *Funds from H-1B visa applications*

An estimated $100 million supports scholarships for low-income, academically talented students, enabling them to pursue associate, baccalaureate, or graduate STEM degrees.

- *Undergraduate Mentoring in Environmental Biology* — *Request:* $0; *Change:* -100%

Program (offered in alternate years) designed for students, particularly from under-represented groups, to pursue a career in environmental biology, providing year-round research activities and sustained mentoring.

- *Program for Research and Education with Small Telescopes* — *Request:* $1.5; *Change:* N/A

Supports undergraduate students in building instrumentation and carrying out research with telescopes of modest aperture.

2. PROGRAMS/INSTITUTIONAL

- *Geosciences Education Program* — *Request:* $2.5; *Change:* N/A

Facilitates the initiation or piloting of highly innovative educational activities, including funds for activities at the undergraduate and K-12 level. An additional $1.0 annually supports linkages to the Louis Stokes Alliances for Minority Participation program.

- *Opportunities for Enhancing Diversity in Geosciences* — *Request:* $4.8; *Change:* N/A

Addresses the problem of underrepresentation of certain groups in geosciences by supporting activities that strengthen teaching and learning in ways that improve access to and retention this field.

- *Interdisciplinary Training for Undergraduates in Biological and Mathematical Sciences* — *Request:* $3.2; *Change:* N/A

Enhances undergraduate education and training at the intersection of these fields, to prepare students for future study and careers in fields that integrate the two, by providing long-term research experiences for cross-disciplinary balanced cohorts of students.

- *IT Education and Research* — *Request:* $6.00 — *Change:* 100%

Supports education and workforce development activities to catalyze the development of both a new integration-oriented computing curriculum and the cross-campus integration of IT education and research.

- *Nanotechnology Undergraduate Education* — *Request:* $2.00 — *Change:* -4.8%

Through a variety of interdisciplinary approaches, introduces nanoscale science, engineering, and technology into undergraduate education with relevance to devices and systems and/or on relevant social economic, and ethical issues.

- *Cross-disciplinary Research at Undergraduate Institutions* — *Request:* $2.00 — *Change:* N/A

Supports research involving faculty and students in cross-disciplinary research projects, seeking also to facilitate greater diversity in student participation and to contribute to the development of the next generation of scientists well-trained in 21st century biology.

3. LARGE & COLLABORATIVE PROGRAMS

- *Undergraduate Research Collaboratives* — *Request:* $3.5 — *Change:* N/A

Supporting research in the chemical or in interdisciplinary areas supported by the chemical sciences, this seeks and supports new models of partnerships that engage first- and second-year college students in undergraduate research and enhance the research capacity, infrastructure, and culture of participating institutions.

- *Centers of Research Excellence in Science and Technology* — *Request:* $29.94 — *Change:* 39.3%

Seeks to upgrade the capabilities of the most research-productive minority serving institutions, through the integration of research and education, promoting the production of new knowledge, and the expansion of a diverse student presence in STEM fields.

- *Partnerships for Research and Education in Materials* — *Request:* $4.00 — *Change:* 5.3%

Seeks to enhance diversity in materials research and education by stimulating long-term partnerships between minority-serving institutions and NSF's Division of Materials Research-supported groups, centers, and facilities.

- *National Science Digital Library (NSDL)* — *Request:* $18.11 — *Change:* 2.8%

C. SUPPORT FOR RESEARCH & RESEARCH/EDUCATION
(People and infrastructure: broad and Foundation-wide)

1. Major Research Instrumentation (MRI) — *Request:* $90.0

MRI funding enables the acquisition of major state-of-the-art research instrumentation too costly to be supported through regular NSF programs. By improving research training and integrated research and education activities, MRI projects strengthen science education. The MRI program directs approximately $20.0 million to support teaching-intensive and minority-serving institutions; in the FY 2005 competition, 281 proposals were received from this group. Minority-serving institutions received 26 awards ($9.20 million) and non-Ph.D. granting institutions received 109 awards ($25.80 million). Overall funding rate in 2005 was 32 percent.

C. BUDGET RATIONALE FROM DIRECTORATE FOR BIOLOGICAL SCIENCES (EXCERPT)

“Transformative studies of complex biological questions increasingly require the tools of genomics, computer and information science, the physical sciences, and mathematics to achieve insights into the nature and function of the molecular machinery of the living cell, the mechanisms by which genetic information is transmitted and expressed, and the processes by which living cells are organized, communicate, and respond to environmental systems. MCB (molecular and cellar biology) continues to forge partnerships with complementary disciplines to support research at these interfaces, to introduce new analytical and conceptual tools for biological research, and to provide unique education and training environments for the next generation of versatile biologists and scientifically literate citizens.”

“...innovations in genomics, molecular biology and computer science are now enabling advancement of the frontiers of knowledge on previously bewildering complex questions such as how does a bird fly, a heart beat, a flower bloom, or a sea urchin evolve.” (Page 49)

National Science Foundation
Selected Crosscutting Programs
FY 2007 Budget Request to Congress

(Dollars in Millions)

Selected Crosscutting Programs		FY 2005 Actual	FY 2006 Current Plan	FY 2007 Request	FY 2007 Request: Change over FY 2005 Actual: Amount	FY 2007 Request: Change over FY 2005 Actual: Percent	FY 2007 Request: Change over FY 2006 Current Plan: Amount	FY 2007 Request: Change over FY 2006 Current Plan: Percent
ADVANCE	Research & Related Activities	19.86	19.63	19.72	-0.14	-0.7%	0.09	0.5%
	Education & Human Resources	-	-	-	-	N/A	-	N/A
	Total, NSF	**$19.86**	**$19.63**	**$19.72**	**-$0.14**	**-0.7%**	**$0.09**	**0.5%**
Course, Curriculum & Lab Improvement - CCLI	Research & Related Activities	1.83	1.34	1.84	0.01	0.5%	0.50	27.2%
	Education & Human Resources	41.93	36.93	33.30	-8.63	-20.6%	-3.63	-10.9%
	Total, NSF	**$43.76**	**$38.27**	**$35.14**	**-$8.62**	**-19.7%**	**-$3.13**	**-8.9%**
Faculty Early Career Development - CAREER	Research & Related Activities	162.71	145.92	149.46	-13.25	-8.1%	3.54	2.4%
	Education & Human Resources	-	-	-	-	N/A	-	N/A
	Total, NSF	**$162.71**	**$145.92**	**$149.46**	**-$13.25**	**-8.1%**	**$3.54**	**2.4%**
Graduate Research Fellowships - GRF	Research & Related Activities	8.07	7.99	8.06	-0.01	-0.1%	0.07	0.9%
	Education & Human Resources	87.87	85.37	88.03	0.16	0.2%	2.66	3.0%
	Total, NSF	**$95.94**	**$93.36**	**$96.09**	**$0.15**	**0.2%**	**$2.73**	**2.8%**
Graduate Teaching Fellowships in K-12 Education - GK-12	Research & Related Activities	7.77	7.60	8.86	1.09	14.0%	1.26	14.2%
	Education & Human Resources	41.66	43.05	46.80	5.14	12.3%	3.75	8.0%
	Total, NSF	**$49.43**	**$50.65**	**$55.66**	**$6.23**	**12.6%**	**$5.01**	**9.0%**
Integrative Graduate Education and Research Training - IGERT	Research & Related Activities	43.28	41.99	42.40	-0.88	-2.0%	0.41	1.0%
	Education & Human Resources	24.31	23.43	24.57	0.26	1.1%	1.14	4.6%
	Total, NSF	**$67.59**	**$65.42**	**$66.97**	**-$0.62**	**-0.9%**	**$1.55**	**2.3%**
Long-Term Research Sites - LTER	Research & Related Activities	22.26	23.07	24.72	2.46	11.1%	1.65	6.7%
	Education & Human Resources	-	-	-	-	N/A	-	N/A
	Total, NSF	**$22.26**	**$23.07**	**$24.72**	**$2.46**	**11.1%**	**$1.65**	**6.7%**
Postodoctoral Programs	Research & Related Activities	16.59	16.01	16.04	-0.55	-3.3%	0.03	0.2%
	Education & Human Resources	-	-	-	-	N/A	-	N/A
	Total, NSF	**$16.59**	**$16.01**	**$16.04**	**-$0.55**	**-3.3%**	**$0.03**	**0.2%**
Research Experience for Teachers - RET	Research & Related Activities	5.47	8.39	8.51	3.04	55.6%	0.12	1.4%
	Education & Human Resources	-	-	-	-	N/A	-	N/A
	Total, NSF	**$5.47**	**$8.39**	**$8.51**	**$3.04**	**55.6%**	**$0.12**	**1.4%**
Research Experience for Undergraduates - REU	Research & Related Activities	55.72	55.82	56.92	1.20	2.2%	1.10	1.9%
	Education & Human Resources	-	-	-	-	N/A	-	N/A
	Total, NSF	**$55.72**	**$55.82**	**$56.92**	**$1.20**	**2.2%**	**$1.10**	**1.9%**
Research Experience for Undergraduates - REU - Sites Only	Research & Related Activities	35.87	34.73	35.64	-0.23	-0.6%	0.91	2.6%
	Education & Human Resources	-	-	-	-	N/A	-	N/A
	Total, NSF	**$35.87**	**$34.73**	**$35.64**	**-$0.23**	**-0.6%**	**$0.91**	**2.6%**
Research Experience for Undergraduates - REU - Supplements Only	Research & Related Activities	19.85	21.09	21.28	1.43	7.2%	0.19	0.9%
	Education & Human Resources	-	-	-	-	N/A	-	N/A
	Total, NSF	**$19.85**	**$21.09**	**$21.28**	**$1.43**	**7.2%**	**$0.19**	**0.9%**
Research Opportunity Awards - ROA	Research & Related Activities	1.35	1.15	1.17	-0.18	-13.0%	0.02	1.7%
	Education & Human Resources	-	-	-	-	N/A	-	N/A
	Total, NSF	**$1.35**	**$1.15**	**$1.17**	**-$0.18**	**-13.0%**	**$0.02**	**1.7%**
Research in Undergraduate Institutions - RUI	Research & Related Activities	27.59	29.68	29.78	2.19	7.9%	0.10	0.3%
	Education & Human Resources	-	-	-	-	N/A	-	N/A
	Total, NSF	**$27.59**	**$29.68**	**$29.78**	**$2.19**	**7.9%**	**$0.10**	**0.3%**
Science and Technology Centers - STCs	Research & Related Activities	49.65	62.38	67.48	17.83	35.9%	5.10	7.6%
	Education & Human Resources	-	-	-	-	N/A	-	N/A
	Total, NSF	**$49.65**	**$62.38**	**$67.48**	**$17.83**	**35.9%**	**$5.10**	**7.6%**

Totals may not add due to rounding.