UNDERGRADUATE SCIENCE, MATH, AND ENGINEERING EDUCATION: WHAT'S WORKING?

HEARING

BEFORE THE

SUBCOMMITTEE ON RESEARCH

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HOUSE OF REPRESENTATIVES

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CONTENTS

March 15, 2006

Page

Appendix: Answers to Post-Hearing Questions

UNDERGRADUATE SCIENCE, MATH, AND ENGINEERING EDUCATION: WHAT'S WORKING?

WEDNESDAY, MARCH 15, 2006

HOUSE OF REPRESENTATIVES,
SUBCOMMITTEE ON RESEARCH,
COMMITTEE ON SCIENCE,
Washington, DC.

The Subcommittee met, pursuant to call, at 10:00 a.m., in Room 2318 of the Rayburn House Office Building, Hon. Bob Inglis [Chairman of the Subcommittee] presiding.

COMMITTEE ON SCIENCE
SUBCOMMITTEE ON RESEARCH
U.S. HOUSE OF REPRESENTATIVES

Undergraduate Science, Math, and Engineering Education: What's Working?

Wednesday, March 15, 2006
10:00 a.m. – 1:00 p.m.
2318 Rayburn House Office Building (WEBCAST)

Witness List

Dr. Elaine Seymour
Author, *Talking About Leaving: Why Undergraduates Leave the Sciences*
Former Director of Ethnography and Evaluation Research
University of Colorado at Boulder

Dr. Carl Wieman
Distinguished Professor of Physics
University of Colorado at Boulder

Dr. John Burris
President
Beloit College

Dr. Daniel Goroff
Vice President and Dean of Faculty
Harvey Mudd College

Ms. Margaret Semmer Collins
Assistant Dean of Science, Business, and Computer Technology
Moraine Valley Community College

HEARING CHARTER

SUBCOMMITTEE ON RESEARCH
COMMITTEE ON SCIENCE
U.S. HOUSE OF REPRESENTATIVES

Undergraduate Science, Math and Engineering Education: What's Working?

WEDNESDAY, MARCH 15, 2006
10:00 A.M.–12:00 P.M.
2318 RAYBURN HOUSE OFFICE BUILDING

1. Purpose

On Wednesday, March 15, 2006, the Research Subcommittee of the Committee on Science will hold a hearing to examine how colleges and universities are improving their undergraduate science, math, and engineering programs and how the Federal Government might help encourage and guide the reform of undergraduate science, math, and engineering education to improve learning and to attract more students to courses in those fields.

2. Witnesses

Dr. Elaine Seymour is the author of *Talking About Leaving: Why Undergraduates Leave the Sciences* and the former Director of Ethnography and Evaluation Research at the University of Colorado at Boulder.

Dr. Daniel L. Goroff is Vice President and Dean of Faculty at Harvey Mudd College. Prior to joining Harvey Mudd, Dr. Goroff was a professor of the practice of mathematics and the Assistant Director of the Derek Bok Center for Teaching and Learning at Harvard University. Dr. Goroff co-directs the Sloan Foundation Scientific and Engineering Workforce Project based at the National Bureau of Economic Research.

Dr. John Burris is the President of Beloit College in Wisconsin. Prior to his appointment, Dr. Burris served for eight years as Director of the Marine Biological Laboratory (MBL) in Woods Hole, Massachusetts, and he served for nine years as a Professor of biology at the Pennsylvania State University.

Dr. Carl Wieman is a distinguished Professor of physics at the University of Colorado at Boulder and the recipient of the 2001 Nobel Prize in physics. Using his Nobel award money, Dr. Wieman has launched an effort to reform introductory physics. Dr. Wieman currently chairs the National Academy of Sciences Board on Science Education.

Ms. Margaret Collins is the Assistant Dean of Science, Business and Computer Technology at Moraine Valley Community College in the southwest suburbs of Chicago, Illinois.

3. Overarching Questions

- What are the obstacles to recruiting and retaining science, math, and engineering majors and what actions are being taken to overcome them?
- What are the obstacles to implementing reforms in undergraduate science, math, and engineering education?
- What role have federal agencies, particularly the National Science Foundation (NSF), played in improving undergraduate science, math, and engineering education? What more should federal agencies be doing in this area?

4. Background

Undergraduate education is the first step toward a career in science, engineering, or mathematics; it is the primary source of education and training for technical workers; and, it is often the last time non-majors will take a class in science and mathematics. Yet the undergraduate level is also the point at which many students who begin college interested in science, math, and engineering decide to move out of these fields.

U.S. Competitiveness

Over the past several years, a number of industry and policy organizations have released reports calling for increased investment in science and engineering research and increased production of students with degrees in scientific and technical fields, including the Council on Competitiveness, the National Academy of Sciences, AeA (formerly the American Electronics Association), the Business Roundtable, Electronic Industries Alliance, National Association of Manufacturers, TechNet, and the Association of American Universities. While the companies and the industry sectors represented by these organizations varies widely, one general recommendation was common to all of the reports: the Federal Government needs to strengthen and re-energize investments in science and engineering education.

The National Academy of Sciences, in its report *Rising Above The Gathering Storm: Energizing and Employing America for a Brighter Economic Future,* recommended establishing 25,000 new four-year scholarships to attract more U.S. undergraduate students to science, technology, engineering and mathematics (STEM) fields, and it encouraged research universities to offer two-year part-time Master's degrees that focus on science and mathematics content and pedagogy. Similarly, the Business Roundtable and other industry groups have recommended creating scholarships and loan forgiveness programs for students who pursue degrees in STEM fields and emphasize the need to improve recruitment and retention of STEM majors at undergraduate institutions.

Challenges in Undergraduate Education

The U.S. contains a large and diverse group of institutions of higher education. While American graduate education in STEM fields is generally considered to be the best in the world, the quality of students' undergraduate experiences can be hindered by insufficient pre-college preparation, poor college instruction, and high rates of attrition among potential STEM majors.

College Readiness

Recent results of national assessments of high school science and mathematics suggest that few students graduate with the mathematical or analytical skills necessary for college-level mathematics or science. According to the National Center for Education Statistics, all of the Nation's community colleges and most four-year institutions offer remedial courses in reading, writing and mathematics. In addition, Freshman Norms[1] trend data also reveals that more than 20 percent of first year college students intending to undertake a science or engineering major and 10 percent of those in the mathematics report that they believe that they will need remedial course work.

Federal education efforts undertaken in the context of the 2001 *No Child Left Behind Act* are providing greater focus on math and science, with annual assessments in mathematics occurring now and assessments in science starting in 2007. But many education experts point out that, until the quality of STEM education at the elementary and secondary levels improves, some students will continue to lack the necessary preparation for undergraduate education in STEM fields.

Attrition

According to the 2005 Survey of the American Freshman, the longest running survey of student attitudes and plans for college, approximately one-third of all incoming freshmen have traditionally contemplated a major in a science and engineering field, with most intending to major in a field of natural or social science and a smaller percentage selecting mathematics, the computer sciences, or engineering. Yet, half of all students who begin in the physical or biological sciences and 60 percent of those in mathematics will drop out of these fields by their senior year, compared with the 30 percent drop out rate in the humanities and social sciences. The attrition rates are even higher for under-represented minorities.

In research for *Talking About Leaving: Why Undergraduates Leave the Sciences,* the authors determined that the most common reasons offered for switching out of a science major included a lack or loss of interest in science, belief that another major was more interesting or offered a better education, poor science teaching, and an overwhelming curriculum. This study reinforced earlier anecdotal evidence that suggested that the sciences did a poor job of retaining young talent. In addition, and contrary to conventional wisdom that suggested that the students who switched out

[1] Higher Education Research Institute (HERI), University of California at Los Angeles, *The American Freshman: National Norms,* 2001.

of science majors were somehow less academically able, the researchers discovered that those who left were among the most qualified students[2] who had initially expressed the greatest interest in pursuing a STEM major.

Many researchers, including Stanford economist Paul Romer, believe that undergraduate education actively discourages more students from majoring in STEM fields or taking additional science or mathematics courses. Many colleges and universities have institutionalized a process partially designed to "weed out" all but the most committed students. While some amount of switching is appropriate, and few would disagree about the selective nature of many science and engineering programs, this "science-for-the few" approach seems to reduce the number of STEM majors unnecessarily and may be particularly alienating to women and under-represented minorities.

According to *Talking About Leaving,* most of the concerns of those who dropped out of science majors were shared by those who continued in science, math, and engineering. The chief complaint, cited by 83 percent of all respondents, was poor teaching. In the university setting, the traditional reward structure for faculty often favors the conduct of research over teaching. This can create an environment where faculty enthusiasm for and commitment to teaching is limited. As a result, undergraduates who take science and mathematics at many colleges and universities often find themselves in large lecture halls, taught by junior faculty. Student interaction with prominent research scientists ranges may be limited, and many of the junior faculty and teaching assistants may not be trained or motivated to teach well. Some may even be discouraged from expressing an interest in teaching or mentoring undergraduates.

In addition to these problems with courses for STEM majors, many introductory courses for non-majors fail to foster scientific understanding among the non-science majors. Without a broader context, many students never understand the process of science or the content of the subject matter. According to research in the *Journal of College Science Teaching,* this narrow approach to STEM courses alienates non-majors who graduate with the perception that science is difficult, boring, and irrelevant to their everyday interests.

Undergraduate Reforms

Individual faculty, departments, professional societies, and institutions of higher education are increasingly involved in reform efforts to enhance STEM curriculum and improve undergraduate teaching. Many of these reforms include the reexamination and restructuring of introductory and lower level courses to benefit both those who go on to careers as STEM professionals and teachers, as well as the vast majority who do not plan to become STEM majors.

The new goal of "science-for-all" seeks to provide opportunities for students of all backgrounds and interests to study science as practiced by scientists. Some faculty are trying to supplement lectures with discussion, small group work on a question or problem, and other short activities that are designed to break up the session and engage students in understanding and applying class materials. The new approaches attempt to present students with a coherent structure of general concepts that are established by experiment and to lead students to use problem-solving approaches that are applicable to a wide variety of situations—something that is typically experienced only in upper level courses. In addition, some colleges and universities are reexamining their incentive structures to encourage faculty to teach or mentor undergraduates and to ensure that introductory courses are taught by experienced faculty.

Federal Support for Undergraduate Education

The National Science Foundation (NSF) has historically been the primary federal agency to provide support for undergraduate education in STEM fields. In 1987, the National Science Board released a report on *Undergraduate Science, Mathematics, and Engineering Education,* better known as the "Neal Report"[3] after its chairman, Homer Neal of the University of Michigan. The Neal Report urged NSF to increase its investment in undergraduate education, and particularly to offer programs to involve undergraduate faculty and students in research activities.

NSF Undergraduate Education

NSF primarily funds undergraduate STEM education programs through its Division of Undergraduate Education (DUE). Funding for DUE programs at NSF has

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[2] Most qualified students were identified by high math SAT scores (at least 650) and their high school preparation.

[3] *Undergraduate Science, Mathematics and Engineering Education,* National Science Board, 1986.

declined each year since fiscal year 2004 (FY04). FY06 funding for DUE totaled $211 million, and the FY07 budget request is $196 million.

Several NSF programs in undergraduate education were created or expanded by the *National Science Foundation Authorization Act of 2002.* This Act established the Science, Technology, Engineering, and Mathematics Talent Expansion Program (STEP) to increase the number of U.S. students majoring in STEM fields. Specifically, STEP provides funding and rewards to colleges and universities that develop creative and effective recruitment and retention strategies that bring more students into science, mathematics, and engineering programs. The FY06 appropriation for STEP was $25.5 million; the request for FY07 is $26 million.

The Act also strengthened and expanded the Advanced Technological Education (ATE) program, which aims to expand the pool of skilled technicians in the U.S. by providing support to community colleges. Specifically, ATE supports curriculum development; professional development of college faculty and secondary school teachers; and efforts to align curricula to allow easy transition from high school to community colleges and community colleges to four year colleges and universities. The FY06 appropriation for ATE was $45 million; the request for FY07 is $46 million.

A third major program in DUE is the Course, Curriculum and Laboratory Improvement Program (CCLI). This program supports efforts to create new learning materials and teaching strategies, develop faculty expertise, implement educational innovations, assess learning and evaluate innovations, and conduct research on STEM teaching and learning. Funding for this program has declined in the past two years, falling from $94 million in FY05 to $88 million in FY06. The FY07 request is $86 million.

Other Undergraduate Support at NSF

In addition to the DUE programs described above, the Division of Human Resource Development (HRD) at NSF supports programs to increase the participation of under-represented students in science at all levels. Undergraduate programs in HRD include the Louis Stokes Alliances for Minority Participation Program ($35 million in FY06, $40 million requested in FY07), the Historically Black Colleges and Universities Undergraduate Program ($25 million in FY06, $30 million requested in FY07), and the Tribal Colleges and Universities Program ($9 million in FY06, $12 million requested in FY07).

Through its Research Experiences for Undergraduates program, which is run through NSF's research directorates, NSF supports active participation by undergraduates in research funded by NSF. Under this program, undergraduate students are associated with a specific research project, where they work closely with faculty and other researchers, and are granted stipends and, in many cases, assistance with housing and travel. (The research work can take place at a student's home institution or elsewhere, usually during the summer.)

Support for Undergraduate STEM Education at Other Agencies

While the U.S. Department of Education (ED) supports programs to strengthen undergraduate education, most are targeted to particular institutions and most are not STEM specific. For instance, ED supports several programs to build the capacity of Historically Black Colleges and Universities, Tribal Colleges, and other minority serving institutions, but funds may be used for a variety of purposes so it is difficult to determine what, if any, portion funds STEM reform. Outside NSF and ED, federal science agencies, including the U.S. Department of Energy and the National Aeronautics and Space Administration, provide opportunity for undergraduates to participate in research experiences at their facilities.

Legislation

While this hearing is not designed to focus on any specific legislation, it is worth noting that several bills have been introduced to strengthen STEM education in response to the various reports and commissions on U.S. competitiveness. Most of these bills seek to address the undergraduate recruitment challenge. Specifically, S. 2109 and H.R. 4654, the *National Innovation Act,* expand NSF's STEM Talent Expansion Program from $35 million in FY07 to $150 million in FY11. S. 2198, *Protecting America's Competitive Edge (PACE) Act,* awards scholarships to students majoring in STEM education who concurrently pursue their teacher certification, and H.R. 4434, introduced by Congressman Bart Gordon, implements the recommendations of the National Academy of Sciences' *Rising Above the Gathering Storm* report. S. 2197, PACE–Energy, also includes undergraduate education provisions, such as a scholarship program for students in STEM fields and the creation of a part-time, three-year Master's degree in math and science for teachers, but the programs are administered by the Department of Energy—not NSF.

5. Questions for Witnesses

The panelists were asked to address the following questions in their testimony before the Committee:

Dr. Elaine Seymour:

- What has your research shown about why potential science majors drop out of undergraduate science programs?
- What changes in undergraduate science education could prevent capable students from leaving science disciplines and perhaps also attract students initially not interested in science? What are the principle obstacles to implementing these changes?
- What role have federal agencies, particularly the National Science Foundation, played in improving undergraduate science education? What more should federal agencies be doing in this area?

Dr. Daniel L. Goroff:

- What obstacles have you encountered at Harvey Mudd College and Harvard University in recruiting and retaining STEM majors and what actions have you taken to overcome them? How are you measuring the effectiveness of those actions?
- What are the obstacles to implementing similar improvements at other institutions of higher education?
- What role have federal agencies, particularly the National Science Foundation (NSF), played in improving undergraduate STEM education? What more should federal agencies be doing in this area?

Dr. John Burris:

- What obstacles have you encountered at Beloit College in recruiting and retaining STEM majors and what actions has Beloit College taken to overcome them? How are you measuring the effectiveness of those actions?
- What are the obstacles to implementing similar improvements at other institutions of higher education?
- What role have federal agencies, particularly the National Science Foundation (NSF), played in improving undergraduate STEM education? What more should federal agencies be doing in this area?

Dr. Carl Wieman:

- What obstacles have you encountered at the University of Colorado in recruiting and retaining physics majors and what actions have you taken to overcome them? How are you measuring the effectiveness of those actions?
- How would your experience apply to other institutions of higher education or to other fields of science?
- What role have federal agencies, particularly the National Science Foundation (NSF), played in improving undergraduate STEM education? What more should federal agencies be doing in this area?

Ms. Margaret Collins:

- What obstacles have you encountered at Moraine Valley Community College in recruiting and retaining STEM majors? What actions has Moraine Valley Community College taken to overcome them? How are you measuring the effectiveness of those actions?
- What are the obstacles to implementing similar improvements at other institutions of higher education?
- What role have federal agencies, particularly the National Science Foundation, played in improving undergraduate STEM education? What more should federal agencies be doing in this area?

Chairman INGLIS. Good morning. The Subcommittee will come to order.

Before we begin, I would like to ask unanimous consent that Mr. Ehlers and Mr. Udall, who are not Members of the Subcommittee, be allowed to participate in today's hearing. Without objection, so ordered.

And I recognize myself for an opening statement.

And thank you to the panel for coming to share some thoughts about STEM education. It is crucial for us, as a nation, to figure out how to continue to lead in technology, and certainly the basis of that is an effective educational system.

I had an opportunity to hear some challenging remarks from David McCullough, the author of one of my favorite books, "John Adams," and I am listening now to 1776. David McCullough said something very interesting to a group of House Members, and Mr. Udall may have been there. He said, "We should eliminate the departments of education at colleges and universities." He said that we shouldn't have people that have education degrees teaching. "We should have experts teaching in their fields." His point of view was that historians should teach history, not education majors. It is a very interesting and provocative thought. He congratulated some work being done at, I believe, the University of Oklahoma that is headed in that direction, and it starts to sound promising, because, you know, when you think of it, when I was in high school, if I had been taught by somebody who loved math, passionate about math, and understood the interconnectivity of math principles, perhaps I might have caught the math bug. If I had been taught by somebody in science that really loved the subject matter, perhaps I might have caught the bug. As it was, my most memorable teachers were word teachers, English teachers who loved English, and the result was I headed more toward words than to formulas.

Now that has to be balanced. David McCullough's view has to be balanced with another observation. And this I have heard from visiting with research facilities at USC, University of South Carolina and Clemson University, for example, where the feedback that I have heard from some students is the teacher, the professor is just boring, as dull as a doornail, cannot teach, cannot inspire, cannot hold anybody's interest, and in some cases, a very difficult question has been raised, "I can't understand what he or she is saying." Now English is a second language for them, and they say "I literally cannot understand what they are saying in class."

Now that being the case, it seems that there is need for balance somewhere between David McCullough's point of view, which is only scientists should teach science, and the observation that if you don't understand education methods, maybe you can't really teach. And so, as always in life, there is a need for balance.

I hope that that is part of what we get at here at this hearing today. And it seems to me, it goes to one of the challenges we have got, which is how do you keep students involved in math and science? How do you capture their imagination? I am a lawyer, and one of the things that I have observed about legal education is that it is pretty interesting because most law is based on cases, and instruction of the law is based on cases. Well, cases are really stories, a story of how Mrs. Pfaltzgraff was standing by the railroad track and something happened and the clock hit her in the noggin, and she sued the railroad company, as I recall. I hope my professor from law school isn't here and remembering that I—realizing that I don't remember all of the facts of that case, but it is something like that. There is a story.

It seems to me, one of the challenges of science education, math education, engineering is making it that interesting. Recently, we on the Science Committee, had an opportunity to go to Antarctica. Yesterday, I was writing a thank-you note to one of the presenters down there. Truly a master teacher. The fellow held our interest for at least an hour, and really we would have begged him to go on, because he truly was a master teacher. He would ask—he would answer questions, but quickly get back to the subject that he wanted to talk about. He just did a masterful job. If I had had such a teacher in math and science, perhaps I would have continued on and not fallen into the dark side of the law.

But those are—I hope we get into that. I hope we figure—we hear some thoughts today about how we captivate the imagination and stimulate the interest of our students. And I thank the panel for joining us today.

Mr. Udall is voting in a committee. This is going to be a challenge today. We need a scientific breakthrough on having people in two places at once, and hopefully that is going to happen, because just as Mr. Udall is out now voting, I have a markup in the Judiciary Committee downstairs, so occasionally, I am going to be running from this room, literally, downstairs three floors to vote in that committee and then coming back.

So—but we do have Mr. Rohrabacher here, and I would be happy to yield to the gentleman from California for an opening statement.

[The prepared statement of Chairman Inglis follows:]

PREPARED STATEMENT OF CHAIRMAN BOB INGLIS

Good morning. Today's hearing on *"Undergraduate Science, Math, and Engineering Education: What's Working"* may be one of the most important hearings this subcommittee has this year and one in which I take a particular interest. I firmly believe that if we are to remain the world's leader in innovation and technology, we must provide our children—at all ages—with the education and tools necessary to excel in math and science, and we must make sure that those entrusted with teaching them possess not just the knowledge but the enthusiasm to inspire and stimulate them to excel in math and science. This is imperative if we are to sustain a strong and competitive science, technology, engineering and math (STEM) workforce capable of solving the known challenges of today and carrying us beyond the unknown challenges of tomorrow.

Recently, I had the privilege of accompanying National Science Foundation (NSF) Director Arden Bement to Mauldin Elementary School in my district. We witnessed a wonderful class project called "A World in Motion," which was originally funded by the NSF through a grant to the Society of Automotive Engineers. We watched fifth graders race small cars propelled by balloons that they had designed, built and studied. We heard their stories of the trials and tribulations they experienced while trying to build the car that would travel the fastest and the straightest. This was not just a project to see whose car looked the coolest. No, they had to learn how to measure speed and distance and figure out what aerodynamics would be best. Needless to say, watching these children with their science project made me ponder the question, "How do we as a nation continue to capture the science and math imagination and enthusiasm of these students as they continue their education?" For those who seemed really fired up and excited about what they were learning. . .and you could see it in their eyes. . .how do we keep that passion and motivation going to produce our next generation of scientists, mathematicians and engineers?

Granted, there are several hearings we could hold to examine the pros and cons of what we're doing along the K–12 path. The purpose of today's hearing, however, is to explore what is happening at the undergraduate level for those students who enter college enthusiastic about pursing a STEM degree and for those non-majors who would still benefit tremendously from a better background in math and science education. As we hear from our witnesses on how our colleges and universities are improving undergraduate STEM programs, we will hopefully be able to determine how the Federal Government might help further encourage and guide the reform of undergraduate STEM education to improve learning and to attract more students to courses and careers in the STEM fields.

While exact numbers tend to differ, all of the recent studies and reports that have recently been released suggest that the U.S. is being outpaced by China and India in terms of degrees granted in science and engineering. If we are to remain competitive, we must reverse this trend. To do so, we need to tackle several impediments that are affecting our ability to attract and retain students in STEM fields, primarily insufficient pre-college preparation, poor college instruction, and high rates of attrition.

Certainly, NSF, the primary federal agency tasked with providing support for undergraduate STEM education—and STEM education in general for that matter—is working hard to overcome these challenges. Other agencies, including the Departments of Education and Energy as well as NASA also have important roles to play. We need to make sure that they are coordinating their education efforts to ensure that this nation is poised for a new generation of innovative progress and prosperity, but that is a topic for another day and another hearing to be held later this month.

Not long ago, I read an intriguing article by a former chemical engineering major who left his course of study "in shame and disgust to pursue the softer pleasures of a liberal arts education." I'll submit the entire Tech Central Station article, "Confessions of an Engineering Washout," by Douglas Kern for the record, but want to kick-off the hearing with his telling admonition:

> If you want more engineers in the United States, you must find a way for America's engineering programs to retain students like, well, me: people smart enough to do the math and motivated enough to at least take a bite at the engineering apple, but turned off by the overwhelming course work, low grades, and abysmal teaching. Find a way to teach engineering to verbally oriented students who can't learn math by sense of smell. Demand from (and give to) students an actual mastery of the material, rather than relying on bogus on-the-curve pseudo-grades that hinge upon the amount of partial credit that bored T.A.s choose to dole out. Write textbooks that are more than just glorified problem set manuals.

I think he makes some valid points.

With that, I'd like to welcome our distinguished witnesses. I look forward to hearing from them on the strides they are making to improve undergraduate STEM education in the U.S., and I turn to the senior Democratic Member, Mr. Udall, for any opening statement he may wish to make.

Mr. ROHRABACHER. All right. Thank you, Mr. Chairman.

And let me just note that I, too, am going to be running off, because I have a markup in my committee, in my International Relations Committee, where I am Senior Member, in which we are marking up a bill dealing with one of the greatest challenges we have for our country today, and that is a relationship with Iran. However, I am leaving a hearing that I believe is focusing on what America's greatest challenge to our future is, our total future, and that is making sure that we are equipped to compete in the world of the—of tomorrow by making sure that our children are properly educated in math and science and engineering.

I would just like to make a couple thoughts for the record. And we had a discussion on this subject somewhat about a month ago. And I mentioned that we need to pay young people and other employees who are—have an expertise in math and science and engineering need to pay them better, and that is a way, perhaps, to attract more young people into the professions. And I got a lot of flack for that, Mr. Chairman. I mean, to me, it is a no-brainer, but I just got a lot of flack for saying that. But the kids who look and see that the lawyers all have the good—nice-looking cars and the big houses and maybe a very smart young person then decides to go into law rather than into engineering. I can understand that.

Well, let me just note that I see cost and compensation as being major factors in this discussion. And cost is what we need to bring down the cost for young people who want to get degrees in math, science, and engineering so when they leave their school they don't end up with a mountain of debt which they are not then hired by some law firm to take care of that debt, because now it is—they are on their own where math and engineering students from overseas, who are here taking advantage of our graduate programs especially, are sponsored by their own government, and they end up in no debt at all where our students end up entirely in debt, and they are almost indentured servants for five or 10 years of their life. That needs to be addressed. And my—I have some legislation aimed at—well, at least providing full scholarships provided by every department of government that uses an engineer or a scientist or a mathematician to provide scholarships designed to—then they—the student could pay it back by working for that government agency, which is a thought that I would like to discuss with the panel.

Second, we do not compensate our teachers in mathematics, science, and engineering at a different scale than we compensate the people who teach basket weaving and self-fulfillment and perhaps things of—and I will tell you, no wonder somebody who is a scientist or someone who is an engineer is not going to be attracted to teaching if, indeed, his compensation—his or her compensation level is no more than somebody who basically has the skills that I was talking about. I am not degrading basket weaving or home economics or anything like that, but perhaps we need the engineers and more skilled people in our schools, and we need to compensate them for it.

Finally, let me note this. When we talk about compensation, we have—I have had many a panel here talking about this problem, and I have seen this over the last—I have been a Member of the Science Committee now for 18 years. But you have these same businessmen who come here talking about the need of, you know, attracting our young people into these fields, and they are the same companies that come here lobbying us for massive numbers of H–1B Visas so that we can bring in people from overseas with these skills. And let me tell you what happens when you bring hundreds of thousands—we are talking about hundreds of thousands of engineers and mathematicians enter into this country over and above what our regular quota is for immigration. What it does is bid down wages. What it does, Mr. Chairman, is mean that the compensation of these young people, American young people, can expect is now lower because companies now can hire some fine young person from India or Pakistan or wherever to do that job at half the wage that they would have to pay an American to do it.

All of these things are impacting on these—on us and trying to solve this problem. And I would suggest again that the way to make sure that we have more young people who are intelligent young people, because, after all, there is a certain level of intelligence that you go into various fields, but we would like young people to go into engineering and math and science, and the best way to do that, Mr. Chairman, is to make sure you pay them more money. And we shouldn't be ashamed of that. We live in a capitalist society, and—but we have to do it based on all of these factors, making sure they are not in debt when they get through school and making sure we don't bid down their wages by bringing in hundreds of thousands of people from overseas in order to make sure that there is less money in their income.

With that, I appreciate my—you letting me have my say, and I will stay as long as I can, but I do have to handle this Iranian crisis, which is on us today, which I might add was created by engineers who are building nuclear power plants for a moolah-driven regime in Iran.

So with that said, that is it.

Thank you.

Chairman INGLIS. Thank you, Mr. Rohrabacher.

I—you will be hearing from the Basket Weaver Association later.

It is like the time I was on the Floor and said something about used car salesmen and then got calls from around the country.

Mr. Udall will be back momentarily, and when he comes back, we will recognize him for an opening statement.

[The prepared statement of Ms. Johnson follows:]

PREPARED STATEMENT OF REPRESENTATIVE EDDIE BERNICE JOHNSON

Thank you, Mr. Chairman and Ranking Member.

Education in science, technology, engineering and mathematics, also called STEM, has long been a passion of mine.

As former Ranking Member of the Research Subcommittee, I know the importance of STEM education and the prosperity and job security it can bring to our communities.

My home State of Texas is investing heavily in nanotechnology industry development and in other high-tech ventures. We need domestic talent to fill future jobs in these areas.

I would like to make the case of the critical importance of attracting ethnic minorities to STEM careers. My district is a "majority-minority" area, meaning we have more minorities than any other ethnic group.

I am interested what today's witnesses will tell us about how to captivate students' attention for STEM from a young age and hold their attention throughout middle school, high school, college and graduate school.

STEM careers often require advanced education, hard work and personal sacrifice.

How can we persuade kids to make a lifelong commitment to a STEM career when they are mired with student loans, academic positions are scarce and those that are open are quickly filled by individuals coming from outside the U.S.?

Major policy changes at every level will be needed. It is my hope that today's hearing can help legislators uncover the greatest leverage points to encourage participation in STEM careers and thus drive our economy forward.

Thank you, Mr. Chairman. I yield back.

[The prepared statement of Mr. Udall follows:]

PREPARED STATEMENT OF REPRESENTATIVE MARK UDALL

I am pleased to join the Chairman in welcoming our witnesses to today's hearing on exploring ways to improve undergraduate science, technology, engineering and math education—or STEM education, for short.

I would like to specifically welcome Dr. Weiman and Dr. Seymour that both have ties within my district at the University of Colorado. As many here know, Dr. Weiman won the Nobel Prize in Physics in 2001. However, what is most relevant to this hearing is how Dr. Weiman has leveraged this Prize to focus on improving undergraduate physics education. I hope Dr. Weiman will share with the Committee some of what he is doing in this area.

Dr. Seymour, the former Director of the Ethnography and Evaluation Research at the University of Colorado, is also joining us today. She is the author of *Talking About Leaving: Why Undergraduates Leave the Sciences.* This book evaluates why students are attracted to STEM fields and what causes them to switch fields of study. It also highlights the interaction of students with faculty.

I would like to again welcome both of you, and all of our witnesses for coming to discuss this important topic.

I see this hearing as addressing two important issues: how do we attract and retain students in associate and baccalaureate degree programs in STEM fields, and how do we ensure that all undergraduate students receive a quality educational experience in their STEM courses, regardless of the career path they choose.

Policy discussions of undergraduate STEM education tend to focus on numbers—are we producing too few scientists and engineers; are other countries out-producing us; can we stay competitive unless we greatly increase production?

Well, I certainly agree we must be sure that we are meeting the needs of the private sector and government for STEM graduates, and there is considerable evidence that we are doing so at present.

I believe the key issue is not only numbers but also the quality of STEM graduates and the capabilities they develop during their post-secondary education.

Project Kaleidoscope, which has been working for 10 years or more to improve undergraduate STEM education, recently released a report, *"Recommendations for Urgent Action,"* that lays out the questions we should ask in assessing whether STEM education is meeting the competitiveness challenge:

> 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?

The answers to these questions should inform STEM educational goals, the kinds of STEM courses offered, and the teaching styles and approaches used in undergraduate education.

Ultimately, the United States cannot out-produce the world in the number of new science and engineering graduates. Rather, we must ensure that our educational system produces graduates with capabilities that set them apart, so that they become successful innovators, life-long learners, and productive members of the Nation's workforce.

Today, we will hear from those who are engaged in undergraduate education in a range of educational settings—two-year colleges, primarily undergraduate colleges, and research universities.

I am interested in the witnesses' assessment of the current state of undergraduate science education and in their experiences regarding efforts to make improvements.

The basic questions today are what works, and what are the conditions necessary for success? I hope to hear what barriers and impediments exist in improving undergraduate STEM education, and in particular, what kinds of federal programs have proven to be helpful—or not helpful—in bringing about reform.

Naturally, the Subcommittee would be interested in your comments on the value of NSF-sponsored programs, and on any recommendations you may have for ways to improve the recruitment and retention of students in the science degree track.

I believe a major goal of efforts to improve undergraduate STEM education must be to institute policies and programs that will tap the human resource potential of individuals from groups under-represented in science and technology.

Simple demographic trends make clear the importance of increasing participation rates of women and minorities in meeting workforce needs of the future.

This is particularly true for attracting individuals to careers in the physical science and engineering. I know some of our witnesses have been engaged in programs that address this issue, and I look forward to learning more about them.

Mr. Chairman, I want to thank you for convening this hearing on this important subject. I appreciate the attendance of our witnesses today and I look forward to our discussion.

Chairman INGLIS. In the meantime, let me go ahead and introduce our panel. Mr. Udall may, in the course of his remarks, want to introduce two folks from Colorado, but first, we have Dr. Elaine Seymour, the author of "Talking About Leaving: Why Undergraduates Leave the Sciences." She is a former Director of Ethnography and Evaluation Research at the University of Colorado at Boulder.

Dr. Carl Wieman is a Distinguished Professor of Physics at the University of Colorado at Boulder and recipient of the 2001 Nobel Prize in Physics. Using his Nobel award, Dr. Wieman has launched an effort to reform introductory physics. He currently chairs the National Academy of Sciences Board on Science Education.

Dr. John Burris is the President of Beloit College in Wisconsin. Prior to his appointment, Dr. Burris served for eight years as Director of Marine Biology—let me try that again, Director of Marine Biological Laboratory in Woods Hole, Massachusetts, and he served for nine years as professor of biology at Pennsylvania State University.

Dr. Daniel Goroff is the Vice President and Dean of Faculty at Harvey Mudd College. Prior to joining Harvey Mudd, Dr. Goroff was a professor of the practice of mathematics and the Assistant Director of the Derek Bok Center for Teaching and Learning at Harvard University. He co-directs the Sloan Foundation Scientific and Engineering Workforce Project based at the National Bureau of Economic Research.

Ms. Margaret Collins is the Assistant Dean of Science, Business, and Computer Technology at Moraine Valley Community College in the southwest suburbs of Chicago, Illinois.

And when my colleague, Dan Lipinski, gets here—he is testifying at an Energy and Commerce Committee Subcommittee meeting, when he gets here, we will get a more full introduction of Ms. Collins by Mr. Lipinski.

So we generally recognize witnesses for five minutes, and then we will look forward to the time of questions and further comments from you and answers as we move beyond the testimony.

So, Dr. Seymour, if you would like to begin.

STATEMENT OF DR. ELAINE SEYMOUR, AUTHOR, "TALKING ABOUT LEAVING: WHY UNDERGRADUATES LEAVE THE SCIENCES;" FORMER DIRECTOR OF ETHNOGRAPHY AND EVALUATION RESEARCH, UNIVERSITY OF COLORADO AT BOULDER

Dr. SEYMOUR. Thank you very much for inviting me, Chairman Inglis. I appreciate this. It is a great honor.

In my written testimony, I structured my response in the following way.

First of all, I said something about factors, which, in my view, are shaping the problem that we have, and then the consequences for current and future STEM undergraduates, and then something about strategies, which I think will make a difference, some of these are underway, some of these are needed, and then some caveats.

What I think is underlying the problem we face is a historic decline in the perceived value of teaching. It has general relevance in the population, but it is particularly salient as part of the professional role of STEM faculty, where it has suffered over the last half-century with respect to the dominance of research. We noted it, in particular, in our book, "Talking About Leaving," in the decline in the number of seniors who were interested in entering K–

12 science and math teaching which dropped from 20 percent to less than seven percent by senior year over the course of our study. And most interesting, they—the seniors described their faculty as discouraging students from entering K–12 math and science teaching. And the students who decided to go on did not disclose their intention, normally, to faculty, because they feared that faculty would take them less seriously.

Now this problem creates, I think, an imbalance in our science structures. First of all, we have a salary structure in STEM faculty which is disproportionate to teaching effort. We have a reward structure for tenure and promotion such that research achievements are more stringently defined than teaching or service work, and teaching and the scholarship of teaching are barely developed or acknowledged.

The consequences are certainly seen in our work that the most serious problem spoken about both by people who field-switched out of the sciences and those who persisted amongst well-qualified students, whom we interviewed on seven different campuses, was that poor learning experiences were their most common problem. So for both groups, this was the main issue. Of the 23 issues that they raised, this was the most common issue.

This problem has not gone on unnoted amongst the many, many reports that we have seen over the last few years—that the quality of undergraduate STEM education has declined and is declining.

The second consequence, I think, shows in the inadequate preparation of teaching assistants who become young faculty, which then contributes significantly to poor quality undergraduate learning experiences, both now and when they become faculty. And we have a terrible shortage of good programs for training TAs, and they tend to be short orientations not specific to the discipline or the course. They do not significantly ground TAs in learning research and the knowledge and the practices that derive from this. And unfortunately, the STEM TAs seem the least likely to receive appropriate preparation. I have reviewed all of this evidence in our latest book “Partners in Innovation,” which is about TAs.

Thirdly, we have serious limitations in the K–12 math and science teaching force. It takes the form both of a serious and growing shortfall of disciplined, qualified math and science teachers in our middle and high schools, and in the quality of those teachers.

I have offered you, in the testimony, some of this evidence. We have vacancies in science and mathematics that we simply cannot fill. And in the latest report of the National Academy of Sciences' *“Gathering Storm,”* 59 percent of middle school students have math teachers who lack even a math education major. We saw this in our own book that just about the same numbers of switchers and persisters in the STEM majors struggled with under-preparation from the deficiencies of their math and science education in schools. The TAs, as I mentioned earlier, also endorsed this situation, over two-thirds of the TAs in our 2005 study, and those in another study done at the University of Nebraska (i.e., the same proportion) reported that students arrived under-prepared in the fundamental knowledge and skills needed to perform adequately.

The strategies that I have outlined in my testimony focus largely on professional development based on methods grounded in research about how students learn. And the groups who are, in my view, in need of professional development are current and future K–12 science and math teachers, they are TAs in STEM undergraduate courses, and they are current STEM faculty.

And matching the faculty incentives and reward system to the objectives of an improved education in science for all is critical if we are going to succeed in any of these strategies.

I will conclude my remarks at this point.

[The prepared statement of Dr. Seymour follows:]

PREPARED STATEMENT OF ELAINE SEYMOUR

The Research Subcommittee has asked me to address the following questions:

- What has your research shown about why potential science majors drop out of undergraduate science programs?
- What changes in undergraduate science education could prevent capable students from leaving science disciplines and perhaps also attract students initially not interested in science? What are the principle obstacles to implementing these changes?
- What role have federal agencies, particularly the National Science Foundation, played in improving undergraduate science education? What more should federal agencies be doing in this area?

On the basis of my work as a science education researcher and as an evaluator of both campus-based and large national initiatives focused on improving quality and access in undergraduate science education, I offer some answers to these questions under the following headings:

1. Factors that shape the quality of undergraduate science, technology, engineering, and mathematics (STEM) education
2. Their consequences for current and future STEM undergraduates
3. Strategies (both underway and needed) that address current difficulties
4. Some caveats: why are some changes difficult to secure

1. Factors that shape the quality of undergraduate science, technology, engineering, and mathematics (STEM) education

Two inter-related factors—one cultural, the other structural—underlie the problems with undergraduate science education that have been identified over the last two decades. These factors also explain some of the difficulties encountered by those who seek to improve STEM education, both at the undergraduate and K–12 levels. The first may be described as a history of **decline in the perceived value of teaching.** Among STEM faculty, teaching has come to be seen as a far less important part of their professional role than research, and STEM faculty overall do not encourage K–12 mathematics and science teaching as a career for their STEM graduates.

In our study of why undergraduates leave the sciences (Seymour & Hewitt, 1997), we noted that, although almost 20 percent of our student sample had seriously considered science or mathematics teaching, this dropped to under seven percent in senior year among those who persisted in their STEM majors. A major factor in this decline was students' awareness that their professors—whose approval and support they sought in developing a career path—defined teaching ambitions as "deviant." Faculty were commonly believed to withdraw from students who openly expressed an interest in K–12 teaching and those who still intended to teach become covert about their intentions:

> I think that's ultimately the problem with math and science in this country—we don't value teachers enough. Professors are valued but the high school teachers are not. If you wanna teach science in high school, that's taboo: you're treated as an outcast by the faculty here. (male white switcher)

> I've never discussed it with any of my chemistry professors. For the most part, I've got a feeling of disdain for teaching from them. This is something that they have to do, but they don't really support anyone who wants to do it. Fortunately, I had an incredible chemistry teacher in high school, and I go back and chat with him still. He tells me, You're going to be a good teacher." I get more

encouragement from him than from anyone on campus. (male white science persister)

Students who wanted to teach also described discouragement from family members and peers who perceived teaching as a career with low status, pay, and prospects. Students of color were the only STEM seniors who reported encouragement from faculty and advisors to become K–12 teachers.

With respect to faculty's own work, the balance of status and rewards has, over time, tipped heavily towards research and away from teaching. Although lecturing has historically been the dominant mode of instruction, it was traditionally supported by various forms of interactive small group teaching such as tutorials and seminars, and by advising and mentoring of students on an individual basis. The pressure to spend more time on research has led to the dwindling of these interactive teaching functions among faculty, and their placement in the hands of (largely untrained) teaching assistants (TAs). Thus "straight lecturing" (often in classes of several hundred students) has increasingly become faculty's main or sole mode of teaching.

This trend has its roots in the 1950's and '60's with a progressive shift from private to public funding for university research. The Federal Government offered increasing funds to carry out large-scale basic research and projects with both military and industrial/commercial relevance (Kevles, 1979; Fusfield, 1986). Professional success in academe is now clearly defined in terms of research grant writing and publication. This imbalance is reflected in **the departmental and institutional rewards systems for tenure and promotion** in which research achievements both outweigh and are more stringently defined than teaching or service work. While the scholarship of teaching is a lively and growing area of intellectual dialogue on campuses nationwide, its application to criteria for faculty rewards is barely developed and under-acknowledged (Boyer, 1990). The main mechanism by which teaching effectiveness is judged, namely student course evaluation surveys administered by institutions, are widely acknowledged to be poor measures of teaching performance and even poorer measures of student learning gains (Kulik, 2001).

The consequences of this situation have not gone unnoticed. Concerns about the quality of STEM undergraduate education have been raised in a number of reports, notably, those of the National Science Foundation (*Shaping the Future,* 1996), the National Research Council/the National Academy of Sciences: *Transforming Undergraduate Education* (1999), *Improving Undergraduate Instruction in Science, Technology, Engineering, and Mathematics* (2003), and, most recently, *Rising above the Gathering Storm* (2005). There has also been a rising demand for course assessment tools that more accurately reflect student learning (Hunt & Peligrino, 2002) by accreditation boards (and others) who no longer view grades given by faculty as acceptable evidence of student learning. State legislatures have also expressed concerns about the quality of undergraduate education (e.g., Colorado Governor, Bill Owens' State of the State address, January 2006) and departments are increasingly called upon to define objectives for student learning and demonstrate their attainment (Wergin, 2005; Peterson and Einarson, 2001).

Although many STEM faculty are currently seeking to improve the effectiveness of their teaching and to develop more accurate ways to assess their students' learning, they do so in the face of deterrents in the faculty rewards structure. In our interview studies, pre-tenured faculty commonly report that they are strongly counseled by their mentors to defer an interest in teaching until after they gain tenure—often seven or so years into their careers. In our evaluation work for two of the five major chemistry initiatives sponsored by the National Science Foundation[1] that have developed and tested modular materials and methods for the teaching of undergraduate chemistry, three active young faculty contributors to that initiative were denied tenure on the grounds of their "over-focus" on educational scholarship (Seymour, 2001). Panelists and participants at the 1998 National Institute of Science Education (NISE) Forum on the future of STEM education concluded, with regret, that younger faculty should be advised to defer their interest in improving their teaching and assessment methods and avoid the introduction of education scholarship into their tenure portfolios (NISE, 1998).

2. Consequences for current and future STEM undergraduates

The lower value placed on teaching compared with research both in STEM faculty attitudes and in academic salary and rewards structures has consequences for the quality of both undergraduate and K–12 education in science and mathematics.

[1] The ChemLinks Coalition ("Modular Chemistry: Learning chemistry by doing what chemist do") and the Modular Chemistry Consortium, now combined as "ChemConnections."

A. STEM undergraduates' problems with their learning experiences

In *Talking About Leaving: Why Undergraduates Leave the Sciences* (1997), Nancy Hewitt and I discussed our findings from a study of field-switching and persistence among well-qualified students (i.e., those with SAT mathematics scores of 650 or above) who entered science, mathematics and engineering majors in seven institutions of different types. Across all seven campuses, we found that reports of poor learning experiences were by far the most common complaint **both** of those who switched out of science, mathematics, and engineering majors (90 percent) **and** of graduating seniors in those majors (74 percent).

Undergraduates' problems with what they referred to as "poor teaching" ranked first among 23 types of problems with their majors identified by graduating seniors in six of the seven institutions. Unsatisfactory learning experiences in their science and mathematics courses were the primary cause of switchers losing their incoming interest in the sciences, and moving into disciplines where they had better educational experiences. The students' concerns about how their courses were taught focused on the following issues:

- Courses (and the curriculum overall) were over-stuffed with material and delivered at too fast a pace for comprehension, reflection, application, or retention;
- Faculty paid insufficient attention to preparing their courses, selecting course content and materials at an appropriate level and depth, or presenting them in a logical sequence;
- Objectives and content of class and lab did not "fit" together; students did not perceive the conceptual connections between them; (for example, students commonly reported that they did not know why they were conducting particular lab experiments); and saw lack of coherence between course content and tests, the text, and/or homework;
- Conceptual material was little applied, illustrated, or discussed;
- Curved grading systems disengaged grades from learning and from students' perceptions of mastery; created artificial and demoralizing forms of competition; and made collaborative peer learning difficult;
- Faculty showed or expressed dislike or disinterest in teaching;
- Faculty appeared to distance themselves from first-and second-year students, and seemed insufficiently available for help and advice;
- Faculty modes of teaching suggested that they took little responsibility for student learning, such as checking to see if students were understanding class material;
- Faculty did not clarify their learning objectives for students and showed little knowledge of pedagogy other than lecturing;
- Able students became bored by their introductory science courses despite their strong incoming interest in science;
- Many students developed instrumental attitudes towards their STEM education: they focused on grades rather than mastery, cheated to beat the curve, and did not retain content knowledge that they memorized mainly for tests.

The aspects of introductory classes that discouraged young women were different from those that deterred young men from continuing in STEM majors (Seymour, 1995; Seymour & Hewitt, 1997). Broadly, features of faculty teaching that reflected the weed-out system (such as fast pace, work and content overload, harsh competition created by curve grading) were far more effective in prompting male students to switch. Young women suffered from different aspects of STEM faculty's approach to teaching undergraduates: they experienced rapid loss of their incoming confidence because they were unable to establish with their professors the kind of interactive learning and support they had enjoyed with high school teachers. Faculty's failure to encourage them was taken as active discouragement. This was compounded in departments where hostile treatment from male peers was a daily experience. Able women quickly came to doubt whether they belonged in the major, and doubts shared with their families provoked more encouragement to switch out of the sciences than was experienced by similarly placed male peers. The result in our own university was that women were switching out of STEM majors with higher Predicted Grade Point Averages (PGPA) than the men who persisted in them.

We concluded that problems with the quality of undergraduate education especially in the first and second years were a major determinant of the consistently high field-switching rates (40 percent to 60 percent) reported for STEM majors in the *American Freshman* studies of the Higher Education Research Institute, UCLA

(HERI, 1992). The students' descriptions of their experiences and their responses to them were also consistent with the view (directly articulated by some students) that many faculty disliked teaching, did not value it as a professional activity, and lacked incentives to learn how to teach effectively:

> About the end of the semester he said, "I guess by now you've all realized that the university is not for teaching students." He put it plain, right out in the open. . ..In effect, he was telling us, "If you want to succeed here, you're going to have to do it by yourself." (male, white, science senior)

The students also reported experiences with science faculty who seemed to enjoy their teaching, took pains to be well organized and clear, and who took an active interest in their students. Seniors were, however, aware of the research pressures on their professors that limited the time and energy they could give to teaching. They were less aware of the tenure and rewards system that made it difficult for faculty interested in education to improve their pedagogy or that made it a highly risky form of activity for pre-tenured faculty.

Some caveats: Students can only describe their classroom problems in light of what they know about teaching and learning from current and prior experience. For less well-prepared students, their undergraduate STEM course experiences often mirror in an extreme form the limitations of their high school science learning experiences. These are characterized by passive reception of information (rather than active engagement with ideas), minimalist attitudes to reading and writing, formulaic approaches to learning focused on memorization rather than conceptual grasp, and carrying out tasks rather than thinking. Students also lack a conceptual framework based in cognitive science research to explain why the pedagogy they have experienced does not enable their learning. Most students in the study simply did not know what other modes of teaching and learning might be available and regarded the lecture format and curved grading systems as inevitable parts of undergraduate life. Lack of knowledge of what alternative pedagogical methods would entail helps to explain a certain amount of student resistance to the introduction of new pedagogies. When faculty begin to address the problems students identify by teaching in ways that require more active student engagement and responsibility, students often resist these unfamiliar, more demanding pedagogies—at least initially. Better the devil you know. . ..

How some STEM faculty have responded to their students' learning problems that they also have recognized is discussed in the next section.

B. The lower level of importance that faculty assign to their teaching role (whether by choice or career necessity) is also reflected in **inadequate educational preparation of graduate students for their roles, either as teaching assistants (TAs), or as young faculty** despite faculty's increased dependence on TAs to provide interactive learning support to students. As I have recently outlined (Seymour, 2005) the need to prepare TAs was first mooted in the 1930s and it continued to be proposed throughout the following decades. However, in a historical review, Nyquist, Abbott and Wulff (1989) comment on the slow progress of universities to provide formal professional development for teaching assistants. After the first national conference on TA issues in 1989, more universities began to offer TA preparation in an effort to improve undergraduate education. However, the available research (summarized in Seymour, 2005, Chapter 10) indicates that most institutions and disciplines either do not offer formal educational preparation for their TAs or offer programs that are informal or limited in scope—most commonly, short orientation sessions that are not discipline- or course-specific. Furthermore, most existing programs do not ground TAs' work in learning research and the teaching practices that derive from this body of knowledge. Most TA training (sic) programs give advice on management of their lab and recitation sections that are relevant only to the lecture mode. Although the STEM disciplines are major employers of TAs in their large introductory classes, Shannon, Twale, and Moore (1998) found that TAs in science, mathematics, and engineering classes were the least likely to receive appropriate educational preparation for their teaching support work. This ongoing situation significantly contributes to poor-quality undergraduate learning experiences. It is of particularly concern because STEM undergraduates attest the importance of good TAs to their learning and academic survival (Seymour & Hewitt, 1997).

A large body of cognitive research and classroom practice exists upon which STEM faculty can draw in rethinking their own teaching and in developing appropriate educational preparation for their TAs. Broadly, research on learning (cf., Brandsford, et al., 1999; 2000) proposes that students progressively build a personal knowledge framework based on what they already understand, and, that conceptual mastery and resolution of misconceptions is best accomplished in active engagement with ideas and problems, including interactive exchanges with teachers, TAs, and peers. Strategies that reflect the findings of cognitive science include a shift in approach from teaching to enabling learning, a focus on problem-based and contextual learning, inquiry and hands-on discovery, and reduction in the breadth of "coverage" in favor of strategies that encourage deeper understanding. Students are also encouraged to connect and apply their knowledge and to take more responsibility for their own learning. Teachers are encouraged to articulate their learning objectives, match their selection of materials, content emphases, and learning assessments to these, make their learning objectives and expectations clear to students, and "signpost" for students the intellectual path they are taking through the content (Seymour, 2001). Teaching methods derived from this body of theoretical and applied knowledge are increasingly referred to as "scientific teaching" (Handelsman et al., 2004). The available literature is too large to summarize here, but, in addition to theoretical and research publications, it includes descriptions and evaluation results from STEM faculty's endeavors to implement these principles in their approaches to the teaching and development of class and lab materials and methods—a body of work that constitutes a growing scholarship of education among an active minority of STEM faculty.

The research, its applications, and outcomes have, in recent years, been offered in forms that are very accessible to faculty who are interested in understanding more about how students learn and how best to enable learning in their own teaching work (reviewed by DeHaan, 2005). Strategies for teaching student to be active, interactive, and independent learners, and for designing problem-based, inquiry-focused class and lab work are offered on a number of web sites, for example: *http://thinkertools.soe.berkeley.edu, www.udel.edu/pbl/, www.bioquest.org, www.provost.harvard.edu/it_fund/moreinfo_grants.php?id=79.* Information about *workshops* that give faculty hands-on experience in using active learning methods (including working with chemistry modules) is available at *www.cchem.berkeley.edu/~midp.* Some web sites focus on *particular disciplines:* In chemistry: *http://chemconnections.llnl.gov,* PLTL: *www.sci.ccny.cuny.edu/-chemwkssp/nde.html,* CPR: *www.molsci.ucla.edu/default.htm,* OGIL: *www.pogil.org/*. In physics: TEAL: *http://evangelion.mit.edu.edu/802TEAL3D,* SCALE-UP: *www.ncsu.edu/per/scaleup.html.* In biology: BioSciEdNet(BEN): *www.biosciencenet.org,* Bioquest: *www.bioquest.org/BQLibrary/bqvolvi.html,* undergraduate bioinformatics: *www.cellbioed.org/article.cfm?ArticleID+157.* Others sites (such as those offered by the University of Wisconsin) offer assistance to faculty in designing *learning assessments* (tests, projects, etc.) that reflect course learning objectives (using the *Field-Tested Learning Assessment Guide*); and in obtaining feedback on the degree to which *students assess their learning gains* in particular aspects of their courses (the on-line "Student Assessment of Their Learning Gains" instrument). Both sites can be found at *www.flaguide.org.* I have been closely involved in the development of both sites and attest to their widespread use by STEM faculty. The University of Wisconsin Center for Education Research also houses web sites offering practical advice to faculty in collaborative learning methods and in the use of technology in their classrooms.

Notwithstanding its growing availability, this knowledge is still unknown to and unused by most, STEM faculty, and the knowledge and expertise of education faculty at their own institutions is often ignored or discounted. A survey of 123 research-intensive universities nationwide by the Reinvention Center at Stony Brooke (2001) found evidence of scientific teaching among only small numbers STEM faculty at approximately 20 percent of these institutions. Failure to convey this knowledge to TAs perpetuates in the next generation of faculty the limited knowledge of research-grounded teaching practices and limited priorities that characterize current faculty teaching. Both our TA study, and that done by French and Russell (2002), note how quickly graduate students can develop misconceptions about how learning takes place, and assume unfortunate attitudes towards teaching that they observe in their professors. Once established, these prove hard to dislodge. Hammrich (1996) found that TAs commonly believe student understanding to be a matter of "automatic transmission or absorption" rather than an "active process of interpreting information and constructing understanding" (p.8). In the innovative science courses included in our study, one (happily minority) source of TA resistance was the requirement that all TAs use the same active, interactive, inquiry-based methods that they were being taught to use in their lab and recitation sections. This affronted some TAs' presumption that, like faculty, they had the right to teach however they saw fit. Creating change among the existing STEM faculty, though not (as I shall later argue) impossible, is a more difficult endeavor than choosing to give graduate students an adequate preparation for their present and future teaching roles that is grounded in a researched-based understanding of how students learn.

C. STEM undergraduate under-preparation and limitations of the K–12 teaching force

Lack of faculty support for science and mathematics teaching careers among their STEM majors, coupled with a historic decline in the number of high-ability women entering mathematics teaching (noted by Schlechty and Vance as early as 1983), and perceptions of lower status and pay for K–12 teachers in the general American population, have combined to create a serious shortfall of discipline-qualified mathematics and science teachers in middle and high schools. The situation has been well-documented over the last decade (e.g., Gafney and Weiner, 1995; Schugart & Hounsell, 1995; Clewell & Villegas, 2001), and was most recently cited in the National Academy of Sciences report, *Rising Above the Gathering Storm* (2005).

Problems of shortage are compounded by concerns about quality. The 1990–91 Schools and Staffing Surveys (SASS) warned that 72 percent of public secondary school mathematics teachers and 38 percent of science teachers had not earned a Bachelor's degree in their disciplines and that those with a disciplinary qualifications were an aging group that was not being replaced by entrants to the profession. In 1997, the U.S. Department of Education reported that 39 percent of school districts had vacancies for mathematics and science teachers, of which 19 percent went unfulfilled. In that year also, President Clinton, in his State of the Union address, urged that, "We should challenge more of our finest young people to consider a career in teaching." Whether in response to this appeal or to a down-turn in the job market, in the late 1990s, the numbers of non-STEM baccalaureate entrants to the teaching profession began to rise. However, this was not the case for science and mathematics teachers where the shortfall continued to worsen. In 2000, National Science Teachers' Association nationwide survey showed that 61 percent of high schools and 48 percent of middle schools were experiencing difficulty in locating qualified science teachers to fill vacancies and that many schools were obliged to fill vacancies with less qualified or temporary teachers. In 2004, Bruillard reported that districts were importing international K–12 teachers to fill their mathematics and science vacancies. The situation has been most acute in schools with more than 20 percent minority enrollment (Clewell & Villegas, 2001). States such as Texas, Florida, and New Jersey with high mathematics and science teacher vacancies have turned to alternative or emergency certification of people with some STEM background, such as retired military personnel. Most recently, the National Academy of Sciences (2005) report warned that only 41 percent of U.S. middle school students had a mathematics teacher who had majored in mathematics education (let alone an undergraduate mathematics major), while, internationally, the average is 71 percent and in many countries is greater than 90 percent.

The consequences of the shortage of qualified mathematics and science teachers in middle and high schools were evident in our *Talking About Leaving* study findings. The discovery of a gap between the levels of knowledge with which students had graduated from their high schools and those demanded of them in introductory college mathematics and science courses was a common experience. However, it was evident that, in 39 percent of all student statements about problems with their educational experiences, the gap reflected serious under-preparation. There was no difference between the switchers (40 percent) and the persisters (38 percent) in this regard. However failure to find remedial help from a tutor, study group, or other means in order to make up the gap was mentioned as a factor in switching.

Many switchers and persisters who had taken Advanced Placement mathematics and science courses were shocked to find that these courses had been offered at too low a level to adequately prepare them for their first college courses. Their experience is echoed in findings of significant variations in the quality of AP courses first reported by Juillerat et al. (1997). There were also regional and race/ethnicity patterns in our findings on under-preparation problems. Students at the east coast state university in our sample experienced the greatest variability in the reliability of their high school science and mathematics grades as an indicator of their college-level work. They expressed frustration that neither they nor their parents could have known the extent of their under-preparation from their grades or their teachers' evaluations of their work. Students of color from high schools predominantly attended by students of the same race/ethnicity were at particular risk of a phenomenon that we labeled, "over-confident and under-prepared." Teachers, parents, and community members had sent students to college with a strong sense that they could succeed in STEM majors, only to find that their science and mathematics preparation seriously undermined their chances. This group gave some of the most heart-rending accounts that we heard in this study of their failed efforts to close the preparation gap. Rather than identifying inadequacies in educational provision as the cause of their problems, most of these students blamed themselves. These students were at high risk, not only of switching, but of dropping out of college altogether. Faculty attitudes towards under-prepared students also played a role in the loss of able students. Questioning the adequacy of their high school preparation was highly evident at institutions where we found the weed-out tradition to be strongest: loss of confidence and discouragement engendered by low grades were highly ranked as a cause of switching in the two western state universities where weed-out assessment practices were strong, particularly in the colleges of engineering.

Teaching assistants in our 2005 study also struggled with high variability in the high school preparation of the undergraduates with whom they worked in recitation and lab sections. The 42 chemistry TAs at the University of California, Berkeley who were helping to prepare students to enter chemistry majors, expected undergraduates to enter the course with sufficient knowledge and skills in chemistry and mathematics to undertake the class work. They assumed that students would be able to solve problems, operate in the lab, write lab reports, and tackle unfamiliar problems by using what they already knew. In all of these expectations, they were disappointed. More than two-thirds of the Berkeley TA sample reported that students arrived under-prepared in the fundamental knowledge and skills needed to perform at least adequately. Their direct experience with students in their lab and recitation sections led them to conclude that many did not posses an understanding of the methods and principles of science and some could not do elementary algebra. TAs also noted that the writing and study skills of some students were poor. Overall, fewer than one-third of the TAs working in this large introductory chemistry class felt that most of their students entered the course with the requisite knowledge and skills to undertake it:

> A lot of these students have problems, not just with the math, but with basic algebra and with manipulating equations to get things in the right form and so on. And the class assumes that they know how to do that kind of thing.

Concern that their first- and second-year students entered their classes under-prepared for their course work was also documented in a survey of 314 TAs in forty-five courses at the University of Nebraska, Lincoln (Luo, Bellows, & Grady, 2000) in which (as at Berkeley) two-thirds of the TAs assessed their students as under-prepared. By contrast, the Berkeley TAs noted that some students were over-prepared for this introductory course. Indeed, the TAs' largest single teaching difficulty was the wide variation in the levels of preparation in mathematics, science, writing, and study skills that their students had received from their pre-college education. Their testimony underscores the problems both of widespread under-preparation in middle and high school mathematics and science, and of significant regional and local disparities in the quality of mathematics and science education offered.

The 110 TAs included in our study were generally not disposed to blame the students for inadequate preparation and we document their efforts to help their students make up for lost ground. However, we also note the irony of STEM faculty treating under-preparation as an indication of students' lesser worth given the contribution of STEM faculty as a whole to the continuing shortage of adequately qualified K–12 science and mathematics teachers. In light of the problems this shortage creates for access, quality, and persistence in undergraduate STEM education, I propose that rethinking the roles and professional development of teaching assistants offers an opportunity to break part of the cycle that has simultaneously perpetuated the decline in the perceived value of teaching, diluted the quality of undergraduate STEM education, and constrained the building of a discipline-educated teaching force in science and mathematics that is adequate to national needs.

3. Strategies (both underway and needed) that address current difficulties

Given my diagnosis of factors contributing to problems in the quality of undergraduate STEM education, I focus on three main areas of activity that seem to offer the best promise of improvement. All three involve active efforts in the professional development of teachers—current and future K–12 science and mathematics teachers, teaching assistants in STEM undergraduate courses, and STEM faculty—based on methods grounded in research on how students learn.

First some caveats: Faculty will always be at varying stages of readiness to change their thinking and attitudes about teaching and learning or consider new practices. Some are already active; others interested, curious, or skeptical; and some will remain firmly committed to current teaching methods regardless of the evidence as to the greater benefits of alternative approaches or evidence of failures in what they are doing now. Providing clear and convincing evidence that innovative forms of teaching are as effective or better than more traditional approaches is always a necessary but not a sufficient condition for change. The idea that good ideas, supported by convincing evidence of their effectiveness, will spread 'naturally' as their success becomes known, is unfounded. As Kuhn (1970) noted, shifts in scientific theory do not occur as an automatic response to accumulations of data. When the shift that is called for is one of values, attitudes, and social behavior, the response is, as Tobias (1992) observed, often unaffected by available evidence. Indeed, there is research evidence that the personal endorsement of classroom innovations by colleagues who are esteemed for their *research* standing is more effective than evidence presented in scientific articles or direct demonstrations of the superior outcomes of particular methods (Foertsch et al., 1997). Thus, change of whole departments or institutions in the same time frame is apt to be difficult, and may prove impossible.

Although I am aware of some STEM departments where every member is actively implementing new forms of teaching and learning, these are a small minority. In most departments, innovation-minded faculty will be a minority. Whether changes are mooted by more radical colleagues, by institutional or state leaders, or by outside agencies, departments in which the majority of faculty are committed to the status quo can effectively resist change. (The exception seems to be accreditation boards which can and do exercise effective leverage.) Departments have the power to resist change, partly because of the established tradition of faculty post-tenure autonomy in matters of academic and professional judgment, and partly because reference to disciplinary standards and practices can be argued by department members to supersede other authorities. While this system has merit for many other reasons, it has proved a serious barrier to widespread faculty use of the many pedagogical alternatives that are freely available to them.

These difficulties suggest two lines of action:

a). Following the argument already laid out, I urge the **design and implementation of department-based, discipline- and course-specific, programs for the professional development and support of teaching assistants** (STEM and otherwise). This preparation should expose them to cognitive science research on student learning, the range of teaching approaches and specific methods that this research reports, and offer guided practice in working interactively with students to enable their learning. In the view of the TAs in our 2005 study, preparation and support programs were best when attached to the faculty and course that each TA served rather than broader preparation in departmental or campus-wide programs that are unrelated to their working experience. As argued earlier, this strategy holds the promise of preparing the next generation of faculty more appropriately and adequately for their teaching role than their predecessors and will make the diffusion of effective educational methods progressively easier with each generation of STEM graduates.

A set of suggestions for what such a course might contain for TAs who are working with faculty who are implementing innovative courses was offered by TAs in my 2005 study. Grounded in their experience, they sought a course that would:

- introduce them to the scholarship of learning and the educational practices that support student learning
- give clear guidance as to the principles and methods of the course they are to work in, its learning objectives, and the methods and materials to be used in working with students
- model for them pedagogical skills and techniques for working interactively with students
- guide them in dealing with common problems—handling questions to which they do not know the answers, disruptive or non-participative group members, and disciplinary problems
- prepare them working alongside faculty for new activities, such as inquiry-based labs and teaching students to work with authentic data
- offer practice and feedback on their work
- enable resolution of issues encountered in implementing course activities through regular (weekly) collegial discussions with each other and their course faculty
- engage them collegially in the development and refinement of new courses, including learning assessment, and their faculty's educational research based on their courses.

The TAs felt that they learned most when their education was firmly related to the work they were doing and where they had opportunities to contribute in a collegial manner to course development.

b) Secondly, I urge concentration on the professional development and recognition of STEM faculty who recognize problems in the quality of STEM education, who are curious about or interested in alternative approaches to teaching and learning, are open to change, and those who have already begun to work with new material and methods. Connect these faculty with similarly-interested colleagues in other STEM departments at the same and other local institutions, and with national disciplinary networks of innovative STEM faculty, to form mutually-supportive communities of learner-practitioners. This strategy is discussed in terms of **professional development workshops for faculty.**

While the *Talking About Leaving* study was underway, faculty around the country who had also recognized many of the problems identified by students had begun to explore and share at conferences and on web sites a body of research-based knowledge about how learning happens and strategies that would better enable it. By the time the book went to press, the first workshops for faculty wishing to learn how to teach more actively and interactively were already being held. These were largely offered by Project Kaleidoscope, organized by Jeanne Narum at the Independent Colleges Office. Project Kaleidoscope has also taken a leading role in the dissemination of materials that promote and describe scientific teaching and learning methods.

In 2000, the National Science Foundation funded the Multi-Initiative Dissemination (MID) Project workshops which were organized and offered by faculty who were active in the undergraduate chemistry initiatives also funded by the NSF. These workshops continued to be held in regional centers until recently when government funding for the NSF's STEM education work was reduced. Faculty-led workshops have proved a highly effective and relatively inexpensive way to:

- make other faculty aware of the range of teaching methods and materials grounded in cognitive science research available to them
- see these methods modeled
- try them out in a supportive group context, and
- begin to develop their own course material and methods with help from workshop organizers and other participants. This activity continues to be supported beyond the workshop.

The faculty who organize and run the workshops are drawn from a growing pool of experienced users of scientific teaching materials and methods. They are paid only a modest stipend and their travel expenses. Workshop evaluators (Lewis & Lewis, 2006; and Burke, Greenbowe, & Gelder, 2004) point to the power of the workshop method to change the participants' conceptions of teaching and learning:

> They leave the workshop sessions thinking in a different way about how effectively their students are currently learning and what modifications they might make to change that. (Burke, Greenbowe, & Gelder, 2004, p. 901)

Teaching practices are well known to be guided by faculty beliefs and conceptions of teaching (Trigwell & Prosser, 1996a, 1996b); thus genuine improvement in teaching must begin with a change in faculty thinking about teaching and learning (Ho, 2000). Lewis and Lewis (2006) found that in the ChemConnections workshops sessions, 43 percent of respondents were using modules by the following spring and another 13 percent were planning to use them in a future course. A larger proportion (57 percent) reported a variety of other changes in their teaching practice and 72 percent described a variety of gains from their experience. Lewis & Lewis also found that uptake of new teaching ideas was greater in workshops lasting two or more days than in shorter workshops. Among respondents to their follow-up surveys, the New Traditions workshop evaluators found an even higher rate of uptake (78 percent) of the teaching and learning strategies that they had experienced (Penberthy & Connolly, 2000). Workshops were found to stimulate faculty new to active learning to try out these strategies. The workshops also helped repeat attenders (i.e., those already experimenting to improve their use of these strategies) to deepen their knowledge and encouraged them to add other methods.

Workshops were also offered as part of the NSF's Undergraduate Faculty Enhancement (UFE) program; their evaluators (Marder et al., 2001; Sell, 1998) estimated that 81 percent of the 14,400 participants in the UFE workshop program made moderate or major changes to their courses, affecting an estimated 2.8 million undergraduates. When the workshops directly addressed teaching methods and provided time for participants to work on their own teaching materials, this was associated with later revision of a course.

As an evaluator for ChemConnections, I observed that the experience of teaching workshops helps active participants to build and sustain their networks of engaged

STEM faculty and expands the pool of faculty with knowledge and expertise to share. (This is also evident in the Project Kaleidoscope workshops which solicit the engagement of senior colleagues by requiring faculty to participate in teams that include two senior members of their department or institution.) The capacity of workshops to engage as well as to educate, and to continually extend the networks of faculty convinced of the value of scientific teaching and learning methods, and ready to share their work with colleagues, makes them a powerful force for sustained change. Regional workshops bring together faculty from different institutions and connect them to like-minded colleagues locally and nationally. These connections are especially important in supporting faculty who lack departmental colleagues with similar educational interests. Connections are sustained by correspondence and reinforced by live encounters at conferences and other meetings. (It is notable that disciplinary conferences have developed education sections to service a growing interest in science education scholarship.) New collaborations form spontaneously, sustained by the intrinsic pleasures of working with like-minded colleagues to build web-sites, develop new projects, produce new teaching materials, undertake research, and co-author articles and grant proposals. In short, faculty development workshops have emerged as a highly productive, cost-effective way to build a nationwide network of STEM faculty who are actively engaged in implementing the principles of scientific teaching and learning in their own courses and ready and able to share their knowledge and expertise with others.

A third set of strategies suggested by the evidence and arguments that I have offered in this paper is to develop national programs:

- to promote mathematics and science teaching as a rewarding and well-rewarded profession using the resources of the media to reach both students and their families; to pro-actively recruit existing STEM undergraduates with an interest in teaching. Incentives might include scholarships or loan waivers, and removal of additional costs to students of additional years in education certification preparation.
- to develop and support baccalaureate programs combining STEM disciplinary degrees with concurrent educational preparation for teaching in the K–12 system. Students would need to be financially supported and mentored through to their early years as teachers (given the high loss rates in early teaching careers). My thoughts in this matter reflect those of the 2005 National Academy Report.

The NSF has sought through a number of ongoing programs—Collaboratives for Excellence in Teacher Preparation, Math and Science Partnerships, the State and Rural Systemic Initiatives, and a variety of outreach programs that engage STEM college faculty and their graduate students to work with K–12 mathematics and science teachers and students—to strengthen the disciplinary preparation of students entering programs of teacher preparation in colleges of education. These will continue to be needed as infusion of the teaching force with new teachers graduating with degrees in STEM disciplines will take time to build.

As a member of the National Visiting Committees of both the Texas CETP and the Puerto Rico Math and Science Partnership, I have observed in action the value of drawing university and college STEM faculty into partnerships with K–12 teachers and the two-way learning and respect that can develop from this. In our own evaluation of outreach programs using volunteer STEM graduate students, we found that the positive effects on graduate students working in K–12 classes in increasing their own interest in teaching and understanding of its challenges were at least as great as the impact that their classroom work had on the levels of interest in and understanding of science among their students (Laursen et al., 2004, 2005).

However, as I am not a specialist in K–12 education, beyond these broad suggestions, I would defer to others better qualified to determine the details of a strategic national plan to address our urgent need for a profound improvement in the quality of our mathematics and science teaching force.

A Major Caveat

For each of these strategies to make a discernible difference to the quality of both undergraduate and K–12 STEM education, ways must now be found to address the fundamental problems with which I began this paper. The beliefs and practices that determine faculty rewards, incentives, and tenure have to be rebalanced so as to encourage and support scientific modes of teaching and educational scholarship. We understand what needs to be done. The principles were clearly laid out by the late Ernest Boyer in *Scholarship Reconsidered: Priorities of the Professorate* (1990), and, in 2003, the National Research Council translated these principles into action items.

Their recommendations include the following: "That presidents, deans and department chairs:

- Should use their visible positions to exhort faculty and administrators to unite in the reform of undergraduate education and dispel the notion that excellence in teaching in incompatible with first-rate research.
- Match the faculty incentive system with the need for reform. Tenure policies, sabbaticals, awards, adjustments in teaching responsibilities, and administrative support should be used to reinforce those who seek time to improve their teaching. . .Rewards should go to those who are teaching with research-tested and successful strategies, learning new methods, or introducing and analyzing new assessments in their classrooms. . .
- Consider efforts by faculty who engage students in learning-centered courses as important activities in matters of tenure, promotions and salary decisions, and modify promotion and tenure policies in ways that motivate faculty to spend time and effort on developing new teaching methods or redesigning courses to be more learning-centered.
- Consider faculty time spent on redesign of introductory courses or in research focused on teaching and learning a discipline as evidence of productivity as a teacher-scholar.
- Create more vehicles for educating faculty, graduate students, post-doctoral fellows, and staff in tested effected pedagogy. Incorporate education about teaching and learning into graduate training and faculty development programs and fully integrate these into the educational environment and degree requirements.
- In hiring new faculty and post-doctoral fellows, place greater emphasis on awareness of new teaching methods, perhaps ear-marking a portion of support packages to fund their attendance at teaching workshops.

As I have argued, we now have a solid, well-disseminated body of theoretical knowledge and practical know-how upon which to build the capacity of STEM faculty and their TAs as enablers of student learning. What we have lacked is the moral and political will to create a climate in STEM departments that will support and reward faculty who use this knowledge to improve student and TA learning. To do this will take strong leadership from university and college presidents and senior administrators, acting both individually and collectively. It will also take financial and other forms of leverage from organizations that provide higher education funding—whether to institutions, or more directly to departments and their members. Such organizations include federal and State legislatures, public and private funding agencies, accreditation boards, university business partners and benefactors. Obviously, it is preferable for all of these efforts to proceed by consultative rather than adversarial processes. It will also be optimal for the disciplinary and professional associations that represent faculty interests to work as partners in a collective endeavor to rethink the rewards, incentive, and tenure structures that shape the choices and practices of their members.

We have side-stepped this difficult issue throughout the two decades that we have been aware of its relevance for the problems of quality and access in STEM and K–12 education. Perhaps we hoped that we could improve the situation without directly addressing it. However, it has now become the elephant in the room that we can neither ignore nor circumvent. We must now squarely face the issues raised by the faculty rewards system and find collaborative ways to make it the norm rather than the exception for faculty in STEM departments to use scientific teaching and learning methods, to ensure the appropriate professional development of the future professorate (the graduate students), and to make K–12 teaching by STEM undergraduates once more an honored and encouraged career choice.

In conclusion, I would like to offer praise to the National Science Foundation and to the many private foundations who have moved us all forward in our understanding of the dimensions of undergraduate STEM education issues, through their support of STEM education research and program evaluation; who have led the way in soliciting and funding initiatives with enough scope to promote innovation among large numbers of STEM faculty; who have encouraged, supported and disseminated model programs; and who have been ready to grapple with difficult issues such as under-representation in STEM disciplines of women and people of color. I also commend the NSF for its experimental approach to fostering change. It intentionally funds innovative, sometime high-risk, programs (such as those that address under-representation) and anticipates that not all funded initiatives will work well. In sum, it is impossible to imagine how limited would be our understanding of the issues that STEM education faces, what strategies are valuable in addressing them, where barriers lie, and how to move forward, without the work of the NSF and the foundations.

This said, I nonetheless urge the NSF to more fully complete the experimental cycle, and invest even more heavily in evaluation and, in particular, long-term evaluation. We do not understand the longer-term positive outcomes—both intended and unanticipated—of the larger programs. The normal project funding span of five years is rarely enough time to develop projects to maturity and track their impacts: it is thus important to fund longitudinal or follow-up studies that can determine the dimensions of change that these larger initiatives continue to promote.

In November, 2005, I was privileged to represent the U.S. science education research and practitioner community at a multi-national Organization for Economic Cooperation and Development (OECD) meeting Amsterdam on issues in STEM education. It was clear that the European universities and school systems were struggling with many of the same issues as the United States in attracting, retaining, and educating effectively their STEM undergraduates. I was struck how much further ahead the U.S. researchers were in their knowledge and experience of how to harness cognitive science research in the service of improved classroom experiences for students. The proportion of faculty actively engaged in raising the quality of U.S. STEM education, though constantly growing, is still a minority. However, it far exceeds the progress made by European colleagues to date in developing, testing, and disseminating research-grounded materials and methods. Since my return, I have responded to many requests from conference participants to supply details of available research publications and STEM web-site locations. Despite our (valid) concerns about the poorer performance of U.S. students in international comparisons of K–12 mathematics and science learning, this is good news.

What is now vital is that, for want of adequate funding, and the will to rebalance the academic rewards and tenure systems to support scientific teaching and educational scholarship, we do not loose the ground we have gained. We owe our progress to date to the investments we have made in educational innovation and program development, in research, evaluation, and testing, and, above all, capacity-building among faculty. Our success to date is especially due to the growing networks of STEM faculty who have shown the insight and the will to take change into their classrooms and labs, and who continue to draw their colleagues into a shared endeavor to rebuild quality in STEM undergraduate education. I cannot, therefore, overstate the importance of developing rewards and tenure systems that will support their excellent work and the effective preparation of our future STEM faculty.

References Cited

Boyer, E.L. (1990). *Scholarship Reconsidered: Priorities of the Professorate.* Princeton, NJ: Carnegie Foundation for the Advancement of Teaching.

Brandsford, J.D. & Pellegrino, J.W. (Eds.) (2000). *How People Learn: Bridging Research and Practice.* National Research Council, Committee on Developments in the Science of Learning. Washington, DC: National Academies Press.

Brandsford, J.D., Brown, A.L. & Cocking, R.R. (Eds.) (1999). *How People Learn: Brain, Mind, Experience, and School: Expanded Edition.* National Research Council, Committee on Learning Research. Washington, DC: National Academies Press.

Bruillard, K. (2004, March 8). New Visa Ceiling Called Threat to Teacher Recruitment. *The Washington Post,* p. A03.

Burke, K.A., Greenbowe, T.J., & Gelder, J. (2004). The Multi-Initiative Dissemination Project Workshops: Who Attends and How Effective Are They? *Journal of Chemical Education,* 81(6):897–902.

Clewell, B.C., & Villegas, A.M. (2001). Absence Unexcused: Ending Teacher Shortages in High Need Areas. Washington, DC: Urban Institute. Retrieved 3/08/06 from *www.urgan.org/url.cfm?ID=310379.*

DeHaan, R.L. (2005). The Impending Revolution in Undergraduate Science Education, *Journal of Science Education and Technology* 14(2):253–269.

Foertsch, J.M., Millar, S.B., Squire, L., & Gunter, R. (1997). *Persuading Professors: A Study in the Dissemination of Educational Reform in Research Institutions.* Report to the NSF Education and Human Resources Directorate, Division of Research, Evaluation, and Communication, Washington DC. Madison: University of Wisconsin-Madison, LEAD Center.

French, D., & Russell, C. (2002). Do Graduate Teaching Assistants Benefit From Teaching Inquiry-based Laboratories? *Bioscience,* 52:1036–41.

Fusfield, H.I. (1986). *The Technical Enterprise: Present and Future Patterns.* New York: Ballinger Publishing Company.

Gafney, L., & Weiner, M. (1995). Finding Future Teachers From Among Undergraduate Science and Mathematics Majors. *Phi Delta Kappan* 76:633–641.

Hammrich. P. (1996) *Biology Graduate Teaching Assistants' Conceptions About the Nature of Teaching.* ERIC Database document ED401155, *www.eric.ed.gov.*

Handelsman, J., Ebert-May, D., Beicher, R., Bruns, P., Chang, A., DeHaan, R., Gentile, J., Lauffer, S., Stewart, J., Tilghman, S.M., & Wood, W.B. (2004). Scientific Teaching. *Science* 304:521–522.

Higher Education Research Institute (1992). *The American College Student, 1991: National Norms for the 1987 and 1989 Freshmen Classes.* Los Anglese, CA: Higher Education Research Institute, UCLA.

Ho, A. (2001). A Conceptual Change Approach to Improving Staff Development: A Model for Programme Design. *The International Journal for Academic Development* 5:30–4.

Hunt, E., & Pelligrino, J. (2002). Issues, Examples, and Challenges in Formative Assessment. *New Directions for Teaching and Learning* 89:73–85.

Juillerat, F., Dubowsky, N., Ridenour, N.V., McIntosh, W.J., & Caprio, M.W. (1997). Advanced Placement Science Courses: High School-College Articulation Issues. *Journal of College Science Teaching* 27:48–52.

Kevles, D.J. (1979) *The History of the Scientific Community in Modern America.* New York: Vintage Books.

Kuhn, T.S. (1970). *The Structure of Scientific Revolutions.* Chicago: University of Chicago Press.

Kulik, J.A. (2001). Student Ratings: Validity, Utility, and Controversy. *New Directions for Institutional Research* 109:9–25.

Laursen, S., Thiry, H., & Liston, C. (2005). Evaluation of the Science Squad Program for the Biological Sciences Initiative at the University of Colorado at Boulder: Career Outcomes of Participation for the Science Squad Members. Boulder, CO: Report prepared for the Biological Science Initiative and the Howard Hughes Medical Institute by members of & Evaluation Research, University of Colorado at Boulder.

Laursen, S., Liston, C., Thiry, H., Sheff, E., and Coates, C. (2004). Evaluation of the Science Squad program for the Biological Sciences Initiative at the University of Colorado at Boulder: 1. Benefits, Costs, and Trade-offs. Boulder, CO: Report prepared for the Biological Science Initiative and the Howard Hughes Medical Institute by members of & Evaluation Research, University of Colorado at Boulder.

Lewis, S.E., & Lewis, J.E. (2006). Effectiveness of a Workshop to Encourage Action: Evaluation From a Post-workshop Survey. *Journal of Chemical Education* 83(2):299–304.

Liston, C., Laursen, S., Coates, C., &.Thiry, H. (2005). *Evaluation of the Teacher Professor Development Workshops for the Biological Sciences Initiative at the University of Colorado at Boulder.* Report to BSI and HHMI. Ethnography & Evaluation Research: University of Colorado, Boulder.

Luo, J., Bellows,L., & Grady, M. (2000). Classroom Management Issues for Teaching Assistants. *Research in Higher Education* 41:353–83.

Marder, C., McCullough, J., Perakis, S., & Buccino, A. (2001). *Evaluation of the National Science Foundation's Undergraduate Faculty Enhancement (UFE) Program.* Report prepared for the National Science Foundation, Directorate of Education and Human Resources, Division of Research, Evaluation and Communication, by SRI International, Higher Education Policy and Evaluation Program. See also references therein. Retrieved 4/9/04 from *http://www.nsf.gov/pubs/2001/nsf01123/*

National Academy of Sciences, National Academy of Engineering, Institute of Medicine (2005). *Rising Above the Gathering Storm: Energizing and Employing America for a Brighter Economic Future. Committee on Prospering in the Global Economy of the 21st Century: An Agenda for American Science and Technology.* NAS: Washington, DC. Available at *www.nap.edu*

National Institute for Science Education (1998). *Indicators of Success in Post-secondary SMET Education: Shapes of the Future.* Synthesis and proceedings of the Third Annual NISE Forum. Editor, S.B. Millar. University of Wisconsin, Madison.

National Research Council (2003). *Improving Undergraduate Instruction in Science, Technology, Engineering, and Mathematics.* Editor, DeHaan, R.L. Washington, DC. Committee on Undergraduate Science Education.

National Science Foundation (1996). *Shaping the Future: New Expectations for Undergraduate Education in Science, Mathematics, Engineering, and Technology.* Report on its review of undergraduate education by the advisory committee to the Directorate for Education and Human Resources, Chairman M.D. George. NSF: Arlington, VA.

National Science Teachers' Association (2000). NSTA Releases Nationwide Survey of Science Teacher Credentials, Assignments, and Job Satisfaction. Arlington, VA: NSTA. Retrieved 3/08/06 from *http://www.nsta.org/survey3/*.

National Research Council (1999). *Transforming Undergraduate Education in Science, Mathematics, and Engineering.* Committee on Undergraduate Science Education, Center for Science, Mathematics, and Engineering Education, National Academy Press: Washington, DC.

Nyquist, J., Abbott, R., & Wulff, D. (1998). Thinking Developmentally About TA Training in the 1990s. *New Directions for Teaching and Learning. (Teaching Assistant Training in the 1990s)* 39:7–14.

Penberthy, D., & Connolly, M. (2000). Final Report on Evaluation of New Traditions Workshops for Chemistry Faculty: Focus on Follow-up Surveys Documenting Outcomes for Workshop Participants. Report prepared for New Traditions Project by the LEAD Center. Retrieved 4/2/04 from *http://www.cae.wisc.edu/?lead/pages/internal.html.*

Reinvention Center at Stony Brook (2001). *Reinventing Undergraduate Education: Three Years After the Boyer Report.* Retrieved, 7/15/03 from *www.sunysb.edu/reinventioncenter/boyerfollowup.pdf.*

Schugart, S., & Hounsell, P. (1995) Subject Matter Competence and the Recruitment Retention of Secondary Science Teachers. *Journal of Research in Science Teaching* 32:63–70.

Schlechty, P.C. & Vance, V.S. (1983). Recruitment, Selection, Retention: The Shape of the Teaching Office. *Elementary School Journal* 83:469–487.

Sell, G.R. (1998). A Review of Research-based Literature Pertinent to an Evaluation of Workshop Programs and Related Professional Development Activities for Undergraduate Faculty in the Sciences, Mathematics and Engineering. Report commissioned by SRI International as part of an evaluation for the Undergraduate Faculty Enhancement (UFE) program for the National Science Foundation. Available from the author.

Seymour, E. (2005). *Partners in Innovation: Teaching Assistants in College Science Teaching.* With Melton, G., Wiese, D.J., and Pedersen-Gallegos, L. Boulder, CO: Rowman and Littlefeld.

Seymour, E. (2002). Tracking the Processes of Change in U.S. Undergraduate Education in Science, Mathematics, Engineering, and Technology. *Science Education* 86:79–105.

Seymour, E., & Hewitt, N. (1997). *Talking About Leaving: Why Undergraduates Leave the Sciences.* Boulder, CO: Westview Press.

Seymour, E. (1995). Explaining the Loss of Women From Science, Mathematics, and Engineering Undergraduate Majors: An Explanatory Account. *Science Education* 79(4):437–473.

Shannon, D., Twale, D. & Moore, M. (1998). TA Teaching Effectiveness: The Impact of Training and Teaching Experience. *Journal of Higher Education* 69:440–466.

Tobias, S. (1992). *Revitalizing Undergraduate Science: Why Some Things Work and Most Don't.* Tucson, AZ: Research Corporation.

Trigwell, K., & Prosser. M. (1996a). Congruence Between Intention and Strategy in University Science Teachers' Approaches to Teaching. *Higher Education* 32:77–87.

Trigwell, K., & Prosser, M. (1996b). Changing Approaches to Teaching: A Relational Perspective. *Studies in Higher Education* 21(3):275–284.

U.S. Department of Education (1997). *America's Teachers: Profile of a Profession, 1993–94.* NCES 9–460. Washington, DC: National Center for Education statistics.

Additional Presentation Materials offered to the
Research Subcommittee of the House Committee on Science,
Hearing: Undergraduate Science, Math and Engineering Education: What's Working?

by
Elaine Seymour,
University of Colorado at Boulder

extracted from:

Seymour E., & Hewitt, N.M. (1997) Talking about Leaving: Why Undergraduates Leave the Sciences. Boulder, CO: Westview Press

Patterns of Persistence in, and Switching from, Declared or Intended Majors by 1991 for 810,794 Undergraduates who Entered a National Sample of Four-Year Institutions in 1987.

Based on unpublished tabulations provided by the Cooperative Institutional Research Program, Higher Education Research Institute, University of California, Los Angeles, April 1993.

ORIGINAL MAJOR	% STAYED IN SAME MAJOR	% MOVED TO MAJOR IN SAME GROUP	% STAYED IN MAJOR OR GROUP	% SWITCHED TO OTHER GROUP OF MAJORS
Biological Sciences	42.0	7.1	49.0	51.0
Physical Sciences	29.9	18.9	48.8	51.2
Engineering	51.4	10.5	61.9	38.1
Mathematics and Statistics	34.1	3.2	37.3	62.7
Math (only)	29.2	8.2	37.4	62.6
Agriculture and Forestry	52.8	0.0	52.8	47.2
ALL S.M.E. MAJORS	**46.0**	**10.2**	**55.9**	**44.1**
ALL S.M.E. MAJORS (ex. Agriculture)	**45.8**	**10.2**	**56.0**	**44.0**
History and Political Science	43.5	21.7	70.4	34.8
Social Sciences	56.0	16.0	72.0	28.0
Fine Arts	50.6	19.5	70.1	29.9
English	56.5	28.4	84.9	15.1
Other Humanities	28.6	40.2	68.8	31.2
ALL HUMANITIES/SOCIAL SCIENCES	**48.1**	**26.0**	**74.1**	**29.9**
Health Professions	29.4	----	29.4	70.6
Computer Science and Technical	46.4	----	46.4	53.6
Business	59.5	----	59.5	40.5
Education	67.7	----	67.7	32.3
Other Non-Technical	37.8	----	37.8	62.2

THE PROBLEM ICEBERG

Factors contributing to switching decisions; and all concerns of switchers and non-switchers, by rank and percent of switchers, of non-switchers, and of all students.

ISSUE	Contributed to switching decisions		All switchers' concerns		Non-switchers' concerns		All students' concerns	
	rank	%	rank	%	rank	%	rank	%
Lack of\loss of interest in SME: "turned off science"	01	43.2	04	59.6	06	35.5	04	48.6
Non-SME major offers better education\more interest	02	40.4	05	58.5	07	31.6	05	46.3
Poor teaching by SME faculty	03	36.1	01	90.2	01	73.7	01	82.7
Curriculum overloaded, fast pace overwhelming	04	34.9	06	45.4	03	41.4	06	43.6
Feel SME career options\rewards are not worth effort to get degree	05	31.1	07	43.1	12	20.4	09	32.8
Rejection of SME careers\ associated lifestyles	06	29.0	07	43.1	11	21.1	08	33.1
Shift to more appealing non-SME career option	07	26.8	11	32.8	14	16.5*	12	25.4
Inadequate advising or help with academic problems	08	24.0	03	75.4	02	52.0	02	64.8
Discouraged\lost confidence due to low grades in early years	09	23.0	10	33.9	16	12.5	14	24.2
Financial problems of completing SME majors	10	16.9	12	29.5	10	23.0	10	26.6
Inadequate high school preparation in basic subjects\study skills	11	14.8	09	40.4	05	37.5	07	39.1
Morale undermined by competitive SME culture	11	14.8	14	28.4	19	9.2	17	19.7

Reasons for choice of SME major prove inappropriate	13	14.2	02	82.5	04	39.5	03	63.0
Conceptual difficulties with one or more SME subject(s)	14	12.6	15	26.8	09	25.0	11	26.0
Lack of peer study group support	15	11.5	20	16.9	20	7.2	20	12.5
Discovery of aptitude for non-SME subject	16	9.8	21	11.5	21	4.6	21	8.4
Prefer teaching approach in non-SME courses	17	8.7	16	24.0	15	15.1	16	20.0
Unexpected length of SME degree: more than four years required	17	8.7	17	20.2	08	27.6	15	23.6
Switching as means to career goal: system playing	19	7.1	22	8.7	23	2.6	22	6.0
Language difficulties with foreign faculty or TAs	20	3.3	12	29.5	12	20.4	12	25.4
Problems related to class size	21	0.0	18	19.7	17	11.2	18	15.8
Poor teaching, lab, or recitation support by (non-foreign) TAs	21	0.0	18	19.7	18	10.5	19	15.5
Poor lab\computer lab facilities	21	0.0	23	4.4	22	4.0	23	4.2

*Issue raised by non-switchers intending to move into non-SME field following graduation.

Research Subcommittee of the House Committee on Science, Hearing: ***Undergraduate Science, Math and Engineering Education: What's Working?***

Testimony offered by
Elaine Seymour, Ph.D., University of Colorado at Boulder

March 15, 2006.

Questions posed by the Subcommittee

- What has your research shown about why potential science majors drop out of undergraduate science programs?

- What changes in undergraduate science education could prevent capable students from leaving science disciplines and perhaps also attract students initially not interested in science? What are the principle obstacles to implementing these changes?

- What role have federal agencies, particularly the National Science Foundation, played in improving undergraduate science education? What more should federal agencies be doing in this area?

Structure of my response

- Factors that shape the quality of undergraduate science, technology, engineering, and mathematics (STEM) education
- Their consequences for current and future STEM undergraduates
- Strategies (both underway and needed) that address current difficulties
- Some caveats: why are some changes difficult to secure

Factors that shape the quality of undergraduate science, technology, engineering, and mathematics (STEM) education

A historic decline in the perceived value of teaching

Teaching has become a far less important part of the professional role of STEM faculty than research

Seymour and Hewitt *(1997) Talking about Leaving: Why Undergraduates Leave the Sciences:*

STEM seniors:

- Described their faculty as discouraging students from entering K-12 mathematics and science teaching
- Those intending to become teachers fell from 20% to under 7% by senior year, and
- They did not disclose their intentions to faculty

The imbalance between teaching and research is reflected in:

- Faculty salary structure

Many faculty raise a proportion of their salaries by grant writing

- Rewards systems for tenure and promotion

Research achievements both outweigh and are more stringently defined than teaching or service work.

Scholarship in teaching is barely developed and under-acknowledged as a criterion for faculty rewards (Boyer, 1990).

Consequences for current and future STEM undergraduates:

1. STEM undergraduate problems with their learning experiences

In our 1997 study of field-switching and persistence among well-qualified students who entered STEM majors in 7 institutions of different types.

- Poor learning experiences were the most common complaint **both** of those who switched out of STEM majors (90%) and graduating seniors in those majors (74%)
- Ranked first of 23 problems with their majors identified by graduating seniors in 6 of the 7 institutions.

(pp 3-4 of written testimony and additional handouts)

Concerns about the quality of STEM undergraduate education have also been raised in a number of reports

- National Science Foundation (*Shaping the Future*, 1996)
- National Research Council (*Transforming Undergraduate Education*, 1999; *Improving Undergraduate Instruction in Science, Technology, Engineering, and Mathematics, 2003*)
- National Academy of Sciences (*Rising above the Gathering Storm*, 2005)

2. Inadequate preparation of TAs (or young faculty) significantly contributes to poor quality undergraduate learning experiences—now and in the future

- Most institutions and disciplines do not offer formal TA educational preparation
- Programs are limited:
  - short orientation sessions not specific to discipline or course.
  - do not ground TAs in learning research and the teaching practices derived from this knowledge
- STEM TAs least likely to receive appropriate preparation

Seymour (2005) *Partners in Innovation: Teaching Assistants in College Science Classes (Chapter 10)*

3. Limitations of the K-12 math and science teaching force.

Serious (and increasing) shortfall of discipline-qualified mathematics and science teachers in middle and high schools

2000 National Science Teachers' Association: 61% high schools & 48% middle schools had problems filling vacancies; many schools employed less qualified or temporary teachers.

National Academy of Sciences (2005): 59% middle school students had math teachers who lacked a math major

Problems with the quality of K-12 math and science courses (inc. Advanced Placement) create under-preparation in STEM undergraduates

- (1997) study: 40% switchers & 38% persisters struggled with under-preparation in introductory college STEM courses
- Over two-thirds TAs in our (2005) study & TAs in 45 courses at the University of Nebraska (Luo, Bellows, & Grady, 2000 reported that:

  students arrived under-prepared in the fundamental knowledge and skills needed to perform adequately

Strategies: ongoing and needed

Professional development of teachers based on methods grounded in research on how students learn, for:

- Current and future K-12 science and mathematics teachers
- TAs in STEM undergraduate courses
- Current STEM faculty

Biography for Elaine Seymour

Elaine Seymour was for sixteen years Director of Ethnography & Evaluation Research (E&ER), located in the Center to Advance Teaching Research and Teaching in the Social Sciences at the University of Colorado at Boulder. The group includes both social and physical scientists whose research focuses on issues of change in STEM education and careers, including evaluation of initiatives seeking to improve quality and access in these fields. The issues of women in these disciplines have been a special focus and, in recognition of this work WEPAN awarded Elaine its 2002 Betty Vetter Award for Research.

Elaine's best-known published work may be *Talking About Leaving: Why Undergraduates Leave the Sciences,* (1997) co-authored with Nancy M. Hewitt. She and E&ER members recently published *"Partners in Innovation: Teaching Assistants in College Science Courses,"* which draws on findings from three science education initiatives. She and her group have been evaluators for several national and institution-based innovations including two NSF-funded chemistry consortia and (currently) an NSF ADVANCE grant intended to accelerate the career progress of STEM faculty women.

Notwithstanding her semi-retirement, she is currently working with E&ER members on a comparative, longitudinal study that explores the benefits and costs of undergraduate research experiences (and the processes whereby benefits are generated) as perceived by students and faculty at liberal arts colleges. She is also working on a study of the nature and sources of resistance to innovation that draws on data from several science education initiatives. Elaine has served as an evaluator and as a member of national visiting committees and advisory boards for many STEM education change projects. In 2005, she was invited to represent the U.S. experience in working to improve undergraduate science education at a multi-nation OECD conference in Amsterdam. She is a sociologist and a British-American whose education (Keele, Glasgow, and Colorado) and career have been conducted on both sides of the Atlantic.

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March 11, 2005

Mr. Robert Inglis,
Chair, Research Subcommittee,
House of Representatives Committee on Science

Dear Chairman Inglis,

This is a letter of financial disclosure.

I am a semi-retired (50% time) member of the research faculty of the University of Colorado at Boulder, working with the research group for which I was, until recently, the director, namely Ethnography and Evaluation Research (E&ER) in the Center to Advance Research and Teaching in the Social Sciences (CARTSS). This is a self-funded unit that depends on research and program evaluation grants for all of its salaries, benefits, research and operating costs.

I am currently working on three pieces of research and evaluation one of which (a study of undergraduate research) is funded by the Howard Hughes Medical Institute. The second is a two-year study of the sources and nature of resistance to innovation in STEM undergraduate education which has been co-funded by the National Science Foundation and my own university. The third is a four-year contract from Harrisburg University of Science and Technology for evaluation of a multi-institution project, Science Education for New Civic Engagement and Responsibilities (SENCER), that has developed and implemented new courses for introductory courses across the sciences. This project pays a portion of the salaries and benefits of several members of my research group and of myself as principal investigator.

My gross half-time annual salary from all three sources is currently $52,154.

I hope this information is adequate and helpful.

Yours sincerely,

Elaine Seymour, Ph.D.

Chairman INGLIS. Thank you, Dr. Seymour.

Dr. Wieman, I should underscore just how much—how impressed we, on the Committee, are with your use of your Nobel award in the furtherance of changing the education method. And that really is very impressive.

So maybe you want to talk about that a little bit in the course of your testimony, if you will.

Dr. Wieman.

STATEMENT OF DR. CARL WIEMAN, DISTINGUISHED PROFESSOR OF PHYSICS, UNIVERSITY OF COLORADO AT BOULDER

Dr. WIEMAN. Thank you.

My main points are simple: one, undergraduate science education is based on an obsolete model and is doing a poor job at providing the education that is needed today; and two, we now know how to fix it; and three, until you fix it, you can't fix K–12 science education.

So the basis of these claims are that there is a relatively recent phenomenon, but a number of people, like myself, are doing education research within the science disciplines, like physics, particularly at the college level. And this scientific approach to science education provides a growing body of evidence showing that the great majority of college students, both science majors and non-science majors, are not gaining worthwhile understanding from their science classes. Most students are learning that science is boring and little more than useless memorization of facts that are forgotten after the exam.

Our methods are different from those of Elaine Seymour, but our research indicates a similar conclusion. Namely, science majors are not being created in college. Rather, they are primarily the few students that, because of some unusual predisposition rather than ability, manage to survive their undergraduate science instruction.

However, this same science education research that shows the dismal results produced by the traditional science instruction is also showing us how to improve this situation. Experimental teaching methods have been developed that achieve much better learning and attitudes about science for most students. Widely adopted, these methods would increase the pipeline of scientists, produce a more technically-literate and skilled general public, and provide better trained K–12 teachers.

I emphasize this latter point, because our studies show that the future K–12 teachers are among the worst in their learning of science and math in college. That is my claim that unless you improve science education at the college level, you are wasting time and money on trying to make major improvements in K–12.

So why haven't universities changed undergraduate science education so that their students do learn math and science much better?

They haven't done it, because, first, while there has never been a shortage of opinions, only recently has there been real data showing how badly they were doing and how could—it could be improved. Second, the computer technology required for economically-practical widespread implementation of these new approaches also didn't exist until recently. And finally, and most important, there are no real incentives to make changes, other than altruism.

I have spent a lot of time visiting and evaluating universities, and I can assure you that their financial support, prestige, and the tuition they can change is quite—charge is quite unrelated to what their students are actually learning in science. To make these changes I talked about will require a significant investment of money and effort. And while these costs are small compared to the total spent on either K–12 or higher education, resources are tight, particularly at public universities.

So how best to bring about this desired change?

I would argue that the first priority needs to be incentives, which can either be positive or negative, to change education at the department level of the large research universities. For better or worse, these research universities set the standards for undergraduate science education in the United States and train nearly all of the college science teachers. The department is the unit for science education, and to have sustained change, departments, as a whole, must change how they approach science education. Virtually none of the federal support for improving college science education addresses the issue at this crucial level. The limited support available is typically spent on short-term projects that involve one or two people per department spread across as many institutions and departments as possible. These programs have had some excellent results, but they are doomed to largely remain localized and short-term, because they ignore organizational realities. It is like trying to change the direction of stream flows by scooping out a few buckets of water and pouring it in a different direction.

So in summary, enough is known about how college students learn science and how to measure and achieve that learning so that undergraduate science education can be dramatically improved for all students. However, it is not going to happen until colleges, particularly the large research universities, have incentives to make the investment required to bring about this change.

Thank you.

[The prepared statement of Dr. Wieman follows:]

PREPARED STATEMENT OF CARL WIEMAN

My main points are simple.

1) Undergraduate science education is based on an obsolete model and is doing a poor job at providing the education that is needed today.
2) We now know how to fix it.
3) Until it is fixed, you can't fix K–12 science education.

Let me explain the basis of these claims.

There is a relatively recent phenomenon that a number of people like myself are doing education research within the science disciplines like physics, particularly at the college level. This scientific approach to science education provides a growing body of evidence showing that the great majority of college students (both science majors and non-science majors) are not gaining worthwhile understanding from their science classes. This research utilizes the improved understanding of how people think and learn coming out of cognitive science and educational psychology, and applies this understanding to the specific situations of individual college science courses. By studying the mental characteristics of expert scientists and those of novice students we are able to better delineate the desired outcome of science education and then measure how well different instructional practices affect students' thinking and understanding to achieve this outcome. The data show that most students are learning that science is boring and is little more than useless memorization of facts that are quickly forgotten after the exam. Our methods are different than those of Elaine Seymour, but some of our research indicates a similar conclusion to hers. Namely, science majors are not being created in college through educating students as to the utility and intellectual challenges and rewards of science. Instead, successful science majors are primarily those few students that, because of some unusual predisposition rather than special ability to do science, manage to survive their undergraduate science instruction.

Modern society has very different needs for undergraduate science education than in the distant past when our current instructional approaches were developed. Then the goal of college science education was primarily to train only the tiny fraction of the population that was preselected to become the next generation of scientists. Now we need to educate a far larger and more diverse student population to become scientifically literate citizens and the technically skilled work force required for a modern economy to thrive. This new, broader educational need does not eliminate the need to educate future generations of scientists. However, all the data suggests that improving science education for all students is likely to produce more and better-educated scientists and engineers as well.

The same science education research that shows the dismal results produced by the standard traditional college science classes are also showing us how to improve this situation. Experimental teaching methods have been developed that achieve much better learning and attitudes about science for most students. These methods recognize that it is not sufficient to follow the traditional practice of simply presenting the material as it is understood and appreciated by expert scientists. This just overloads the students' cognitive processing capabilities and is perceived in a very different way than is intended. Research shows that effective science instruction recognizes the gap between the initial thinking of the student and that of the expert and provides structure and feedback to guide the student to actively construct their own "expert-like" understanding. This understanding must be based on the foundation of their prior thinking, which may be wrong, and hence must be explicitly examined and adequately addressed. Desirable features of instruction include presentation of ideas, homework, and exam problems in a form that has some obvious real-world connection and utility rather than as mere abstractions, and making reasoning, sense-making, and reflection explicit parts of all aspects of the course. Inherent in this more effective research-based instruction is the need to assess the individual student's background and thinking and provide effective feedback and guidance. This would not have been practical to do on a widespread basis in the past, but computer technology now makes this economically feasible. More research and development of this technology, particularly software, is still needed to fully utilize this potential, however.

Widely adopted, these instructional methods and technology would increase the pipeline of scientists, produce a more technically literate and skilled general public, and provide better trained K–12 teachers. I emphasize this latter point because our studies show that the future K–12 teachers are among the worst in their learning of science and math in college. Elementary education majors have by far the least expert beliefs about science of all the different populations of college students that my group has measured. We also found that in a typical class of graduating elementary education majors who had completed all their math and science requirements, 30 percent of the students thought that the continents float on the oceans, and virtually none of them were able to answer the question, "if it takes you two minutes to drive a mile, how fast are you going?" These future teachers have to learn math and science better than this in college if they are to teach it decently! That is why I claim that unless you improve science education at the college level first, you are wasting your time and money on trying to make major improvements in K–12.

So why haven't colleges changed undergraduate education so that their students learn science much better? They haven't done it because, first, while there has never been a shortage of strongly held opinions, only recently has there been real data showing how badly the traditional science education was failing for most students and how it could be improved. Also, while enough research has been done to clearly establish the general problem and the characteristics of more effective approaches, this work does not cover all subjects and grade levels, and the results are not yet widely known throughout the science community. Ultimately, what is needed is research and development to establish the specifics of how to measure and achieve effective learning across the full range of college science courses for the full range of college student populations. That does not yet exist, although it is clear how to do it. The second reason colleges have not yet changed is that the computer technology required for widespread implementation of these new teaching methods also did not exist until recently. Finally, and most important, there are no incentives to make such changes other than altruism. I spend a lot of time visiting and evaluating colleges and universities, and I can assure you that their financial support, prestige, and the tuition they can charge is quite unrelated to what their students are actually learning in science. Making the necessary educational changes, while inexpensive compared to the total spent on either K–12 or higher education, will require significant investments of money and effort. With budgets so tight, particularly at public Universities, no one should be surprised that science faculty and departments primarily invest their time and resources in trying to excel in areas for which success is recognized and rewarded.

So how can one bring about this desired and attainable improvement in undergraduate science education?

I would argue that the first priority needs to be incentives to change education at the departmental level of the large research universities. These research universities set the standards for undergraduate science education in the U.S. and train nearly all the college science teachers. The department is the unit for science education and to have sustained change, departments as a whole must change how they approach science education.

Virtually none of the federal support for improving college science education addresses the issue at this crucial level. The limited support available is typically spent on short-term projects that involve one or two people per department spread out across as many institutions as possible. This is a politically attractive approach and these programs have had some excellent results, but they are doomed to largely remain localized and short-term, because they ignore organizational realities. They are the equivalent of trying to change the direction that a stream flows by scooping out a few buckets of water and pouring it in a different direction.

In summary, enough is known about how college students learn science and how to measure and achieve that learning so that undergraduate science education can be dramatically improved for all students. However that is not going to happen until colleges, particularly the large research universities, have incentives to make the investment required to bring about this change.

BIOGRAPHY FOR CARL WIEMAN

Carl Wieman grew up in the forests of Oregon and received his B.S. from the Massachusetts Institute of Technology in 1973 and his Ph.D. from Stanford University in 1977. He has been at the University of Colorado since 1984 where he holds the titles of Distinguished Professor of Physics, Presidential Teaching Scholar, and Fellow of JILA. He has carried out research in a variety of areas of atomic physics and laser spectroscopy, including using laser light to cool atoms. His research has been recognized with numerous awards including the Nobel Prize in Physics in 2001 for the creation of Bose-Einstein condensation in a vapor. He has worked on a variety of research and innovations in teaching physics to a broad range of students, including the Physics Education Technology Project, *(http://www.colorado.edu/physics/phet)* that creates educational online interactive simulations. He is a 2001 recipient of the National Science Foundation's Distinguished Teaching Scholar Award and the Carnegie Foundation's 2004 US University Professor of the Year Award. He is a member of the National Academy of Sciences and chairs the Academy Board on Science Education.

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March 1, 2006

Research Subcommittee Chairman Bob Inglis

Dear Chairman Inglis:

Thank you for the invitation to testify before the Committee on Science of the U.S. House of Representatives on March 15 for the Research Subcommittee hearing on undergraduate STEM education. In accordance with the Rules Governing Testimony, this letter serves as formal notice of the federal funding I currently receive related to the hearing topic:

$15,000,000 (this is an award shared among 18 investigators), grant number: PHY 0096822, Group Research in Atomic, Molecular and Optical Physics at JILA, National Science Foundation, received 2001.

$450,000, grant number: N00014-06-1-0169, Bose-Einstein Condensation and Optical Traps, Office of Naval Research, received 1/1/06.

$656,005, grant number: N00014-03-1-0096, Bose-Einstein Condensation and Optical Traps, Office of Naval Research, received 10/15/02.

$443,000, grant number: DUE 0442841, Physics Education Technology Project, National Science Foundation, received 6/1/05.

$932,846, grant number: DUE 0302134, Transforming Science and Mathematics Teacher Preparation (STEM-TP), National Science Foundation, received 5/15/03.

$5,000,000, grant number: DAAD19-00-1-0163, Ultracold Atom Optics Science and Technology, Department of the Army, Army Research Office, received 4/30/00

Sincerely,

Carl Wieman

Carl E. Wieman
Distinguished Professor of Physics
Fellow of JILA

Mr. EHLERS. [Presiding] Thank you very much for your testimony. And I appreciate all of the testimony that I have heard. I, of course, have previous affiliation with the University of Colorado, and so it is like old home week here.

Dr. Burris, and I have got a friend who taught at Beloit for a while, I am pleased to have you with us.

STATEMENT OF DR. JOHN E. BURRIS, PRESIDENT, BELOIT COLLEGE

Dr. BURRIS. My name is John Burris, and I am the President of Beloit College.

I speak today from the perspective of a President of a liberal arts college with a long and distinguished record in science and math education. My comments are also guided by my career as a research biologist and educator, most recently as the Director of the Marine Biological Laboratory in Woods Hole, Massachusetts, an institution dedicated to research and graduate education.

Although there are a number of challenges in science and engineering education, I will focus my comments today on STEM education at the college undergraduate level.

First, let me summarize my main recommendation for your consideration.

As NSF's budget is doubled in the next 10 years, I recommend that double dollars be targeted for building and sustaining a robust, learning environment for undergraduates in colleges and universities across the United States.

It is important to note that we already have a good idea of how to improve undergraduate STEM education as many years of direct observation and research have shown that students learn science best in small classes with extensive hands-on experience using an inquiry-based approach. Lectures and laboratories are often merged, and there is ample opportunity for learning in groups and group discussions, not just learning by individuals working alone.

At Beloit College, the success of these approaches is apparent. For in contrast to national averages, we retain to graduation more than 80 percent of the students who express an interest in a STEM major. We also introduce non-science majors to STEM in a meaningful way, helping to ensure an educated public that will provide the support and encouragement needed if the United States is going to remain the world leader in science and technology.

In fact, the primary reason I came to Beloit College was my interaction at the MBL with students from small, liberal arts colleges, such as Beloit. I was incredibly impressed with the preparation of these young men and women in our Semester in Environmental Sciences program. They had clearly been thought to think independently and critically and were able to conduct graduate-level research while in Woods Hole.

Successes at the liberal arts colleges have not translated to all other colleges and universities. There are a number of reasons: our small class sizes, use of research equipment, and heavy dependence on tendered faculty to do teaching are expensive. We are committed to that expense, a cost that is partially defrayed by our annual tuition, but also underwritten by alumni donations and grants. Federal Government, state legislatures, and other financial supporters have to acknowledge and face squarely the fact that hands-on science is expensive.

As I stated in my recommendation, we need the NSF budget doubled to help cover some of these costs. We cannot rely on science being effectively taught in lecture rooms with 400 students and in laboratories that use antiquated equipment and rely on teaching assistants and cookbook lab manuals.

To excite and interest students in science, we need to have them do science as it is actually done. Many of our nation's colleges and universities have opted for a cost-effective method of instruction with little concern for the educational effectiveness of that approach. We need to eliminate overly large introductory courses, often with instructors who see their role being to discourage, rather than to encourage, majors.

But none of us can rest on our laurels any more than a research scientist stops studying and investigating after a successful experiment. Instead, we need to continue to refine the way we teach. We need to do research pedagogies, we need to disseminate what works, and just as importantly, what doesn't. We need to concern ourselves with what we teach. Textbooks have gotten enormous. We can't jam all of the material down our students' throats. My friend, Bruce Albert's, textbook, is endearingly nicknamed "Fat Albert" by the students. We have to sift and winnow, and we need to constantly be reviewing and refining the curriculum. We need to keep learning how people learn and let that inform our teaching. The world is not waiting for us. We have to keep changing, improving, and educating.

What can the Federal Government do to help strengthen the pipeline at the undergraduate level? The NSF needs to support the development of new pedagogies and new curricula and then support the implementation and dissemination of the methodologies that are successful. Funds must be provided for the equipment and supplies that are needed to implement the most effective teaching. At Beloit, we have discovered that students' use of research-grade equipment, even at the introductory course level, has been enormously successful in teaching all students how science is done. We need to have support to build the new science and engineering buildings that will enable us to apply the latest methodologies and house the needed classroom laboratories for exciting and interesting science education. Finally, we need to support our faculty to do research and remain scientifically current.

Science and engineering education is expensive. It does cost more than other fields, and that fact needs to be acknowledged and the funds need to be provided. The future is challenging, but there is no reason that we can't be successful in providing an exciting STEM curriculum that includes all of our students.

Thank you for your attention.

[The prepared statement of Dr. Burris follows:]

PREPARED STATEMENT OF JOHN E. BURRIS

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

[1] Project Kaleidoscope Report on Reports II: Recommendations for Urgent Action, Executive Summary and Calls to Action

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

[2] Report on Natural Sciences and Mathematics at Beloit College

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 percent 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

[3] *NSB Science and Engineering Indicators, 2006: Volume 1*

[4] NSF FY07 Request (Selected Programs Re: Undergraduate STEM)

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 task force 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 FY07 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).

EXHIBIT A
PROJECT KALEIDOSCOPE REPORT ON REPORTS II:
RECOMMENDATIONS FOR URGENT ACTION

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.

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.

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.

◄
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

◄
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

◄
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 inter-

[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, pp. 271–240.

[4] Erik Stokstad, "Reintroducing the Intro Courses," *Science,* Vol. 293, 31 August 2001, pp. 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.

mediate 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 ongoing 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

[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.

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.

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 percent 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 percent 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 percent from 2002 to 2012, while employment in all occupations is projected to grow 15 percent 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.

BIOGRAPHY FOR JOHN E. BURRIS

EDUCATION:

September 1972—December 1976: Ph.D. in Marine Biology from the Scripps Institution of Oceanography, University of California, San Diego. Thesis title: Photorespiration in Marine Plants—advisors A.A. Benson and O. Holm-Hansen

September 1971—June 1972: M.D.–Ph.D. program at the University of Wisconsin, Madison

September 1967—June 1971: A.B. in Biology from Harvard University

PROFESSIONAL EXPERIENCE:

August 2000–present: President, Beloit College, Beloit, Wisconsin

September 1992–August 2000: Director and Chief Executive Officer, Marine Biological Laboratory, Woods Hole, Massachusetts

July 1988–September 1992: Executive Director, Commission on Life Sciences, National Research Council, Washington, D.C.

October 1984–January 1989: Director, Board on Biology, Commission on Life Sciences, National Research Council

June 1989–2001: Adjunct Professor of Biology, the Pennsylvania State University, University Park, Pennsylvania

October 1985–June 1989: Adjunct Associate Professor of Biology, the Pennsylvania State University

June 1983–October 1985: Associate Professor of Biology, the Pennsylvania State University

December 1976–June 1983: Assistant Professor of Biology, the Pennsylvania State University

September 1972–December 1976: Research Assistant in Marine Biology, Scripps Institution of Oceanography, University of California, San Diego

BOARDS AND ADVISORY COMMITTEES:

Member, National Science Foundation Science of Learning Centers Site Visit Team in October, 2005

National Associate of the National Academies (November, 2003–present)

Chairman, Committee to Review the Partnership for Interdisciplinary Studies of Coastal Oceans (PISCO) for the Packard Foundation (September–December, 2003)

Member, Executive Committee, Wisconsin Association of Independent Colleges and Universities (2003–present)

Member, Board of Directors, Wisconsin Foundation for Independent Colleges (2003–2005)

Member, Board of Directors, American Association for the Advancement of Science, Washington, D.C. (2002–2006)

Member, Board of Directors, Radiation Effects Research Foundation, Hiroshima, Japan (2001–present)

Member, Board of Trustees, The Grass Foundation, Braintree, Massachusetts (2001–present)

Member, Consiglio Scientifico, Stazione Zoologica 'Anton Dohrn,' Naples, Italy (1996–present)

Member, Awards Committee for Biodiversity Leadership, Bay and Paul Foundations, New York, NY (1996–present)

Chairman, Advisory Committee on Student Science Enrichment Program, The Burroughs Wellcome Fund (1995–2002)

Consultant, Committee on Science and Human Values, National Conference of Catholic Bishops (1993–2002)

Member, Board of Trustees, The Krasnow Institute, Fairfax, Virginia (1999–2002)

Co-Chairman, Scientific Advisory Committee of the Law and Science Academy of the Einstein Institute for Science, Health and the Courts, Washington, D.C. (1999–2001)

Member, National Aeronautics and Space Administration Life and Microgravity Sciences and Applications Advisory Committee (1997–2001)

Member, Commission on Life Sciences, National Research Council/National Academy of Sciences (1993–1997)

Member, Steering Committee, the Policy Center for Marine Biosciences and Technology, The University of Massachusetts, Boston (1993–2001)

Awards Committee, American Institute of Biological Sciences (AIBS) (1998)

Member, Science Curriculum for State Court Judges Presiding in Toxic Exposure Cases, Georgetown University Medical Center and Law Center (1991–1992)

Co-chair, Disciplinary Workshop on Undergraduate Education in Biology for the Directorate for Science and Engineering Education at the National Science Foundation (1988)

Chairman, External Advisory Committee for the University Research Initiative Program in Marine Biotechnology at the University of Maryland and The Johns Hopkins University (1987–1991)

Member, University Research Initiative Evaluation Panel in Marine Biotechnology, Office of Naval Research (1986)

PROFESSIONAL AND HONORARY SOCIETIES:

Member: American Association for the Advancement of Science, American Institute of Biological Sciences (AIBS), Phi Beta Kappa

Past-president, January–December 1997, American Institute of Biological Sciences (AIBS)

President, January–December 1996, American Institute of Biological Sciences (AIBS)

President-elect, January–December 1995, American Institute of Biological Sciences (AIBS)

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February 28, 2006

The Honorable Sherwood Boehlert
Chairman, Science Committee
2320 Rayburn Office Building
Washington, DC 20515

RECEIVED
MAR 10 2006
COMMITTEE ON SCIENCE

Dear Congressman Boehlert:

Thank you for the invitation to testify before the Committee on Science of the U. S. House of Representatives on March 15 for the Research Subcommittee hearing on undergraduate STEM education. In accordance with the Rules Governing Testimony, this letter serves as formal notice of the federal funding that Beloit College currently receives related to the hearing topic (all from the National Science Foundation).

$1,414,857, #0127498, Bioinformatics Education Dissemination: Reaching Out, Connecting, and Knitting-together (BEDROCK), Awarded 2002

$147,657, #0421139, Acquisition of Instrumentation for Biophysical Studies: Differential Scanning Calorimeter and Isothermal Titration Calorimeter – MRI Program, Awarded 2004

$145,206, #0455322, Seeing and Understanding: Gordon Conference, Workshops, and Mini-Grants to Guide Visualization Research in Science and Education, Awarded 2005

$24,708, #0419340, ITWF: Collaborative Research: Increasing the Representation of Undergraduate Women and Minorities in Computer Science, Awarded 2004

Sincerely,

John E. Burris

Chairman INGLIS. Thank you, Dr. Burris.
Dr. Goroff.

STATEMENT OF DR. DANIEL L. GOROFF, VICE PRESIDENT FOR ACADEMIC AFFAIRS; DEAN OF THE FACULTY, HARVEY MUDD COLLEGE

Dr. GOROFF. Chairman Inglis and distinguished Representatives of the Subcommittee, I very much appreciate the opportunity to participate in these hearings on what is working in undergraduate science, mathematics, and engineering education.

And to illustrate what is working, I think of a senior named Stephanie at Harvey Mudd College, who has been invited to professional physics conferences as the only undergraduate there to speak about her research findings. Actually, this happens rather routinely to our students. Once, though, a well-known researcher came over to her faculty advisor to praise Stephanie and her talk and to ask if the advisor had thought about how very unlikely it was that Stephanie's discovery could lead to a product with commercial potential. The advisor cut him off and said, "You don't get it." She pointed across the room at Stephanie and said, "That is my product. I produce physicists."

Three quick points about this story.

First of all, the United States needs more undergraduate "products" like Stephanie. "But how many do we need?" everyone asks. All of the recent reports about competitiveness raise alarms based on the number of scientists and engineers being trained abroad. As a mathematician, I am a big skeptic about numbers. Perhaps China really is producing hundreds of thousands more engineers annually than we do. Well, the Chinese Army is also very big. But regarding either our military forces or our scientific workforce, I am less interested in body counts and more interested in the capacity that young people like Stephanie demonstrate for teamwork, communication, innovation, and creativity, not to mention a familiarity with the latest technology.

We may never be able to recruit as many technical students as the Chinese are now, but we do have lots and lots of potential Stephanies, and U.S. institutions can, precisely because we do not have to operate at such huge scales, do a better job at selecting and enculturating productive members of our scientific communities. As with the Army, more scholarships and other incentives may help with initial recruiting, but what ultimately keeps people working effectively is a sense of belonging to a community that is purposeful, well-equipped, and important to society.

I have met so many undergraduates at Harvey Mudd and at Harvard and throughout the country who passionately want to become scientists, engineers, mathematicians, or teachers so that they can devote their talents to solving some of the world's problems. My hope is that the admirable intentions of the President's American Competitiveness Initiative will be implemented in ways that not only provide these passionate students with temporary scholarships but that also demonstrate to them that careers in these professions can be as sustained and sustaining over a lifetime as the other kinds of opportunities available to U.S. students.

Which brings me to point number two. We need more faculty like Stephanie's advisor. Again, I find little of the interest or talent, but much to be learned from community-building organizations like Project Kaleidoscope and Harvard's Derek Bok Center for Teaching and Learning.

Point number three. We need more programs that can prepare students like Stephanie for exciting work as an engineer, mathematician, teacher, or scientist. What good is it to attract young people to study a field unless we have the institutions and the infrastructure for providing appropriate programs, courses, and experiences?

Changes in science and technology are so rapid and so expensive today that it is hard to expect each individual college on its own to keep its facilities, its curricula, and its facilities all up-to-date without benefiting either from an occasional grant or from the result of grants made to other organizations.

The Division of Undergraduate Education at NSF has traditionally supported everything from teacher preparation to course, curriculum, and laboratory improvement. The budget for such work has been slashed in recent years, though. Regardless of what you think should happen to K–12 educational efforts at NSF, support for undergraduate education should not only remain based at the National Science Foundation, it should thrive there. This is essential to achieving the goals of the American Competitiveness Initiative since the college years are so very critical for both the future teachers we need to improve K–12 science and mathematics education as well as the technical specialists we need to improve innovation and economic competitiveness. Trying to promote innovation and competitiveness without paying careful attention to the role of undergraduate education would be as absurd as trying to promote progress in science and engineering without paying careful attention to the role of mathematics.

And finally, let me assure you that Stephanie, with four published papers so far, is not a magical exception but rather an inspirational example of what can work widely. Over 20 original mathematical papers have been published in reference journals by Harvey Mudd College undergraduates during the past four years. And Mudders' names were on 13 patent disclosures last year alone.

Through our clinic program, students work on real design-testing or research projects, cases, if you will, proposed and sponsored by industries or by the Federal Government. These clinic experiences are carefully structured to develop those student skills related to communication, teamwork, leadership, and creativity. For example, Fluid Master will soon begin manufacturing a toilet designed by Harvey Mudd undergraduates that saves 10 percent of the water needed per flush. The National Institute of Standards and Technology has supported the development at HMC of a system that first responders can use to warn them when a burning building is about to collapse. And both Hewlett Packard as well as Amgen are commissioning international clinics this year that will also help students learn to work, think, and cooperate globally.

These are just a few examples and principles illustrating what works when you actually set out to produce engineers, educators, and mathematicians, not to mention scientists like Stephanie.

I would be happy to provide more details during the question period.

[The prepared statement of Dr. Goroff follows:]

PREPARED STATEMENT OF DANIEL L. GOROFF

Chairman Inglis and distinguished Members of the Subcommittee, I appreciate the opportunity to participate today in hearings on *"Undergraduate Science, Mathematics, and Engineering Education: What's Working."*

There is a story many of us like to tell about what has made America's economy run like clockwork that goes like this:

(1) Investment in instruction
(2) Invigorates innovation and
(3) Increases incomes.

This three-step process for producing prosperity and progress is somewhat oversimplified, as I will point out. But that has hardly mattered much in the past because the theory was not testable anyway. We could not, after all, run history over again to experiment with whether investing in Science, Technology, Engineering, and Mathematics (STEM) education as we did, say, after Sputnik, really was an important cause of our subsequent economic prosperity and growth.

The good news is that we now have better evidence that some form of this STEM-winder story was right all along. The bad news, according to many Americans, is that this evidence is being generated in countries like China and India rather than in the U.S. But is this such bad news? A threat to our nation? A perfect storm that will wash away all we treasure?

Opportunity or Threat?

I want to begin by arguing that, although global trends in STEM education and employment do demand our attention, we should welcome them for at least three reasons besides the fact that us storytellers are being proven correct:

First, these global trends are good for the world. We are witnessing how STEM education can lift diverse, poor, and even hopeless people from socioeconomic status lower than most Americans can imagine into the stable middle or even entrepreneurial classes of their countries. Science need not discriminate on the basis of race, religion, or gender; its efficacy is a heritage potentially available to all. And in a world that feels more and more like it is about to fall apart, we can still communicate and agree about scientific findings more easily than about matters that divide civilizations.

Second, these trends are good for science. There is growing excitement and enthusiasm all over the world for STEM and STEM education. And so there is so much we can learn from one another, especially if the U.S. remains a hub for the scientific exchange of both people and ideas. Enthusiasm and excitement about STEM still exists among many young Americans, too, not to mention a great deal of idealism in the undergraduates I meet about dedicating their talents to serving others and solving problems by teaching, innovating, and leading: they volunteer to Teach for America; they want to help address world-wide challenges like AIDS or global warming or sustainable energy or cyber security; and some just want to make an amazing discovery or start the next big high-tech company along the way, too.

A third reason why the trends abroad are good is that they provide a wake-up call. We must re-examine our STEM policies and practices in ways that mattered less when the U.S. enjoyed such undisputed dominance in science and technology. For decades, the oversimplified STEM-Winder story we started with was good enough. Now it is time to examine, critique, and refine how we imagine and design policy based on each of the three steps in our recipe for economic bliss.

The Chinese Army

As an organizational leader these days, one of my favorite questions is, "What problem are we trying to solve?" Our challenge today is not simply to devote more dollars to STEM, or even to create more STEM majors. Those may be means to an end, at least if we go about such tasks wisely. But the real goal is to reap the prosperity and progress promised by our original story. Most recent attention has focused on how many STEM specialists different countries are educating. What conclusion should we draw from reports that, while the U.S. trained 70,000 new engineers in 2005, India produced 350,000 and China 600,000? Or was it only 400,000 in China (they counted people without B.S. degrees) and 100,000 in the U.S. (including computer scientists as in the Chinese data)?

As a mathematician, I am very suspicious about numbers (though I am sometimes impressed by growth rates). The Chinese Army is also very big, after all. But quality counts as well as quantity. What gives me faith in the U.S. military has less to do with efforts to recruit more individuals (especially since we cannot keep up anyway) than with the teamwork, communications, leadership, creativity, and innovation embodied in its institutions. Similarly, I want to emphasize and illustrate how STEM policy recommendations should not only support incentives for individuals, but also support the kinds of infrastructure and institutions those individuals need to get the job done well. This point of view helps, at each step, with distinguishing among: (a) good policies aimed at individuals; (b) better policies that address the collective nature of STEM work; and (c) best examples to inspire us.

Step 1: Will investing in education produce more STEM workers?

(1a) There are currently some good policy recommendations before Congress dealing with individual incentives. Kavita Shukla in her Bachelor's degree thesis at Harvard, recently asked fellow students about the $20,000 annual scholarships for STEM majors called for by the NRC report *Rising Above the Gathering Storm* (RAGS). While 50 percent professed no interest whatsoever in science or engineering, 14 percent said they would switch to a STEM field if such support were available. At present, only 18 percent of Harvard undergraduates are STEM concentrators, so this would be a huge increase.

Will there be enough students arriving at college with the prerequisites to make such a switch into STEM fields? RAGS sets ambitious goals for expanding Advanced Placement classes in high school. One basis for my confidence that we can meet these goals has been the success of the ThinkFive Services for supporting AP teachers and students online, whose development I helped advise in partnership with AgileMind, Inc. and the Dana Center at the University of Texas at Austin.

Will there be enough qualified teachers? Again, I take heart from the success of examples like the "Masters in Mathematics for Teaching" degree program founded as a partnership between the Harvard Mathematics Department and the Division of Continuing Education.

Will undergraduates continue on in STEM? Tables in Appendix 1 show that applications for NSF graduate fellowships improve both quantitatively and qualitatively in response to the kinds of spending enhancements advocated by RAGS. This data was compiled by Richard Freeman and Tanwin Chang for the Scientific and Engineering Workforce Project at the National Bureau of Economic Research.

(1b) While we can help produce more STEM degree holders in these ways, will they then go on to become working scientists and engineers? The opportunity costs to a U.S. undergraduate incurred by going into the life sciences, say, as opposed to business, law, or medicine are substantial—approximately $1 million in present value according to calculations by Richard Freeman. So policy must also address retention through means that are not just financial.

Besides dollars, what makes people persist in their fields is a shared sense of collective purpose and mutual support. This sense of community is what works in the military, after all. Policies will therefore be even more effective to the extent that they build infrastructure and institutions that reduce uncertainty, indignities, and delays for groups of young STEM workers.

(1c) The best policy levers for promoting the healthy growth of STEM communities are, for now, at the National Science Foundation (NSF). It is no secret that the Education and Human Resources (EHR) Directorate at NSF is being decimated. Significant funds have been taken out of the hands of scientists, engineers, and mathematicians there, and transferred to the Department of Education. This may or may not make sense for K–12. But the staff and clientele of the Division of Undergraduate Education (DUE) at EHR used to represent a strong community of expertise dedicated to improving STEM education at the college level. While funding can and should be restored and predictably grown at least in proportion to total NSF budget growth, the community associated with DUE is in danger of scattering irretrievably.

Step 2: Will more STEM workers produce more innovation and invention?

(2a) The RAGS report is one of dozens of similar accounts that implicitly link the number of STEM workers present with the rate of technological innovation and invention. Obsession with counting bodies seems rooted in romantic idealism about scientific discovery: inspiration, like lightning, unpredictably strikes those with good STEM educations, so the more well-educated lightning rods in your country, the higher the likelihood of a hit? Again, we are not so special that we can ignore lessons from other countries. During the Cold War, for example, the Soviet Union did not innovate or invent in proportion to its highly talented, vast, and technically well-trained workforce—mainly because the economic infrastructure functioned so poorly under communist central planning.

Of course, the RAGS report does present good suggestions for providing individual incentives and rewards to STEM workers who innovate or invent, including 200 new grants of $500,000 over five years for young researchers as well as a new Presidential Innovation Award. These would be welcome additions to the already large number of "winner-take-all" tournaments in STEM. But Richard Freeman has pointed out that, although setting up competitions this way may motivate people who believe themselves likely to win, many others may also be discouraged from trying their best. Compared to schemes that acknowledge and reward cooperation, the net result could actually be less effort and fewer discoveries in total.

It is not just individual winners, but whole communities that are important enablers of STEM progress. The number of research papers or patent applications with multiple authors has been exploding relative to the number from lone geniuses. It takes teamwork, communication, as well as interactions within and between fields to make discoveries. Rather than flashing from the sky, think of scientific energy as coursing around networks. Scientists are at the nodes of these networks, and I am all in favor of increasing their numbers, but it is the strength, density, reach, and interfaces of their networks (STEM cells?) that promote the innovation and invention we seek.

(2b) In the STEM wars, then, as in military or political campaigns, the one with the biggest staff does not necessarily win. We have to make sure our forces are well deployed, equipped, connected, and coordinated if we expect results against overwhelming odds. So better policy menus will not just address individuals, but also support institutions and infrastructure, associations and assemblies, international and interdisciplinary interactions, etc. Besides the hardware in laboratories, the software in machines, and the wetware in brains, we need this kind of fragile STEM-ware, too, to give shape to scientific efforts that might otherwise be fluid, fleeting, and dispersed.

(2c) The best example of a group that has vigorously promoted innovation and invention by STEM faculty and students has been Project Kaleidoscope (PKAL). Founded in 1989 as an ad hoc organization, PKAL is dedicated to improving the environment for undergraduate STEM education—including everything from the design of science buildings to the career development of young academics. Most recently, PKAL has also worked on establishing international exchanges of undergraduate STEM activists. The spectacular success of this kind of association needs to be institutionalized and expanded, perhaps in the form of a national center for undergraduate STEM education.

Step 3: Will innovation and invention produce more progress and prosperity?

(3a) The RAGS report also presents good suggestions for providing incentives to individual corporations and commercial endeavors in the U.S. New R&D tax breaks and intellectual property protections would certainly be welcome by those organizations. This is the RAGS to riches section of the report.

(3b) But if globalization teaches us anything, it is that new ideas do not stay put. So even if, in the romantically idealistic account, inspirational lightning strikes a scientist in one country, there is no real way of stopping that energy from being transmitted, sooner or later, to other specialists and entrepreneurs throughout the world. Who eventually benefits? We all might, when discoveries lead to better, cheaper, or more healthy products. The real question, however, concerns whether new industries and their profits are retainable within one country or another. We often talk as if comparative advantage in high technology production necessarily accrues to nations with a large and inexpensive supply of interchangeable STEM workers. Perhaps it is the networks that matter more than the individuals for this purpose, too. Think of the robust economic success embodied by communities that are close-knit, well-connected, and have well-established rules for trust and competition like Silicon Valley, the consumer electronics business in Finland, the diamond district in New York, or the shipping trade in Hong Kong. Such examples are the result of high investments not just in human capital, but in social capital—that is, in the ability to form and sustain mutually beneficially relationships.

(3c) The best example of how to form mutually beneficial relationships between undergraduate STEM students and STEM employers is the Clinic Program at Harvey Mudd College (HMC). For over 42 years, companies, national laboratories, and others with real technical problems they need solved have been bringing them to the Clinic Program for small groups of undergraduates to solve. Last year alone, the sponsors, who retain the intellectual property rights to the work, put students names on 13 patent disclosures. Whole divisions and product lines of corporations have been based on HMC projects. The students, in turn, learn about communication skills, teamwork, leadership, and innovation in addition to technical matters. A list of sample clinic projects appears in Appendix 4.

Harvey Mudd College also conducts undergraduate research under other programs on topics ranging from the use chitosan—a remarkable healing agent secreted by shrimp shells—in hemorrhage control bandages to the mechanisms specific enzymes use to repair and remove damaged DNA; and from the design and testing of new GPS protocols to the invention of portable systems that give first responders a few minutes warning before a burning building collapses.

Projects like these are not part of undergraduate education in other countries. Precisely because China and India have such enormous populations, their institutions of higher education operate at scales that do not facilitate the selection or education of students for creativity. The four-year liberal arts college is a uniquely American invention whose students contribute disproportionately to the STEM workforce. The economics of higher education, particularly in STEM fields, is particularly challenging at small schools like these. Like PKAL and DUE, the continuing ability of these institutions to continue their good work is not assured without some wise and timely policy interventions. The short answer about what works is community. That is why recommendations and reforms should support not only individual incentives, but also infrastructure and institutions.

With less than six percent of the world's population, the United States cannot expect to dominate science and technology in the future as it did during the second half of the last century when we enjoyed a massively disproportionate share of the world's STEM resources. We must invest more the resources we do have, encourage those resources to produce economically useful innovations, and organize the STEM enterprise by working with diverse groups to make sure that innovations developed here or overseas produce prosperity and progress for all.

Many believe that U.S. investments in STEM education following Sputnik paid off handsomely in later technological and economic advances. In 2005, word came that the European Union is sponsoring a satellite designed and built entirely by students. We must re-dedicate ourselves to what is working in undergraduate science, mathematics, and engineering education.

Appendix 1

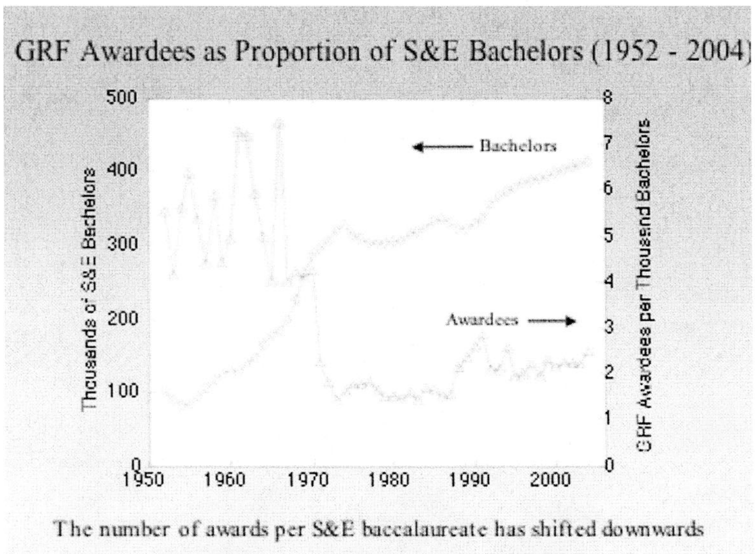
Undergraduate STEM Education Principles

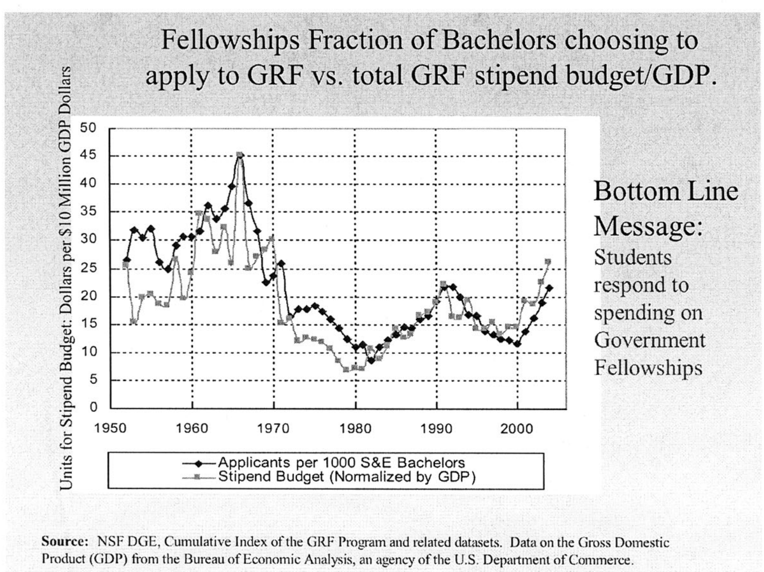
1. I believe that what makes an educational institution great has less to do with the criteria used in magazine rankings and more to do with a shared sense of purpose and identity.
2. I believe that professors want to teach well and students want to learn well, but they sometimes need, and often welcome, help with figuring out how. Many also share my belief that education can help fix the world.
3. I believe that, just as you cannot fatten a calf by weighing it, simply requiring undergraduates to take standardized tests will not automatically improve college education.
4. I believe that teaching to the test is fine if it is a good test, but that Advanced Placement examinations should not be used to predict or preempt student performance in college courses.
5. I believe that content knowledge is necessary but not sufficient in order to become a successful teacher.
6. I believe that the sticker price of a college education can be crushingly high for too many families, that a college diploma should still be worth every penny paid for it (whether by the student or by society), and that tuition still does not cover the full cost of an undergraduate education, especially in technical fields such as science and engineering.
7. I believe in accountability, but also that accountability is not just a matter of collecting data. I believe in collecting data systematically, but also that the lack of statistical proof of what works does not excuse inaction.
8. I believe changes in science and technology are so rapid and so expensive that it is hard to expect each individual college on its own to keep its faculty, curricula, and facilities all up to date without benefiting either from an occasional grant of its own or from the results of grants made to other organizations.
9. I believe in competition when it comes to awarding grants. That should involve requests for proposals and peer review, organized by people who know how.
10. I believe that interdisciplinary work is exciting but not a goal in and of itself, that students also need solid grounding in the basics, and that confronting real problems is one of the best ways for them to master both.
11. I believe that science is best learned and practiced in groups rather than by lone geniuses. More important than the number of individual scientists available is the density, strength, reach, and organization of the relational networks connecting those scientists, both within a given country and internationally.
12. I believe that sincere and thoughtful philosophical differences about education or government are healthy as long as they do not get in the way of working together for the good of the next generation.

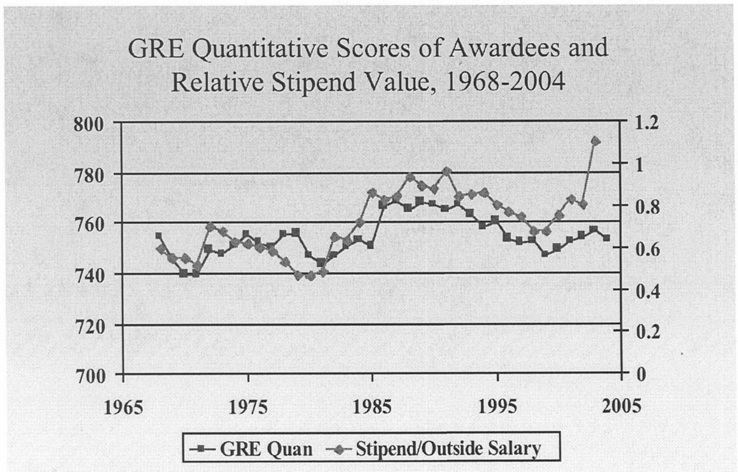
Appendix 2

NSF Graduate Research Fellowship Data

Prepared by Richard Freeman and Tanwin Chang for the Scientific and Engineering Workforce Project of the National Bureau for Economic Research.







Source: NSF DGE, Cumulative Index of the GRF Program and related datasets. Salary data estimated from the Integrated Public Use Microdata Series (IPUMS) of the March Current Population Survey.

Appendix 3

Facts About Harvey Mudd College

A member of the Claremont University Consortium, Harvey Mudd College was founded in 1956 as "The Liberal Arts College of Science, Mathematics, and Engineering" and remains true to its mission statement:

> Harvey Mudd College seeks to educate engineers, scientists, and mathematicians well versed in all of these areas and in the humanities and social sciences so that they may assume leadership in their fields with a clear understanding of the impact of their work on society.

The students at HMC are truly among the best and the brightest in the United States. According to applicant pool data, the four institutions with the greatest number of overlap applications are MIT, U.C. Berkeley, Caltech, and Stanford. Statistics for the 2005–6 entering class include:

- Median SAT 1480
- 27 percent National Merit Scholarship finalists
- 91 percent in top 10 percent of their senior class
- 26 percent valedictorians
- 35 percent women
- 35 percent students of color.

HMC ranks 18 among liberal arts colleges in the *U.S. News & World Reports* survey, and second among undergraduate engineering programs. *The Washington Monthly* placed HMC fourth in its ranking of "what colleges are doing for the country."

In 1997, HMC became the first undergraduate institution to win the prestigious International Association of Computing Machinery Programming Contest from among over 1,000 entries worldwide. In the prestigious William Lowell Putnam Mathematical Competition, HMC teams have earned top-ten spots in three of the past four years and finished twice in the top five, a record unsurpassed by any other undergraduate institution.

In 2005, the American Mathematic Society presented HMC with its first-ever "Award for an Exemplary Program or Achievement in a Mathematics Department." The citation reads:

> The American Mathematical Society (AMS) presents its first Award for an Exemplary Program or Achievement in a Mathematics Department to Harvey Mudd College in Claremont, California. The Mathematics Department at Harvey Mudd College excels in numerous dimensions. Its exciting programs have led to a doubling of the number of math majors over the last decade. Currently more than one out of every six graduating seniors at Harvey Mudd College majors in mathematics or in new joint majors of mathematics with computer science or mathematical biology. Furthermore, about 60 percent of these math majors continue their education at the graduate level.
>
> The Harvey Mudd College Mathematics Clinic has served as a trailblazer and a model for other programs for more than thirty years. This innovative program connects teams of math majors with real-world problems, giving students a terrific research experience as well as a glimpse at possible future careers. Undergraduate research is a theme throughout the mathematics program at Harvey Mudd College, as exemplified by the over twenty papers published in the last three years by Harvey Mudd College mathematics faculty with student co-authors.

Appendix 4

The Clinic at Harvey Mudd College:

- Sponsor proposes real problem
- The responsible Clinic Director appoints a *team* of 3–5 students, a student *project manager,* and a *faculty advisor*
- The sponsor appoints a *liaison*
- The students prepare a *work statement* (subject to liaison agreement) to produce scheduled deliverables:
  - — Presentations, reports, prototype, models, analyses, code. . .
- No guarantee of unique solution
- Fee paid by Sponsor = $41,000

Clinic Project Selection:

- Must be important to Sponsor
- Emphasizes design and experimental skills
- Allows for team interaction
- Work scope 1,200–1,500 person hours
- Fixed end date
- Concrete measurable goals

Computer Science Clinic Examples

The Boeing Company/ATM (2002–03)
Design and Prototype of a Low-Cost Weather Information System for General Aviation
Liaisons: James Hanson '64, Paul Mallasch
Advisor: Geoffrey Kuenning
Students: Paul Paradise, Luke Hunter, Kyle Kuypers, Rafael Vasquez

Boeing ATM has tasked us with the design and implementation of a proof-of-concept design for delivering weather data to aircraft pilots in-flight. Using a Pocket PC PDA as a hardware architecture and a custom client and server, we are able to deliver METAR (Meteorological Reports) and NEXRAD (NEXt-generation RADar) to pilots. Our current implementation uses 802.11b wireless technology for the communication, but is ideally suited for satellite-based broadcast as a final product.

Medtronic MiniMed (2003–04)
Diabetes Data Management Software API Design and Implementation
Liaison: Pam Roller
Advisor: Belinda Thom
Students: Jessica Fisher, Mark Fredrickson, Aja Hammerly, Jon Huang

With approximately 17 million people in the U.S. with diabetes, Medtronic MiniMed has produced several distinct lines of diabetes devices to aid in the treatment of the disease. These devices, however, do not utilize a standard communication format. The Clinic team is designing and implementing an extensible interface that will unify communication with Medtronic MiniMed's current and future insulin pumps, glucose sensors, and related diabetes technology.

Engineering Clinic Examples

The Aerospace Corporation (2003–04)
Development of Picosat Add-On Boards
Liaisons: Samuel Osofsky '85, Nelson Ho
Advisor: John Molinder
Students: Andrew Cole (Team Leader), Nathan Mitchell, Brian Putnam, Daniel Rinzler, Gabriel Takacs, Philip Vegdahl

Picosats are very small satellites (typically a 4" cube) launched in conjunction with a larger satellite. Aerospace designed the original Picosats, with the first placed in orbit in 2000. The technology has the potential to be used for a variety of tasks, including imaging of the launch vehicle to evaluate damage. A Harvey Mudd College Engineering Clinic team developed digital camera and GPS add-on boards for the Picosat platform. A single board was designed that is able to support either a camera or a GPS daughterboard. The engineers at Aerospace were surprised and pleased that the team was able to accomplish the project goals using primarily commercial off-the-shelf technologies, thus increasing the system's reliability. The board is provisionally scheduled to fly on an upcoming Space Shuttle mission.

Center for Integration of Medicine and Innovative Technology (2004–05)
Design of a Prototype Cooling System to Prolong and Preserve Limb Viability
Liaisons: Alex Pranger '92/'93
Advisor: Donald Remer
Students: Nicolas von Gersdorff (Team Leader), Jay Chow, Michael Le, Robert Panish, Ajay Shah

While combat armor advancements have increased soldiers' survival rates, modern weaponry ravages warfighters' extremities, causing massive trauma and tissue loss; two-thirds of the more than 10,000 combat injuries in Iraq and Afghanistan afflicted patients' limbs. Inducing local hypothermia (i.e., significant cooling of the affected limb) would prolong limb viability, lengthening the window for soldiers to obtain restorative and regenerative care and thereby avoid amputations. The Harvey Mudd team developed a lightweight, easily deployable, evaporative cooling wrap to induce therapeutic hypothermia on the battlefield. A patent disclosure has been filed, and the next stage of development is underway by the project sponsor.

9**Fluidmaster, Inc.** (2004–05)
Innovative Designs for Flushing Systems
Liaisons: Chris Coppock
Advisor: Lori Bassman
Students: Joe Laubach (Team Leader), Shawna Biddick, Rami Hindiyeh, Joey Kim, John Onuminya, Sarah Taliaferro

Fluidmaster, Inc. is a worldwide supplier of plumbing products. The company is determined to aid in the conservation of scarce fresh water as well as to enable people worldwide to enjoy the benefits of safe and reliable sanitation. This requires a cost-effective and reliable flushing system that uses a consistent low volume of water regardless of variations in supply water pressure and toilet resistance. The HMC team designed and prototyped two designs that accomplished these goals, resulting in a reduction of 0.1 gallon per flush, a potentially very significant improvement. Two provisional patents were awarded to the team, and Fluidmaster has indicated their intention to take one of the designs to market.

UVP, Inc. (2004–05)
Uniform Illumination for Fluorescent In Vivo Imaging
Liaisons: Sean Gallagher, Darius Kelly, Colin Jemmott '04
Advisor: Qimin Yang, Deb Chakravarti (KGI)
Students: Alyssa Caridis (Team Leader), Stephanie Bohnert, Ekaterina Kniazeva, Erika Palmer, Laura Moyer, Jeremy Bolton (KGI), Linda Chen (KGI)

In order to improve the accuracy and effectiveness of live animal *in vivo* imaging, UVP tasked a team of Harvey Mudd College and Keck Graduate Institute students to design, simulate, and test innovative imaging systems to achieve unparalleled illumination uniformity. Uniform lighting is needed for quantitative analysis of images of live creatures, which are used for research into cancer and other diseases. The team developed novel methodologies for measuring light uniformity as well as several successful designs for the lighting system itself. A successful 3–D image lighting system will allow researchers to follow the pattern of tumors in the same test animal, improving the understanding of the disease and simultaneously reducing the number of animals needed for such tests. UVP filed several patent disclosures based on the team's work, and is in the process of bringing one of the designs to market.

Mathematics Clinic Examples

HP Labs (2004–05)
Analyzing and Correcting Printer Drift
Liaisons: John Meyer, Gary Dispoto
Advisor: Weiqing Gu
Students: Jeffrey Hellrung (PM), Brianne Boatman, Durban Frazer, Katie Lewis

In color printing, a look-up table (LUT) is a mapping from a computer's color space to the ink combinations required to print these colors. An LUT will drift over time due to a variety of factors including mechanical and environmental changes, resulting in an undesirable change in the printed results. Currently, constructing a new LUT is a time consuming process. This project focused on developing a quicker method to recalibrate a printer when drift occurs.

VIASAT, INC. (2001–02)
Using Elliptic Curve Cryptography for Secure Communication
Liaison: Hunter Marshall
Advisor: Weiqing Gu
Students: Simon Tse (TL), Colin Little, Cameron McLeman, Braden Pellett

The ViaSat clinic team will present methods for performing secure cryptography over an insecure network by 1) Introducing the use of algebraic objects known as elliptic curves to accomplish this task 2) Presenting Diffe-Hellman key exchange protocol using elliptic curve cryptogtaphy (ECC) 3) Discussing potential attacks on this cryptosystem and 4) Demonstrating their implementation of this algorithm allowing two network users to agree upon a secret key over an insecure connection.

Physics Clinic Examples

University of California Irvine Department of Otolaryngology (2003–04)
Modification of a Laryngoscope for Optical Coherence Tomography
Liaison: Brian Wong
Adivisors: Elizabeth Orwin, Robert Wolf
Students: Nikhil Gheewala (PM), River Hutchison, Tonya Icenogle, Rachel Lovec

Currently laryngeal cancer can only be diagnosed with biopsies which are invasive, permanently damaging, and can miss cancerous tissue. Optical Coherence Tomography (OCT) is an imaging technique that non-invasively images several millimeters into tissue to seek structural abnormalities, which can indicate cancer. We will design and construct an OCT device for attachments to a laryngoscope that will image two-dimensional cross-sections in the larynx, for the purpose of diagnosing laryngeal cancer in its early stages.

Sandia National Laboratories
Optical Characterization of Coated Soot Aerosols or "Flames and Laser"
Fall 2004 Students: Mark Dansson, Rachel Kirby, Tristan Sharp, Shannon Woods, Mike Martin. Spring 2005 Students: Patrick Hopper, Brendan Haberle, Matt Johnson, Julie Wortman, Mark Dannson, Octavi Semonin
Advisor: Peter Saeta

The optical properties of coated soot aerosols produce the greatest uncertainty in climate change models. This project aims to measure the scattering and absorption of light by sub-micron-sized soot particles similar to those produced in diesel exhaust. Total absorption and scattering cross sections of 635 nm laser light are measured using cavity-ringdown and angle-resolved scattering techniques. Soot particles are created *in situ* by partially combusting ethylene and coated with a volatile organic compound.

BIOGRAPHY FOR DANIEL L. GOROFF

Daniel Goroff is Vice President for Academic Affairs and Dean of the Faculty at Harvey Mudd College. He has held this post since July of 2005, when he also became a member of both the Mathematics and the Economics Departments.

Goroff earned his B.A.–M.A. degree in mathematics *summa cum laude* at Harvard as a Borden Scholar, an M.Phil. in economics at Cambridge University as a Churchill Scholar, and a Ph.D. in mathematics at Princeton University as a Danforth Fellow.

Goroff's first faculty appointment was at Harvard University in 1983. He is currently on leave from his position there as Professor of the Practice of Mathematics, having also served as Associate Director of the Derek Bok Center for Teaching and Learning, and Resident Tutor at Leverett House.

A 1988 Phi Beta Kappa Teaching Prize winner, Goroff has taught courses for the mathematics, economics, physics, history of science, and continuing education departments at Harvard. He was also the founding director of a Masters Degree Program in "Mathematics for Teaching" offered through the Harvard Extension School.

In pursuing his work on nonlinear systems, chaos, and decision theory, Daniel Goroff has held visiting positions at the Institut des Hautes Etudes Scientifiques in Paris, the Mathematical Sciences Research Institute in Berkeley, Bell Laboratories in New Jersey, and the Dibner Institute at MIT.

In 1994, Goroff was elected to a three-year term on the Board of Directors of the American Association for Higher Education (AAHE). During 1996–97, he was a Division Director at the National Research Council (NRC) in Washington, and during 1997–98, Goroff worked for the President's Science Advisor at the White House Office of Science and Technology Policy (OSTP). That year he was named a "Young Leader of the Decade in Academia" by *Change: The Magazine of Higher Education.*

As Director of the Joint Policy Board for Mathematics (JPBM) from 1998 to 2001, Daniel Goroff was called to testify about educational and research priorities both by the House and again by the Senate during the 106th Congress. He currently serves as Chair of the U.S. National Commission on Mathematics Instruction at the National Research Council, and co-directs the Sloan Scientific and Engineering Workforce Project at the National Bureau of Economic Research.

March 9, 2006

The Honorable Sherwood Boehlert
Chairman, Science Committee
2320 Rayburn Office Building
Washington, DC 20515

Dear Congressman Boehlert:

Thank you for the invitation to testify before the Committee on Science of the U.S. House of Representatives on May 12th for the hearing entitled "***The Future of Computer Science Research in the U.S.***." In accordance with the Rules Governing Testimony, this letter serves as formal notice of the federal funding that Harvey Mudd College currently receives.

Harvey Mudd College
Current federal grant support

Amount	Grant number	Agency	Title	FY
$134,810	2-R15-GM065911-02	NIH	AREA: Host-Guest Interactions in Catanionic Vesicles	1997
$395,000	DMR-0109077	NSF	Creation of Nanoscopic Structures at Various Interfaces	2001
$146,640	DMS-0301129	NSF	RUI: Combinatorial Fixed-Point Theorems, Polytopes, and Fair Division	2003
$524,718	MCB-0318282	NSF	RUI: Structure and Function of Dynein-2 in Tetrahymena Thermophila	2003
$146,414	CMS-0301779	NSF	RUI: Thermo-electro-mechanics in Polycrystalline Film Structures	2003
$328,283	DMS-0414011	NSF	Mathematical Modeling of Cancer Therapy	2004
$200,763	IIS-0416364	NSF	GenderQuest	2004
$156,000	CHE-0353662	NSF	REU: Chemistry REU at Harvey Mudd College	2004
$265,083	DMR-0421565	NSF	MRI: Open-Architecture Cryosystem & 9-Tesla Magnet	2004
$355,583	DBI-0420538	NSF	MRI: Acquisition of a Confocal Microscope	2004
$74,982	DUE-0338565	NSF	CCLI: Interrelationship of Chemistry and Society	2004
$255,000	CHE-0353199	NSF	Electronic Coupling in Metalloporphyrin Dimers and Trimers	2004
$41,227	DUE-0410115	NSF	CCLI: Service-Learning in Chemistry: Analysis of Lead in Soil	2004
$132,252	DUE-0411176	NSF	CCLI: Next-Generation Robotics Laboratory	2004
$503,041	NNG05GA56G	NASA	Application of Machine-Learning Technology to Martian Geology	2005
$251,315	PHY-0456898	NSF	RUI: Collaborative Research: Enhancement of Relativistic Nonlinear Interactions	2005
$59,462	DUE-0443012	NSF	CCLI: TinkerNet: Low-Cost Networking Laboratory	2005
$286,209	CNS-0451293	NSF	REU: Artificial Intelligence, Systems, and Optical Networks	2005
$219,072	EF-0531570	NSF	Collaborative Research: Assembling the Tree of Life - Cnidarian Phylogeny	2006
$403,510	IIS-0546809	NSF	CAREER: Smarter Educational Software through Sketch Recognition	2006
$133,133	DUE-0536173	NSF	CCLI: Laptop Robotics: Expanding Student Access and Robotics Application	2006
$5,012,497				

Sincerely,

Daniel L. Goroff
Vice President for Academic Affairs
and Dean of the Faculty

Office of the Dean of the Faculty 301 Platt Boulevard, Claremont, California 91711 909/621-8122 Fax 909/621-8465
A MEMBER OF THE CLAREMONT COLLEGES

Mr. EHLERS. [Presiding] Thank you very much.

And I apologize for the musical chairs here, but Chairman Inglis has another committee he has to go to periodically to vote.

I also thank you for reminding us of the important role both of you at the smaller liberal arts colleges play, and I think they provide the best teacher candidates that I have seen in many cases. I also have a connection to Harvey Mudd, because your—one of your predecessors, a dean, tried to recruit me some years ago to come and teach at Harvey Mudd, and——

Dr. GOROFF. We are going to try again.

Mr. EHLERS. I am too old. Thank you.

But next, we are pleased to recognize Ms. Collins from Moraine Valley Community College, which I have no connection with, but welcome. We look forward to your testimony.

STATEMENT OF MS. MARGARET SEMMER COLLINS, ASSISTANT DEAN OF SCIENCE, BUSINESS, AND COMPUTER TECHNOLOGIES, MORAINE VALLEY COMMUNITY COLLEGE

Ms. COLLINS. That is okay. By the time I am done, you will all feel very comfortable with Moraine Valley Community College.

Good morning, Mr. Chairman, and Members of the Committee. Thank you for this opportunity to testify on behalf of Moraine Valley Community College. My name is Margaret Collins, and I am the Assistant Dean of Science, Business, and Computer Technologies.

Moraine Valley is located in the southwest suburban Cook County in Illinois. I mention this because community colleges are all about the communities they serve. I have considered this community my home for my entire life, and I consider myself a southsider, just like the World Champion Chicago White Sox. I was raised in a little suburb called Marinette Park and now live and raise my children, Carly and Billy, in Evergreen Park. My sister lives two blocks away, and my parents are right down the street.

Moraine Valley is the second largest community college in Illinois out of 48 with a spring 2006 headcount of just under 16,000. We offer 123 degree and certificate programs and have just over 46,000 students enrolled annually. We also encounter obstacles to recruitment and retention of STEM majors.

As we converse today about the recruitment and retention of STEM undergraduates, I bring the unique perspective of the community college. Certainly, our struggles are similar to institutions that grant upper-level degrees, and I echo the sentiments of the panel here today, but distinctive to the community college and unique to Moraine Valley Community College are issues that arise because of demographics, geographic boundaries, and open admission policies.

Community colleges serve all people, and we are proud to do so, but we also must face obstacles, including under-preparedness in math and science. With the high school population, we also encounter misalignment between secondary and post-secondary math and science, which causes a gap—a knowledge gap for many of the students entering Moraine Valley Community College. By all means, as an educator who works closely with area high schools, and who has children in a local elementary school, I sympathize with their struggles to meet and exceed state standards while providing a quality, well-rounded education. I praise all of these teachers and educators for their efforts in this challenging time.

Despite these obstacles, our discussion today must focus on solutions. Our most recent accomplishment has resulted from finely-tuned collaboration and lots of human energy. I am lucky to work with so many dedicated individuals. The Academy Awards would have the orchestra playing only a third of the way through my thank-yous. CSSIA, the Center for Systems Security and Information Assurances with much-appreciated funding from the National Science Foundation, also an ATE center, enables us to address issues of recruitment and retention from several perspectives.

Briefly now, but in greater detail in the written testimony, the ATE center has been—helped us to develop curriculum, expand internship opportunities, build a Women In Technology mentoring program, produce video that showed technology in a more appealing and interesting way, offer a career development course that dispels common myths. We have also been able to provide low or no-cost teacher training and curriculum development. We have also developed an excellent outreach program, which I wanted to tell you a little bit more about today.

During the past two years, I have had the opportunity to work with a very special group of students as part of our CSSIA outreach program. The high school students that attend the Mirta Ramirez Computer Science Academy in Chicago, Illinois do so because they seek careers as programmers, IT professionals, IT security specialists, and network engineers. Our efforts to assist these young people focus on providing a seamless transition from our high school—from high school to college. We have sponsored several on-campus events, combined with activities at their own school, that allow students to earn college credit, gain skills, and understand the importance of continuation beyond high school.

Through our community outreach event and computer health clinics, students assist the community members by conducting virus scans and other security-related operations on PCs. The students also competed in teams and presented their projects before a judging committee. The winning teams were invited to Washington, DC to present at the annual ATE conference. My best experience as an educator was participating in the travel with these dozen or more students. The experience for all of us was pretty amazing, and the result of hard work, dedication, and good funding was visible to all.

In addition to NSF funding, we have appreciated funding from other federal sources. It is outlined in greater detail in the written testimony, but Carl Perkins and Tech Prep funding has significantly aided our efforts to recruit and retain STEM majors. It has done this through dual credit, math alignment programs, tutoring, implementation of contextual learning, career exploration opportunities for high school and elementary students, and of course, to purchase equipment and supplies. The college also engages TRIO funds to provide support services, academic advising to create awareness, and again, to provide some tutoring and academic support.

The colleges uses operational funds to help recruit and retain STEM majors. We do this by providing dual enrollment opportunities for advanced placement high school students in calculus, statistics, college algebra, trigonometry, biology, and chemistry. We work closely with the upper level colleges to create two-plus-two agreements that assists Moraine Valley students to transition into engineering and computer science programs. We improved diversity in our full-time teaching faculty through a strong commitment to diversity in our hiring practices.

As for the measurement of effectiveness, my written testimony outlines in more detail the scrutiny and thoroughness applied to all of our assessment activities. At Moraine Valley, institutional effectiveness has always been, and will remain, a high priority for our institution, and I would be glad to entertain your questions upon conclusion of this statement.

In closing, I would like to emphasize ways in which the Federal Government may continue to help us address the obstacles we face. We need to continue to emphasize the seriousness of the social and economic issues related to recruitment and retention of STEM majors. We need to provide more recognition to the role of the community college in providing pathways and opportunities in higher education, especially for the under-served and under-represented. We need to support—we need more support for post-secondary collaboration through Tech Prep and Carl Perkins. We also need to emphasize the social issues, including gender, race, and socioeconomic status. We also need to replicate successful best practices and programs.

Thank you again for allowing the voice of the community college to be present at this hearing today. Community colleges have become, and will remain, a vital means for students otherwise unable to participate in higher education. The issue of recruitment and retention of science, technology, engineering, and math majors is crucial—is a crucial economic and social issue that demands greater consideration. I feel honored to have been afforded this opportunity to sit with an esteemed panel and to contribute to the discussion. I look forward to the positive outcomes that result from this conversation.

[The prepared statement of Ms. Collins follows:]

PREPARED STATEMENT OF MARGARET SEMMER COLLINS

Good morning Mr. Chairman and Members of the Committee. Thank you for the opportunity to testify on the role of community colleges in the recruitment and retention of undergraduate science, math and engineering majors. I would like to introduce myself, my name is Margaret Collins and I come to you with fourteen years of experience in higher education. My experience includes college teaching, career and workforce development, grant writing and most recently academic affairs administration. My last twelve years of employment have been at the community college. Currently, I am the Assistant Dean of Science, Business & Computer Technologies at Moraine Valley Community College.

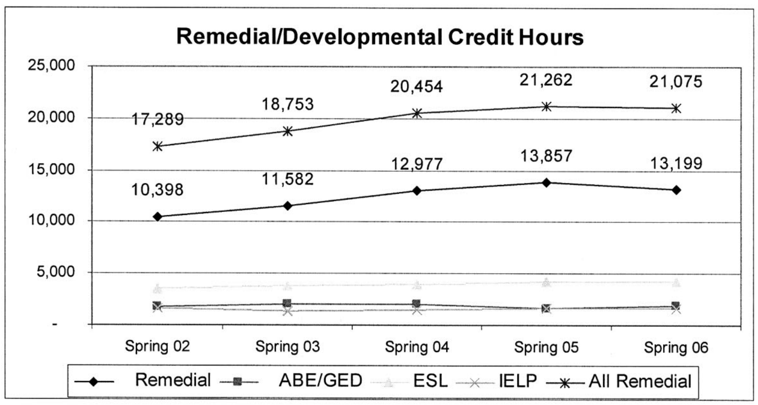
I recognize the tremendous challenge that our nation's educational institutions face as we prepare graduates to compete in a global economy. My testimony today comes from the perspective of the community college, from my experiences at Moraine Valley Community College (MVCC). I intend to address obstacles to recruitment and retention of Science, Technology, Engineering and Math (STEM) majors at Moraine Valley Community College and discuss how we work towards minimizing the obstacles through extensive collaboration, grant funding and human capital.

Question One: What obstacles have I encountered at Moraine Valley Community College in recruiting and retaining STEM majors?

Students who attend community college, specifically at Moraine Valley Community College face unique obstacles that students at upper division colleges and universities may not. Regardless of the particular institution, most STEM programs remain challenged by issues considered more universal to recruitment and retention.

1. Under preparedness or college readiness (traditional aged students coming from high school). According to the United States Department of Education, (2005) college readiness is one of the seven national education priorities and although improvement has been seen in recent years, too many students remain unprepared for college.
   a. Math remediation—based on the MVCC placement test scores 54 percent of students in 2004 require some level of developmental math before entering college level algebra. This figure is up from 48 percent in 1999 (2005).

Table 1



   b. High school science requirement for graduation—Graduation requirements in the State of Illinois dictate that students complete two years of science credit which is typically taken in the 9th and 10th grades. (Office of the Governor, State of Illinois, 2005). This leaves a large gap between the completion of high school science requirement and entrance into community college science.
   c. Curriculum not aligned across secondary and post-secondary institutions—Secondary curriculum is aligned with the Illinois Learning Standards and the statewide standardized exam. However, community college curriculum aligns with the Illinois Articulation Initiative (IAI) and the requirements of higher level post-secondary colleges and universities. This often causes a gap in the knowledge base that contributes to under preparedness.
   d. Transitional opportunities not well understood or conveyed—Developmental guidance programs in area high schools continue to improve in our region but extensive work remains related to helping students understand career paths, career development and their associated educational plan. This task has become more complex because of increasing specialization in STEM careers.
2. Lack of Opportunity
   a. 1st generation college students (neither parent has a four year college degree or higher)—Ample research on first generation college students exists. These investigations consistently indicate that, compared to students whose parents are college graduates, first generation students are more likely to leave at the end of the first year, be on a persistence track to a Bachelor's degree after three years, and are less likely to stay en-

rolled or attain a Bachelor's degree after five years. (Pascarella, Pierson, Wolniak & Terenzini, 2004). First generation students represent 67 percent of the MVCC student population.

b. Economically disadvantaged—Community colleges by nature serve populations of students with great diversity including socioeconomic status. MVCC is no exception with a portion of the student based considered economically disadvantaged.

c. Multiple priorities including work, other courses, and family obligations—Community college students trend towards having multiple priorities. According to the MVCC spring 2005 Community College Survey of Student Engagement, 60 percent of the respondents indicated that their full time employment is likely to lead to withdrawal, while 50 percent of the students surveyed indicate that caring for dependents is a likely reason to withdraw from class or the college.

3. Negative perceptions associated with science, technology, engineering and math including:

   a. Perception of poor labor market, few job opportunities—Persistent belief that few jobs exist for science, technology, math, and engineering majors continues. At MVCC, informal student surveys reflect this perception. nationally, most job outlook surveys bolster this perception. For example, in the March 10th edition of the *USA Today,* an excerpt from a recent study compiled by the Department of Labor (2005), showed strong job opportunities in allied health and nursing, a brief mention of technology-related jobs, and no mention of job opportunities in the traditional areas of science and engineering.

   b. Perception that STEM is unattractive, uninteresting and only for the super smart—For decades our society has perpetuated the stereotypical perception that people who work in science, math, technology, and engineering tends towards being very smart and less interesting. Work to dispel the notion of the science and computer geek has not progressed. Students continue to associate these majors as being for a small group of capable and stereotypical individuals. In a recent survey of students published in the proceedings of the 2005 American Society for Engineering Education, students listed as some reasons for not persisting in STEM majors as due to the excessive work load, sedentary lifestyle, anti-social nature, dullness/tediousness and competitiveness. (Yasuhara, 2005).

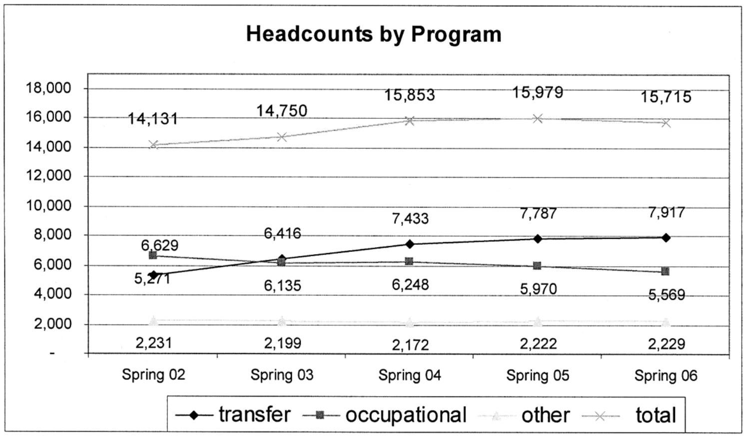
   c. Perception of STEM as male oriented and male dominated—The issue of gender bias in STEM majors receives an abundance of research attention related to the perception that these are male oriented and male dominated fields. Research shows that many female students not only have low expectations of themselves in science classes, but also have stereotypical views about scientists, believing that boys are more likely to become scientists. This view has a negative effect on the probability of girls considering science as a career (Bohrmann & Akerson, 2001).

What actions has Moraine Valley Community College taken to over come the obstacles?

At Moraine Valley Community College addressing the obstacles faced by students in STEM majors takes on different fundamental nature depending on the precise student population at hand. Moraine Valley, like most community colleges, enrolls students interested in a community college education as a means to an end, i.e., job training. Often referred to as the career program students, at MVCC these students make up half of our student population. The other half consists of students interested in earning credit hours and/or degrees that transfer to other institutions. We refer to these students as transfer program students and they are interested in a community college education as a vehicle to a Bachelor's degree or higher.

For the career program students, those interested specifically in technology and engineering programs and degrees. Critical funding from the National Science Foundation, Carl Perkins and Tech Prep has enabled several of our programs to reverse the national trend of declining enrollment. Many of our programs have experienced increased enrollment and higher retention.

Table 2



Funding from the National Science Foundation (NSF) over the past five years has resulted in significant impact on our success. These successes include the college's ATE Center and the Center for Systems Security and Information Assurances (CSSIA). The funding has resulted in helped us to:

1. Develop curriculum in mechanical design, pre-engineering, Internet specialist, information technology security, wireless and Voice Over IP (through two projects and the ATE center).
2. Expand internship opportunities by hiring an internship/externship coordinator exclusively designated for CSSIA.
3. Build a "Women in Technology" mentoring program that was originally funded from a previous NSF project and now funded through CSSIA.
4. Develop an outreach program for economically disadvantaged inner city Hispanic youth who attend a computer science charter school. The student population is half female.

During the past two years, I have had the opportunity to work with a very special group of students as part of our CSSIA outreach program. The high school students, who attend the Mirta Ramirez Computer Science Academy, a charter school sponsored by Aspira of Illinois, are inner city Hispanic youth (Half Mexican and half Puerto Rican), of which half are also young women. They attend the computer science academy because they seek careers as programmers, IT professionals, IT security specialists, and network engineers.

Our efforts to assist these young people focus on providing a seamless transition from high school to college. We have sponsored several on campus events combined with activities at their own school that provide opportunity for the students to earn college credit, learn about IT careers and understand the importance of continuation their education beyond high school. We organized a community outreach event, a computer health clinic, that enabled students to assist community members by conducting virus scans and other security related operations on PCs brought to the event. The students also competed in teams and presented their projects before an audience at the all day event. The teams with the best projects were invited to Washington, D.C. to present at the annual ATE conference. Twelve students traveled from their west side neighborhoods. The experience for all of us was pretty amazing and the result of hard work, dedication and good funding was visible to all.

5. Produce video segments that show technology related careers as more appealing, interesting and attractive
6. Offer a career development course that dispels myths about the poor labor market, provides career exploration through specialized interest inventories, provides an outlet for career related research in the areas of information technology

7. Provide low or no cost teacher training and curriculum development opportunities that foster program updates. The CSSIA faculty development opportunities have enabled us to train over 800 faculty members on information assurance, network security and wireless technologies.

Carl Perkins and Tech Prep funding has significantly aided our efforts to recruit and retain STEM majors by enabling us to:

1. Provide dual credit opportunities for students in Career and Technical Education (CTE) classrooms.
2. Develop a math alignment program that brings high school teachers and college faculty together to discuss math remediation and ways to better prepare high school students for college math.
3. Develop and offer a tutoring program for Management Information Systems students.
4. Provide professional development opportunities to teachers at the secondary and post-secondary level to better implement contextual learning.
5. Provide career exploration opportunities for high school and elementary students that portray technology and engineering in a more positive light.
6. Purchase updated instructional equipment supplies and equipment to meet the ever changing demands of industry.

The obstacles for transfer students, although similar to those of career program students, are handled differently and through different funding streams:

Specifically, the college has several large Department of Education (DOE) grants from the TRIO program (Upward Bound, Talent Search and Student Support Services) that help us overcome obstacles and address recruitment and retention for STEM majors through activities that:

1. Provide support services, academic advising and career planning for students already attending MVCC.
2. Create awareness about college opportunities for pre-high school under-represented students who are economically disadvantaged and/or first generation college bound.
3. Provide tutoring and academic support that addresses remediation issues for under prepared students.
4. Offer career development opportunities that emphasize the importance of college education after high school.

In addition to grant funds that enable Moraine Valley Community College to directly address issues of recruitment and retention for STEM majors, the college also utilizes operational funds that assist to:

1. Provide dual enrollment opportunities for Advanced Placement high school students in calculus, statistics, college algebra, trigonometry, biology, and chemistry.
2. Create 2+2 agreements in mechanical design and information technology that assist MVCC student's transition into engineering and computer science Bachelor's degree programs.
3. Improve diversity in our full-time teaching faculty through a strong commitment to diversity in our hiring practices.

How are we measuring the effectiveness of these actions?

Measuring the effectiveness of our efforts to recruit and retain STEM majors is a multi-tiered process. Because grant funded programs require high standards of accountability and because NSF grants specifically are awarded on a competitive basis, we adhere to stringent standards for program evaluation and effectiveness. The best model for evaluating program effectiveness comes from a process recommended by the National Science Foundation. With help from the NSF we contract an external evaluator whose purpose is to monitor our progress against our grant objectives. A National Visiting Committee is also designated to assist in the evaluation of CSSIA. This committee provides an annual appraisal with extensive feedback. Also through NSF funds we conduct large scale surveys that assess productivity and accomplishment.

In addition to NSF determined evaluation processes, at MVCC, we benefit from opportunities available to us through our resource development and institutional research offices. These resources assist front line program administrators and coordinators with report writing, data gathering and quality analysis of our programs.

Through Tech Prep funding we contract a research associate to perform a longitudinal inquiry on dual credit and articulation related data. The outcomes from our extensive assessment of programs and yearly reporting on effectiveness are used as a basis for continuation of activities as well as in the development of new initiatives.

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

An issue of importance to all academic institutions and an issue often difficult to fully address concerns the magnitude of role models related to retention of STEM majors. At MVCC we address this issue with a strong effort towards diversifying the faculty. Hiring is a long-term commitment that requires a constant focus every single year and consumes a great deal of resources.

A major obstacle faced by other institutions of higher education is the lack of financial resources necessary to pursue competitive funding programs. In the State of Illinois our level of State funding has declined over the past few years and continues to decline. The college now finds itself more dependent on grant funded initiatives like NSF, Perkins and Tech Prep. Due to the volatile status of funding it becomes difficult to make long-term plans. We have a strong commitment to pursue NSF funding but it is very competitive. Unlike many other institutions of higher education, our institution is committed to providing the time and resources needed for the extensive proposal process.

Illinois community colleges were plagued by a lack of statewide curriculum alignment. The standardized general education core (Illinois Articulation Initiative) helps to alleviate the problems. Other states continue to struggle with this alignment.

Question Three: What role have federal agencies, particularly the National Science Foundation (NSF) played in improving undergraduate STEM education? What more should federal agencies be doing in this area?

This has been addressed in the context above.

What more should federal agencies be doing in this area?

- Federal agencies should continue to emphasize the seriousness of the social and economic issues related to recruitment and retention of STEM majors.
- Federal agencies should provide more recognition to the role of community colleges in providing pathways and opportunities in high education especially for the under-served and under-represented.
- More support should come from the federal agencies related to secondary-post-secondary collaboration (Tech Prep, Carl Perkins).
- Curriculum alignment and refinement of standards in STEM should remain a priority of the federal agencies.
- Social issues including gender and race bias in higher education should remain high priority for federal agencies.
- Continued federal support of faculty development programs should remain a priority through NSF and DOE grants.
- Investment in replicating best practices and programs that experience continued successful achievement should be prioritized at a national level.

In closing, thank you again for allowing the voice of the community college to be present at this hearing today. Community colleges have become and will remain a vital means for students, otherwise unable, to participate in high education. The issue of recruitment and retention of science, technology, engineering, and math majors is a crucial economic and social issue that demands greater consideration. I feel honored to have been afforded this opportunity to contribute to the discussion and look forward to the positive outcomes that result from this conversation. Thank you.

References

Bohrmann, M.L., & Akerson, V.L. (2001). A Teacher's Reflections on Her Actions to Improve Her Female Students' Self-Efficacy toward Science. *Journal of Elementary Science Education* 13(2), 41+. Retrieved October 27, 2005, from Questia database: *http://www.questia.com/PM.qst?a=o&d=5002438891*

Facts & Figures: Past Present and Future (2005). Moraine Valley Community College, Office of Institutional Research and Planning.

Pascarella, E.T., Pierson, C.T., Wolniak, G.C., & Terenzini, P.T. (2004). First-Generation College Students: Additional Evidence on College Experiences and Outcomes. *Journal of Higher Education* 75(3), 249+. Retrieved March 10, 2006, from Questia database: *http://www.questia.com/PM.qst?a=o&d=5005988022*

Office of the Governor, State of Illinois. Plan increases high school graduation requirement, better prepares students for success after high school. Retrieved on March 10, 2006 from: *http://www.illinois.gov/PressReleases*

United States Department of Education (2000). Reasons for Optimism, Reason for Action. Retrieved on March 10, 2006 from: *http://www.ed.gov/news/pressreleases/2005/08/08182005.html*

USA Today, March 10, 2006.

Yasuhara, K. (2005). Choosing Computer Science: Women at the start of the undergraduate pipeline, Proceedings of the 2005 American Society for Engineering Education Annual Conference and Exposition. Retrieved March 10, 2006 from *http://www.cs.washington.edu/homes/yasuhara/cv/publications/*

BIOGRAPHY FOR MARGARET SEMMER COLLINS

Education:

Candidate: Doctorate of Education, Adult, Counseling and Higher Education,

Research Agenda: Recruitment & Retention of Women in Science, Technology, Engineering and Math

Dissertation Topic: Gender Gaps in Advanced & Emerging Technologies at Midwestern Community Colleges; Northern Illinois University, DeKalb, IL; Anticipated completion: August 2006.

Master of Arts, Communication Studies (1992), University of Illinois at Chicago, Chicago, IL

Bachelor of Science, Communication Studies (1987), Northern Illinois University, DeKalb, IL

Professional Experience:

Moraine Valley Community College 1994 to present
Assistant Dean, Science, Business & Computer Technologies (2002 to present)

- Provide administrative leadership on grant projects that include the Center for Systems Security and Information Assurances (CSSIA), CSSIA Supplemental Grant, Tech Prep Support Grant and Tech Prep Consortium grant.
- Chair search committees to select and hire math, science, business and information technology faculty.
- Lead non-tenured faculty evaluation process by chairing evaluation teams.
- Direct program improvement projects for career and technical education programs that include Tech Prep, 2+2, dual enrollment, career development and work based learning.
- Assist in the oversight and management of sub-division and grant budgets.
- Work closely with faculty to strategically address marketing, outreach and improved collaboration with high schools, four-year colleges/universities and the community.
- Advocate and encourage the development and enhancement of recruitment/retention efforts geared at non-traditional students especially women in IT.

Moraine Area Career System, Oak Lawn, IL 1999 to 2002
Assistant Director/Tech Prep Coordinator, Moraine Area Career System

- Administer all fiscal and administrative responsibilities for the three regional Career and Technical Education grant programs. Responsible for budget management, progress reporting, grant writing, program development, and program supervision. Work collaboratively with staff at the Illinois State Board of Education, secondary administrative personnel, community college administration and teachers at both the secondary and post-secondary levels. The grants managed include: Federal Tech Prep, State Tech Prep and Work Based Learning.
- Lead efforts to enhance career and technical education within the Moraine Valley region by promoting and managing the development of articulated and/or dual enrollment courses aligned with Business, Industrial Technology, and Family and Consumer Sciences.
- Research local, State, and national labor market data and monitor educational trends at Moraine Valley Community College for the purpose of in-

troducing progressive Career and Technical education programs, into local high schools.

- Develop and implement professional development opportunities for area educators including secondary and post-secondary teachers, counselors and administrative staff that help educators align curriculum with the standards, learn about alternative instructional delivery techniques, and examine the latest trends in learning, instruction and curriculum development.

Coordinator for Work Based Learning, Education to Careers (1998 to 1999)

- Coordinated the development of regional work based learning programs for six high school districts and twenty-one elementary school districts in the Moraine Valley region.
- Collaborate with business and industry representatives to develop and implement work based learning strategies that meet the needs of employers and address labor shortages.

Recruiter (1997 to 1998)

- Developed and implemented recruitment strategies that promote Moraine Valley's educational offerings and community services including all credit and non-credit, adult basic education, continuing education and professional development programs.

Contractual Grant Writer (1997 to 1998)

- Researched, developed, wrote and edited grant proposals aimed at securing external funding for programs servicing the college and the region. Worked on several large federally funded TRIO grants as well as professional development grants through the Illinois State Board of Education.

Placement Specialist (1994 to 1997)

- Provided job search and career development assistance to students, community residents and alumni through one-on-one advisement, instruction of workshops and presentation of customized classroom discussions.
- Initiated and implemented the improvement of many Job Placement Center programs and procedures.
- Collaborated with instructional faculty to serve the students' job placement needs, keep abreast of labor market trends and prepare students for life after college.

Adjunct Faculty (1994 to 1997)

- Instructed basic speech communication course focussing on public speaking, group dynamics, interpersonal skills, effective listening and cultural consciousness in communication. (COM 103).

Robert Morris College, Chicago, Illinois 1992 to 1994
Placement Coordinator/Career Development Instructor

- Designed from start-up an internship and job placement program for students requiring non-paid clinical experience that included the creation of contracts, evaluation materials, tracking devices and correspondence.
- Coordinated closely with business and industry to customize each training and/or internship experience that met specific requirements of the school and employer.
- Taught career development courses designed to promote college and career success through an emphasis on work place skills and work based learning.

Publications & Presentations:

- National Tech Prep Network Annual Conference, Presenter Topics: NSF ATE Pre-conference. The Center for Systems Security and Information Assurances (CSSIA) 2004 Minneapolis, 2005 Orlando and "Math and Science Alignment the Tech Prep Way." Minneapolis, 2004.
- Wisconsin Careers Conference, Spring 2003, Madison, WI; Showcase Presentation. Topic: "Working Together for Workplace Skills Success."
- National Tech Prep Network Annual Conference, Presenter Fall 2002. Topic: "Working Together for Workplace Skills Success."

- Illinois State Board of Education, Connections Project, Conference Presenter Spring 2002. Topic: "The Aspen Health Sciences Academy, Moraine Valley Community College and Aspen High School Working Together."
- Illinois State Board of Education, Connections Project, Connections Conference, St. Charles, Illinois. "The Moraine Area Cisco Academy." Presentation to Educators. Spring 2001.
- Illinois State Board of Education, Connections Project, Connections Conference, Springfield, Illinois. "Tech Prep Transition Grant." Presentation to Educators. Spring 2000.
- American College Personnel Association, *Eleven Update,* Fall 1997 "An Emerging Professionals Perspective on Leadership." (Article published in association newsletter).
- Department of Leadership and Educational Policy Studies, Graduate Student Symposium, Northern Illinois University, "Effective Conference Planning." Presentation. Spring 1999.

Margaret Semmer Collins is the Assistant Dean of Science, Business and Computer Technologies at Moraine Valley Community College in Palos Hills, Illinois. She received her Bachelor's of Science from Northern Illinois University, a Master of Arts from University of Illinois at Chicago and is currently a Doctoral Candidate in Education from Northern Illinois University. Margaret's research agenda concentrates on gender gaps in science, math, and technology, with her dissertation specifically related to retention of women in emerging technologies at community colleges. She began her career in community college administration at Moraine Valley Community College 12 years ago. As Assistant Dean she is the lead administrator for the National Science Foundation Advanced Technical Education Center (The Center for Systems Security and Information Assurances) and provides programmatic leadership for Tech Prep, dual enrollment and 2+2 articulation with four-year colleges and universities. Margaret is a single mom with two children ages 7 and 9.

Moraine Valley
Community College

March 13, 2006

The Honorable Sherwood Boehlert
Chairman, Science Committee
2320 Rayburn Office Building
Washington, DC 20515

Dear Congressman Boehlert:

Thank you for the invitation to testify before the Committee on Science of the U.S. House of Representatives on March 15th for the hearing entitled "***Undergraduate Science, Math and Engineering Education: What's Working?***." In accordance with the Rules Governing Testimony, this letter serves as formal notice of the federal funding I currently receive related to the hearing topic.

I received no federal funding directly supporting the subject matter on which I testified, in the current fiscal year or either of the two proceeding fiscal years.

Sincerely,

Margaret Collins,
Assistant Dean, Science, Business and Computer Technology

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DISCUSSION

Chairman INGLIS. Thank you, Ms. Collins.

Thank you all for your testimony.

I will recognize myself for a round of questions.

Dr. Wieman, you said in a very interesting part of your testimony that unless you—we improve science education at the college level first, we are wasting our time and money on making major improvements in K–12. And I wonder if you could help us, because we are getting ready to spend a fair amount of money on K–12 education. We do year after year. The President has requested somewhere in the nature of $380 million I believe it is for some of his initiatives that are aimed at K–12. And I wonder if you might tell us, if you were in Congress evaluating those proposals, where would you focus the money? And also, what challenges have you found from the Administration, in the administration of your university, in implementing the kind of changes that you think would make a difference?

Dr. WIEMAN. Okay. So those are quite different questions, so——

Chairman INGLIS. Right.

Dr. WIEMAN.—let me just talk about the K–12 situation.

And I don't presume to be an expert on K–12 education, so—and it is a vast program. What I will claim to be somewhat of an expert on is looking at the science preparation—you know, the undergraduate math and science preparation of K–12 teachers, and not just both their content knowledge, but we also looked at, sort of, their general beliefs about what science is, how you learn science, and it is dismal. That is the bottom line. And so we—it is just clear that these future teachers have to have a better understanding of science, and they have to have a better understanding of what science is as well as, sort of, being competent at it if they are going to present it in a reasonable way to students. Now—so that, in terms of how that breaks down into focusing on what you would do, that—I mean, I would have to give it more detailed thought, but I think that it is clear that too often people can become certified teachers and then end up teaching math and science without ever the—I mean, teacher certification does not imply, and often is quite independent, of any competence in those subjects, and certainly a level of competence required to teach them effectively.

Chairman INGLIS. Let me just ask, on that point, to see if anyone else in the panel would like to comment on that.

Dr. Seymour.

Dr. SEYMOUR. Okay. I think we are, Mr. Chairman, in an emergency situation. And this is gradually getting worse. We have both a shortfall in the supply of teachers who have at least an education major in math or science, or even a minor in math or science, to replace the teaching force that we have. We have depended, for many years, on very able women mathematicians who used to fill our classrooms as math teachers that are now retired or retiring, but young women with math qualifications are not going into school teaching. So we have taken a resource for granted. We are now in a situation where we cannot fill the vacancies that we have with qualified math and science teachers in many states. I have cited Texas, New Jersey, and Florida as three states of which I am aware where their vacancies are largely filled by alternative and emergency certification by bringing people who have some background in STEM majors to fill those places. And the provision of math and science teachers across the country is extremely patchy. It is very variable. In our research, we have found that even in the same state, there is enormous variation at what you can expect if you happen to be a student in those classes. It is very bad in schools which predominately contain minority young people. We saw that very clearly in our research. For instance, young people who came from predominately black and Hispanic and higher middle schools into university STEM classes presented some of the most dismal stories that we heard in our "Talking About Leaving" research. They came in, as we called it, "overconfident and underprepared": They were strongly supported by their communities and their teachers in coming to the university to take STEM majors, but when they got there, were very shocked to find that they were not remotely prepared for what they had to undertake. And this was a devastating experience from which they tended not to recover.

So huge variation, as well as a shortfall, in the country in what is offered. It is regionally very, very different. And we have a crisis such that we both, I think, are obliged to support and improve the teaching force that we have by any means at our disposal—by outreach work, by summer workshops, and so on. These go on. They are well supported by the National Science Foundation and others. These have to go on. But at the same time, we must recruit teachers for our system that have disciplinary degrees in the STEM majors. And that is where we are woefully short. That is what is not happening. And I agree with my distinguished colleague that unless we attend to the supply of teachers from the universities, from baccalaureate students, we are in a deepening, serious national crisis in the quality of our K–12 teaching force. And the comparisons with the international situation, I think, are very, very well known.

Chairman INGLIS. Okay.

Now the second part of my question, I am interested in getting Dr. Wieman and Dr. Burris to talk about the second part of that, which is right here we have a professor and the President of a college sitting side by side. What are the challenges that you have faced in terms of getting an administration to move the college culture, the university culture?

Dr. WIEMAN. I think it is important to appreciate. I mean, I work at a large research university. At large research universities, the culture is really not set by the administration. You can't go and tell a physics department or a chemistry department or a biology department—as a President, you just can't go and tell them what they should teach, how they should teach, what fields they should go into. They just ignore you. That is the way those structures work. So that is why I am saying is if it really happens at the department level and, to a large extent, those departments, they succeed or fail on their external success. I mean, that is why they are kind of decoupled from the administration. Successful departments go out and they find federal agencies that will support them to get—bring in more research dollars. They can be more active. They can get more prestige. And so that is what I am saying. That is where the reward system—and, you know, the Federal Government is somewhat responsible for that. But that is really graded, the reward system, and, really, the structure in who answers or doesn't answer to whom, in the large research universities.

Chairman INGLIS. Dr. Burris, your comments on that.

Dr. BURRIS. Well, I don't want to sound overly Pollyannaish, but the situation at small liberal arts colleges is really quite different. My sense is that both the faculty and the administration, in making decisions about what model we think works, in fact, means that there is little or no resistance to implementation of small classes, hands-on learning, inquiry-based methodology. I certainly know that is the case at Calvin College where the physics is taught that way, I am sure. But the point being, it is exactly as Dr. Wieman said. We are comparing a little bit apples and oranges. The reward system, which I think very successfully produces K–12 teachers as well as future scientists at small liberal arts colleges, is based very much on the success of the faculty as teachers. They must be scholars, and we strongly believe the emphasis and importance of their scholarship, but they first and foremost must be teachers. As teachers, they see their primary responsibility being to teach in the best possible way. And that is one of the arguments for the value of small liberal arts colleges, not only to train future scientists but train future teachers. We have an education department. Anyone who wishes to be a teacher in biology or physics or math must major in the disciplinary field. The education department provides some of the pedagogical assistance, but their majors, upon graduation, will be in the various fields that they will ultimately teach.

So I don't think—I think it is a very different reward system. If I can comment on my own career, where I started at Penn State, the reward system would be very similar to the University of Colorado, that is I was judged on my ability to receive external funding. I was judged on my publication record. And to be quite frank with you, my teaching was very low on the totem pole in terms of a reward system. That is not the case at liberal arts colleges. And until research universities are willing to attach a reward and that reward translates into promote and 10-year salary increases to teaching, we are not going to change the system easily. And I am sure that Dr. Wieman would—could speak further to that, but we have a very different system, as an administrator at a small liberal arts college.

Dr. WIEMAN. I—can I make a—I actually spend a reasonable amount of time visiting, not Beloit, but many small colleges, and I speak lots of places. And there is a difference between being dedicated to teaching and valuing it and doing it effectively. And I see many small colleges where their—and faculty universities as well are very committed to teaching, but they are following an obsolete model that our research says just doesn't work very well. And that happens at small colleges, big colleges, universities, and so on. It is really a different method. It is really an evidence research-based method that, by and large, is not implemented at any institutions on a widespread basis.

Chairman INGLIS. I am extending my time quite a bit. And I should call on Dr. Ehlers, I believe, next.

So Dr. Ehlers.

Mr. EHLERS. Thank you. It is very difficult for me to answer—ask a question. I basically feel like saying "Amen," because it is rare that I have—that I agree with things that are said by almost the entire panel of witnesses that are before us.

But you are all right on target. You are looking at different parts of the target, in some cases, but I really appreciate the work that—not just the work you are doing, but the work you represent. And I am very absolutely delighted to see what I would call the awakening of the consciousness of universities and colleges about the importance of teaching and the search to do it properly and do it correctly. As some of you know, because I have had conversations with you, I have spent a good deal of my academic career trying to teach elementary school teachers both science and how to teach science. And that arose out of something very simple. I became concerned about what was called scientific illiteracy in the late '60s, and I simply asked myself, "What can I, as a physicist, do? How can I impact that?" And I decided that I was not likely to ever have a national impact, since I had never intended to get into politics, but I decided what I could do is, in my classroom, teach—I could volunteer to teach future elementary school teachers. And that guaranteed me the job of doing it, because no one else really wanted to do it. And I tried to develop programs that would assist them and make them feel comfortable once they got into the classroom. I also taught a couple of National Science Foundation summer institutes for teachers who were already in the classroom, which is, by far, the greatest problem in this country at the moment, how do you reach the teachers who are already there who did not learn enough science and don't know how to teach it properly. And it is through no fault of their own. I never knock the teachers, because every classroom I have worked in, teachers desperately wanted to teach science and mathematics properly, and they were afraid of the subject. They did not feel qualified to teach it. And so, I think, number one, an immediate objective has to be to make them at least have enough knowledge so that they feel confidence about what they are trying to teach and not avoid it. But teaching future teachers is equally important. And we have to do both.

My question for you is what role do you see the Federal Government having? We have no control over curriculum at the federal level, no control over textbooks, anything of that sort. Most of our efforts are going to try to help poor school districts and poor students. And by that, I mean financially poor in both cases. What would you advise us to do in terms of developing programs that can help people like you and the people at your institutions do an effective job of reaching both existing teachers and the future teachers?

Dr. GOROFF. I would like to agree with my colleagues that I think the first priority should be investments in in-service and preservice work with teachers, including content faculty at the college level, working with those teachers. And I just wanted to say, though, that my experience with this is a little bit different from my colleagues, and give some hope to the notion that federal and other dollars can make a difference in all of this. So at Harvard, a place where, I would say, some people have heard that the faculty and administration can be a bit obstinent, I was the founding director of a program, a masters degree program, in mathematics for teaching. It is run by the mathematics department. It is offered through the Harvard Extension School. And right now, we are enrolling about 100 teachers per semester in these courses. And I also want to say that throughout the mathematical community, there have been a great deal of reports and reforms specifically about teacher preparation and its importance for the country and for the discipline. So I want to say that it can be done and it can make a difference.

Mr. EHLERS. I personally think one of the roadblocks has been—is strictly a cultural one that I don't see in very many other countries, and that is this cultural belief that somehow math and science are not for women and, perhaps, even minorities. And that—the tragedy is not that it is—that that view is being imposed, but that these groups tend to feel that within themselves. And since the majority of our teachers are female, that creates a real problem, and I have spent years trying to overcome that cultural bias. I don't know how we could address that.

But I gather, from the response and the smiles I see, that someone else asked this question before me. I am sorry. I had to step out to go to something else. But where would you envision the programs best being housed? The National Science Foundation? The Department of Education? Or should we simply hand the money to the states and ask them to do it, following certain guidelines? I see——

Dr. BURRIS. You have lots of hands on that one, and my answer is very quick and simple. The National Science Foundation, I think, is absolutely the best place for such programs to be housed. Unequivocally. No arguments.

Mr. EHLERS. Is that—is everyone agreed on that? It is very important for you to send that message to the Congress and to the Administration as well, because there seems to be a shift in opinion on that.

Dr. SEYMOUR. Yeah.

Mr. EHLERS. Yes. Go ahead.

Dr. SEYMOUR. Working, as I do, as an evaluator of programs, many of which are funded by the National Science Foundation, I would say that I have seen stunning work done in the Collaboratives for Teacher Preparation, which are regional, in the Math and Science Partnerships. I am a member of the board of the partnership in Puerto Rico. Quite magnificent. That work needs to continue. I have also seen, both as evidence, and in person, the work done by the workshops—many different kinds of workshops—some by private foundations, like Project Kaleidoscope, but also ones which have been funded by the National Science Foundation—the M.I.D. workshops in chemistry, and others. Workshops are one of the very best ways to get the knowledge out there to faculty who are interested, or curious, or even skeptical, about new ways of teaching. They can come into a safe place and try new methods hands-on and learn them with other people without loss of face. And with the assurance of camaraderie can go away and work on these in their own classrooms, and still have that support from the workshop members. It is a wonderful way of building the whole community, nationally, of people who are interested in and engaged in the business of how students learn. So NSF workshops are very, very important.

And then something which we have not done well, which I would advocate, it—we need programs to educate the teaching assistants in how to teach in accordance with the new knowledge that we have. There is plenty of knowledge out there. It is very, very available, and it is also very accessible. So we are not short of knowledge about how to teach well, but we are a little bit primitive in our understanding of how to educate our teaching assistants how to use it in active and interactive support of the classes. Unfortunately, most students do not learn their science and math in Beloit College. It would be nice if they did. The majority are learning their math and science in the major universities, and that is where the support for the TA is needed—TAs who work for professors who are constrained increasingly to work just in a lecture mode. We need support for the TA who is the person who has the active engagement with the student. That is where the effort needs to be placed, I think. And, nationally, we are not doing that well. And I would love to see the National Science Foundation and others supporting that effort.

Mr. EHLERS. A very pragmatic question. You say you have been in a lot of workshops. What do you think is the optimum length of time in a workshop?

Dr. SEYMOUR. I think good. I have reviewed in my testimony what we know from evaluation of the workshops. What I see—I have said is a building of a national network which connects people who are not of the same department or even necessarily of the same institutions and builds them into a virtual community, which is actually the mainspring for what is now happening in improving science education. People are connected. People meet each other at professional meetings. The professional societies have responded by developing educational sections. So I see, over the last 15 years, the building up of a skilled workforce amongst science and math faculty who are the people who teach others and who constantly replenish the workshop teachers. So I am very, very impressed with them, and we should support them financially. Incidentally, they are extremely cheap, because the faculty who man the workshops and woman the workshops do it for free if you just pay their expenses.

Mr. EHLERS. Thank you.

And if I may have a little more time, Mr. Chairman.

Chairman INGLIS. Certainly.

Mr. EHLERS. Dr. Wieman, you have talked about the research you have done and the results are clear, have—has this been adopted by your university and by your departments, or are you a prophet without honor in your own country?

Dr. WIEMAN. Somewhere in the middle. It is—you know, it is being somewhat adopted, so they—you know, but it is sort of on an individual by individual basis. Again, it is—you know, and I think my department isn't any different from many other departments. It is a question of everybody is busy, you know, trying to be as successful as possible. It takes extra time to change, you know, to develop new teaching materials, new teaching methods, to assess and do good assessment, if they are working. And so, you know, the—

convincing people to do that right now, it is pure altruism. You know, you talk to them enough and you show them the results and they will try and fit it in a little bit here and a little bit there, but change driven by altruism is pretty slow whereas when I see you get big changes are when there is a major—I mean, I see changes in physics departments that clearly follow federal funding where there is, you know—it is—but it is always in the research side where there is a major program. It is clear there is going to be a large amount of money over a sustained time that really could, you know, transform a department. Suddenly, a department decides that, you know, plasma science or nanotechnology is suddenly the wonderful, important, high-priority thing for their department and because it can support, you know—they see it correctly as supporting programs and faculty for many years, and they will move into that area, if there was something. But you know, for teaching, it—you put in the extra time because you get a warm, fuzzy feeling inside, but that is about all it comes down to.

So you know, that is within my department and lots of other places.

Mr. EHLERS. Yeah. It sounds very familiar.

Now do you think that an NSF program, which was aimed at a specific department at a specific unit, in other words, they would apply for a grant to, perhaps, even provide some faculty time for this, but certainly something that would develop the camaraderie, the spirit, the altruism that is necessary? What—do you think that could be successful?

Dr. WIEMAN. If it was designed right, I would be optimistic it could be. I mean, like I say, you just—the best model is how research funds have transformed departments and institutions and—but I would say right now, those are the only examples we have of really—where you have major cultural changes in higher education is—following the money is what it comes down to.

Mr. EHLERS. We need altruistic people who will cough up the money.

Thank you very much.

You had a comment?

Dr. GOROFF. Can I offer a different perspective, actually?

Dr. WIEMAN. At Harvard, they have so much money.

Dr. GOROFF. Well, I think altruism is actually an important motivator. But I also want to mention that these problems are intellectually interesting and that that is the reason why most academics went into the field that they did, because they like to solve problems and they want to know about the research and the kind of work that Dr. Wieman was talking about before. And if you present it that way, people can be very engaged in it. And again, at the Derek Bok Center for Teaching and Learning at Harvard, where I was the Associate Director, we were able to bring people in to do a great deal of work, got themselves videotapes to participate in research, to get all sorts of feedback on their teaching, and this was done confidential and voluntary. There were no rewards for it or anything else, but the important part about it, and an extensive work, by the way, with the graduate students, none of the people teaching calculus in the mathematics department were allowed near students before they had gone through a detailed apprenticeship with visiting classes and doing practice sectors and being videotaped and getting all sorts of feedback from coaches who they were paired with. And only then were they allowed to stand up in front of calculus teachers—in front of calculus students, I should say. But the important part about it was that we made all of these things intellectually interesting and useful. And people showed up, and they continue to show up, and I think that it really can make a difference in that way.

Mr. EHLERS. Interesting. When I was a student at Berkeley, my thesis advisor advanced the theorem that the people who are really concerned about teaching well are the ones who don't really have to worry about it, because they generally are already good teachers. And in fact, when I was teaching there, I always used student evaluation sheets several times during the semester. And he scoffed at that and says, "People who hand those out don't—are the ones who don't need it. The people who really need it are afraid to hand them out and don't."

Dr. GOROFF. These were programs, really, for all of the different——

Mr. EHLERS. And people didn't——

Dr. GOROFF.—graduate students and for faculty, including people, who, I have to say, started off really unemployable. Great, talented mathematics from other countries who could not teach at all, and who, after work and after getting the idea that the culture of the department was that this was important, this was interesting, and something that you could get feedback on and improve with, that some of these graduate students who, as I said, were totally unemployable to begin with, ended up earning teaching awards.

Mr. EHLERS. Excellent.

Dr. GOROFF. And so it can be done. We just need more examples and a little bit more resources.

Mr. EHLERS. Well, you have established that you think the National Science Foundation should be running the programs. What we haven't established clearly is the types of programs, and I don't think there is time for that here. But I would certainly appreciate any ideas you would want to send the Committee about the best types of programs for them to sponsor.

Dr. WIEMAN. And you have already said there isn't time, but I will jump in anyway. That is—when I said the doubling of the NSF budget, which is going to happen, we want to make sure that that doubling includes funding of research on pedagogy, on curriculum, makes it an intellectually interesting problem, makes it something that faculty are rewarded for doing, can compete for grants. And then the second part is sustainability, that it is not simply one program works for two to three years. There has to be some sustainability. So within the NSF budget, just making certain that this is not lost in the shuffle, as the doubling occurs and the money moves primarily to the research directorates, make certain that there is money specifically for these questions like curriculum and learning how people learn and pedagogy.

Mr. EHLERS. Thank you.

Dr. GOROFF. I would echo that.

Chairman INGLIS. Thank you.

Now let me recognize Dr. Lipinski.

Dr. LIPINSKI. Thank you, Mr. Chairman.

I apologize for being here—getting here late. This is a—something that is very near and dear to my heart, and I think it is critically important. I had an unfortunate—I have been working on this bill. I have been working for a year to get a hearing on this, and I was testifying over there. It is actually a bill introduced with the Chairman. So I was taking care of that.

But I want to thank all of the witnesses here, and especially send a special thanks to Ms. Collins for being here from Moraine Valley Community College, which is located in Palos Hills, which is Palos Hills, Illinois, in my District. And I would like to thank her for what she is able to add to this hearing, because we—so much, we sort of overlook the community colleges, and they are critically important. And if we don't get kids interested there, the ones who are attending, then, you know, they are not going to go on. They are not going to continue in any of the STEM fields. So I thank Ms. Collins for her work and for her testimony here today.

STEM education, like I said, is near and dear to my heart. I have a—one of the few Members of Congress who actually has a degree in engineering. I got a mechanical engineering degree from Northwestern. I got a degree in engineering economic systems from Stanford. My wife actually was a math major in college, and so I have a lot of experience between myself and her. And I am very happy to hear what Mr. Goroff was saying about training of TAs, because certainly TAs, when I was in—an undergraduate, I don't think they were trained very well to teach, and when I was a TA, when I was—I went on to grad school and a—in political science. I actually turned over to the dark side. But I wasn't trained. And I think that is really critical to do. We do more of that, because that is where you lose so many. You know, you go to calculus class and, you know, you go to the TA and the TAs just cannot teach and just really—students lose interest at that point.

I wanted to focus on Ms. Collins here on the—what her institution does. First of all, what would you have to say about the role of your institution in educating undergraduates who transfer, then, to a four-year institution to complete their bachelor degree in science and engineering? I mean, how does your—how do you go about doing that? How do you specially try to prepare them for this?

Ms. COLLINS. At community colleges, we have primarily two types of students, if I can make it that simple. Career program students are ultimately interested in gaining skills so that they can become employed after an associate degree. And then our other population is what we consider primarily transfer students, and those are the students we are preparing to transfer to four-year institutions or higher degree granting institutions. We provide many, many resources for the students at Moraine Valley Community College to help them succeed, and we do use funds from a variety of sources to ensure that there is tutoring, academic assistance through academic advising, and also to help with remediation. It is an issue at the community college probably more so than at the large universities and the smaller liberal arts colleges that students come in and are in need of remediation for math and science. Oftentimes the high school students, in particular, that wind up at the community, they are there because they have chosen that intentionally or they end up there for other reasons. And oftentimes they don't have the amount of—or the level of science or the years of science that students planning to go to the university have. So we have to address that right off the bat. And what I have found to be an extremely useful effort is the collaboration between the teachers at all levels and that—those conversations. And as we were talking about how the National Science Foundation can help, I believe in collaboration. I believe that we should get institutions together. We should get math teachers together. We should get science teachers together. And we should really talk honestly about those issues. We were a little nervous bringing our math and science teachers in a couple of years ago when we wanted to have this conversation. We thought it would go much like, "Oh, it is their fault." "No, it is their fault," because no one really wants to take any blame for remediation issues. And what happened was a really profound and enlightening conversation between educators who really care about students, who really care about their success. And since then, we have developed programs to work on preparing students in high school to take entrance exams, to take placement tests, to—we have worked in—with our high schools to develop bridge science courses to help them prepare and become—come to Moraine Valley so that they can assume that position at college level and then successfully transition on to the four-year school.

All of these efforts are about collaboration. And I will speak to collaboration over and over. But it is also about energy and it is also about good educators caring about the students. We also tried to develop two-plus-two programs. We have developed a few where we work with the universities. I am an advocate of that seamless education. I work with the high schools. I work with the four-year colleges. And how I work with them is to understand the curriculum and where we meet and where we need to better meet. And those conversations are always, always beneficial. Most of the time it comes down to math when we are gearing up towards an agreement. And most of the time, it comes down to calculus. So we are working now to help prepare our students at Moraine Valley to be able to transfer to a university and do better at calculus. So——

Dr. LIPINSKI. And I am relying on the Chairman here to close this down. We have to vote, so I am just going to—I am going to keep going until he does that.

Chairman INGLIS. Go right ahead, Dr. Lipinski. We will let you know when we have got to run to vote.

Dr. LIPINSKI. Okay.

The—in your testimony, Ms. Collins, you described Moraine Valley's involvement with the NSF advanced technology education program. What do you see is the—is there anything that you would recommend for changes to it?

Ms. COLLINS. Our ATE center is very successful. In the past several years, we have trained over 800 faculty members throughout the country in areas of IT security, in wireless, in other emerging technologies. So the teacher training component of it is very successful, and it is an excellent model that should be replicated. I would definitely like to see those efforts in the areas of—the other areas of STEM that took on that flavor, because that has been hugely successful. Some of the issues that we have pertain to money or budgetary issues and working with six other institutions as we try to spend the money. Those kinds of conversations between and among institutions can be complicated, as we all do thing so differently. But we figure out a way. And the programs that we develop are certainly worth the effort and the headaches we have at times. But we will continue to challenge ourselves to spend that money and learn how to do it in a consortium-like atmosphere.

Dr. LIPINSKI. Okay. Thank you.

I think I probably should wrap—I will wrap up my questions here, I think.

Thank you all very much. And thank you all for your testimony.

Chairman INGLIS. And we do thank all of you for your testimony. Thank you for taking time to be with us today. We appreciate your testimony and look forward to continuing to work towards solutions on this challenge. It is particularly gratifying as—being—having the opportunity to chair the Research Subcommittee, which authorizes the budget of the NSF to hear that earlier resounding note of approval of the NSF's work. And that is very encouraging to all of us on the Subcommittee, and I am sure encouraging to the people at NSF.

There being no further business to come before this hearing, the hearing is adjourned.

[Whereupon, at 11:35 a.m., the Subcommittee was adjourned.]

Appendix:

Answers to Post-Hearing Questions

ANSWERS TO POST-HEARING QUESTIONS

Responses by Elaine Seymour, Author, "Talking About Leaving: Why Undergraduates Leave the Sciences;" *Former Director of Ethnography and Evaluation Research, University of Colorado at Boulder*

Questions submitted by Representative Eddie Bernice Johnson

Q1. Regarding ethnic minorities and STEM, what in your experience is the best federally-funded program or entity to encourage minorities to enter STEM careers?

A1. Perhaps the most effective federally (and privately) funded programs in encouraging students of color to become interested in STEM careers (and that have successfully sustained them into such careers) have been the undergraduate research (UR) programs that have been specifically targeted towards groups that have been historically under-represented in the sciences. Undergraduate research programs of this type have been better evaluated than most other UR programs so we know more abut their benefits.

Our research group recently wrote a report (Melton et al., 2006) on the Significant Opportunities in Atmospheric Research and Science (SOARS) project which introduces young people of color to the environmental sciences. It is funded partially by the National Science Foundation (NSF) and partially by the program organizers, the National Center for Atmospheric Research (Boulder, Colorado). It is typical of UR programs targeting students of color in its emphasis on mentoring and support for its participants, all the way from high school recruitment to STEM graduation.

Other studies of programs that aim to increase the participation of under-represented groups in the sciences, including men of color, women of all races and ethnicities, and first-generation college students, all show that undergraduate research experiences are the primary factor prompting these students' decisions to enter graduate school. (Foertsch, Alexander and Penberthy, 1997; Alexander, Foertsch and Daffinrud, 1998; Hathaway, Nagda and Gregerman, 2002; Adhikari and Nolan, 2002; Barlow and Villarejo, 2004, Russell, 2005). Bauer and Bennett (2003) found that UR alumni were about twice as likely as non-UR alumni to pursue a doctoral degree and Russell (2005) found a significant correlation between UR participation by Hispanic and African-American students and their expectations of receiving Ph.D.s

The success of these targeted UR programs argues for renewed and increased financial support via the NSF, the National Labs, and private foundations.

My caveat about the undoubted value of targeted UR programs is that they can only serve relatively small numbers of students because of their labor intensive character. As the national figures for the production of minority STEM graduates show, despite considerable expenditure of money (both public, largely via the NSF, and private, via the Foundations) and over a decade of serious effort, we have made very little progress in drawing students of color into the sciences and sustaining them there into STEM careers.

One prime cause of our failures is that we focused too much on encouraging students of color to become interested in the sciences and to aspire to STEM careers without providing them with an adequate K–12 education in science and mathematics to support such ambitions. The effect has been to create a revolving door in which we increase minority STEM enrollment only to see these students fail out, field-switch, or drop out of college altogether. As I indicated in my testimony, it is the height of cruelty to encourage seriously under-prepared students to undertake a STEM major.

My answer to the question, therefore, is that, to make a substantial improvement in both our enrollment, retention, and successful placement of students of color in STEM-based careers will require a proactive, well-funded policy of recruitment of seasoned and well-qualified mathematics and science teachers into middle schools and high schools in greatest need. These schools tend to be in inner cities, rural areas, and especially include schools with high minority enrollments. (I say "seasoned" because initiatives such as "Teach for America" have found it problematic to send young volunteer teachers into such settings; there is also a high drop out rate among trained young teachers in such schools.)

Our national priority should be to improve the science and math preparation of all K–12 students. On the premise that a rising tide will lift all ships, such a policy will disproportionately enable more students of color (and also women) to participate in STEM careers. Without such a policy in place, encouraging seriously under-prepared students to aspire above what they can reasonably accomplish is a waste of money and damages young lives.

Q2. How can we help teachers do their jobs better to captivate kids and encourage them to pursue STEM careers?

A2. My answer to this question is connected to that above. One root cause of our difficulties is (as outlined in my testimony) the serious (and worsening) shortage of adequately qualified science and mathematics teachers throughout our K–12 system. There are two ways to address the problem:

1. to improve the quality of the teaching force that we already have
2. to induce more people with STEM undergraduate degrees to enter K–12 teaching.

The NSF has worked hard to address the first problem, through (for example):

- the Collaboratives for Excellence in Teacher Preparation
- the Math and Science Partnerships
- the State (sand also Rural) Systemic Initiatives
- a variety of outreach programs that draw STEM faculty and graduate students into working with local science and math teachers to build their knowledge and research capacity, and that often include working in K–12 classrooms to model what it is to be a scientist and to convey to students what scientists do
- enrichment workshops for science and math teachers.

The NSF are currently hampered in these efforts because of serious cuts in their recent budgets for education support work.

An example of the benefits both to STEM graduate students and to the middle and high school students that they teach may be found in our recent reports (Laursen et al., 2004; 2005) that evaluate the Science Squad Program for the Biological Sciences Initiative at the University of Colorado at Boulder.

Thus, the answers to both questions include:

1. increasing and sustaining financial support for the NSF's educational programs
2. launching a national campaign that will both enhance the quality of the existing science and mathematics K–12 teaching force, and actively recruit and support STEM undergraduates into K–12 teaching. (Again, the NSF has an important ongoing role to play in both endeavors.)

References Cited

Adhikari, N., & Nolan, D. (2002). "But What Good Came of It at Last?": How to Assess the Value of Undergraduate Research. *Notices of the AMS* 49(10):1252–1257.

Alexander, B.B., Foertsch, J.A., & Daffinrud, S. (1998, July). *The Spend a Summer With a Scientist Program: An Evaluation of Program Outcomes and the Essential Elements of Success.* Madison, WI: University of Madison-Wisconsin, LEAD Center.

Barlow, A., & Villarejo, M. (2004). Making a Difference for Minorities: Evaluation of an Educational Enrichment Program. *Journal of Research in Science Teaching* 41(9):861–881.

Bauer, K.W., & Bennett, J.S. (2003). Alumni Perceptions Used to Assess Undergraduate Research Experience. *The Journal of Higher Education* 74(2):210–230.

Foertsch, J.A., Alexander, B.B., & Penberthy, D.L. (1997, June). *Evaluation of the UW–Madison's Summer Undergraduate Research Programs: Final Report.* Madison, WI: University of Wisconsin-Madison, LEAD Center.

Hathaway, R., Nagda, B., & Gregerman, S. (2002). The Relationship of Undergraduate Research Participation to Graduate and Professional Educational Pursuit: An Empirical Study. *Journal of College Student Development* 43(5):614–631.

Laursen, Thiry & Liston, May, 2005. *Evaluation of the Science Squad Program for the Biological Sciences Initiative at the University of Colorado at Boulder: 11 Career Outcomes of Participation for Science Squad Members.* Report prepared for the Biological Sciences Initiative and the Howard Hughes Medical Institute. Available on request from *sandra.laursen@colorado.edu*

Laursen, S., Liston, C., Thiry, H., Sheff., E., and Coates, C. (2004). *Evaluation of the Science Squad Program for the Biological Sciences Initiative at the University of Colorado at Boulder: 1. Benefits, Costs and Trade-offs.* Report prepared for the Biological Sciences Initiative and the Howard Hughes Medical Institute. Available on request from *sandra.laursen@colorado.edu*

Melton, G., Pedersen-Gallegos, L., Donohue, R., Hunter, A–B (2006). SOARS: A Research-With-Evaluation Study of a Multi-year Research and Mentoring Program From Under-represented Students in Science. Available on request from *pedersel@colorado.edu*

Russell, S.H. (2005, November). *Evaluation of NSF Support for Undergraduate Research Opportunities: Survey of STEM Graduates.* Contributors C. Ailes, M. Hancock, J. McCullough, J.D. Roessner, and C. Storey. (Draft Final Report to the NSF.) Menlo Park, CA: SRI International. Retrieved 2/19/06 from *http://www.sri.com/policy/csted/reports/*

ANSWERS TO POST-HEARING QUESTIONS

Responses by Carl Wieman, Distinguished Professor of Physics, University of Colorado at Boulder

Questions submitted by Representative Eddie Bernice Johnson

Q1. Regarding ethnic minorities and STEM, what in your experience is the best federally-funded program or entity to encourage minorities to enter STEM careers?

A1. Although I am aware of several programs, I do not know enough to say which of them is best. Judging from the tiny number of ethnic minorities in my own field of physics, there is no program that is achieving significant success in encouraging ethnic minorities to go into physics. I have looked a little at the numbers of ethnic minorities graduating with Bachelor's and Ph.D. degrees in physics and they remain minuscule from essentially all the major colleges and universities in the U.S. except for HBCUs. There is no indication that anyone has found a successful way to attract and retain ethnic minority students at the college level, except for HBCUs, and few of them go on to get Ph.D.s at non-HBCUs.

Q2. How can we help teachers do their jobs better to captivate kids and encourage them to pursue STEM careers?

A2. This is a big question that could have many different answers. I would say that one essential item is to have teachers who understand STEM subjects well enough so that they are not afraid of them and they understand the full intellectual richness and excitement of the subjects. Currently, only a very small fraction of K–12 teachers have that level of mastery of STEM subjects, and virtually no teachers do who teach at the critical K–6 grade levels. So pre-service and in-service training for teachers to provide them with the necessary mastery and comfort level in STEM disciplines, as well as recruitment programs to attract people with talents in STEM disciplines into K–12 teaching are essential steps. They are probably not the only things that need to be done to successfully encourage kids to pursue STEM careers, but if they are not done, it is hard to see how any other programs will be successful. I am aware of two very similar programs that have been quite successful at attracting talented STEM majors in college into K–12 teaching. They are the U–Teach program at University of Texas at Austin, and the STEM–Teacher Preparation program here at University of Colorado at Boulder.

ANSWERS TO POST-HEARING QUESTIONS

Responses by John E. Burris, President, Beloit College

Questions submitted by Representative Eddie Bernice Johnson

Q1. Regarding ethnic minorities and STEM, what in your experience is the best federally-funded program or entity to encourage minorities to enter STEM careers?

A1. Beloit College is a member of the Wisconsin Alliance for Minority Participation (which, as you know, is a Louis Stokes program). This works because it is a statewide alliance with the entire University of Wisconsin system and several invited private colleges, including Beloit and Lawrence (both members of the Associated College of the Midwest). Within the Alliance, we participate in regional working groups (with several of the UW campuses) which have been very successful in planning joint internship activities for STEM students, beginning with rising first-year students, and also actively engaging students from the two-year campuses in the undergraduate research opportunities sponsored by the Alliance. So to answer your question directly—programs such as WiscAMP work because of several reasons:

First, the intent is to give students the experience of doing science-introducing them to the joy of discovery;

Second, for the summer programs, the stipends replace what they might have earned in a summer job;

Third, students join a community of scientists within the region, that includes successful upper-level minority students mentoring the younger ones, and we have a stellar group of faculty who are passionate about science and about students;

Fourth, this is a five-year program, with challenging goals set for that time period, but without the annual applications that are so time consuming.

Finally, I should emphasize that the program is built on "what works" on campuses like Beloit, which is recognized by our colleagues from public institutions in this state. This means that moving quickly and cost-effectively is possible and makes the best use of the investment of federal dollars.

Further, I draw attention to the McNair Program, a program that serves the same students with the same goals. Although McNair is not exclusively for STEM undergraduates, several of our participants have pursued STEM careers. As a result of our involvement in WiscAMP, we currently have a cohort of students in STEM disciplines who will be entering the McNair Scholars Program in the next entering class. We are very proud of the success of our McNair scholars and have watched as they have pursued graduate careers in the sciences.

Q2. How can we help teachers do their jobs better to captivate kids and encourage them to pursue STEM careers?

A2. Let me answer this question from the perspective of how to help "undergraduate" teachers, and as a president. First, there have to be institutional programs and structures in place that address the need for faculty development. Dr. Wieman spoke directly about this at the Hearing on March 15, that the skills of teaching, of incorporating new pedagogies and technologies, of being able to incorporate research on learning into their scholarly work, are skills that have to be nurtured intentionally. We cannot expect that faculty can gain these skills without guidance in exploring models of effective practices. So the kind of NSF-funded workshops that Beloit colleagues John Jungck (BioQuest) and Brock Spencer (ChemLinks) have been leading for almost a decade are critical, and they should be part of a national agenda to strengthen student learning. Again, as with my discussion about WiscAMP, faculty are also better equipped to captivate students and to encourage them, when faculty are up-to-date with their field of research and have good connections to the world of work their students will enter upon graduation. This faculty development dimension of ensuring a strong STEM infrastructure must be taken seriously as we shape programs for the future.

ANSWERS TO POST-HEARING QUESTIONS

Submitted to Daniel L. Goroff, Vice President for Academic Affairs; Dean of the Faculty, Harvey Mudd College

These questions were submitted to the witness, but were not responded to by the time of publication.

Questions submitted by Representative Eddie Bernice Johnson

Q1. Regarding ethnic minorities and STEM, what in your experience is the best federally-funded program or entity to encourage minorities to enter STEM careers?

Q2. How can we help teachers do their jobs better to captivate kids and encourage them to pursue STEM careers?

ANSWERS TO POST-HEARING QUESTIONS

Responses by Margaret Semmer Collins, Assistant Dean of Science, Business, and Computer Technologies, Moraine Valley Community College

Questions submitted by Representative Eddie Bernice Johnson

Q1. Regarding ethnic minorities and STEM, what in your experience is the best federally-funded program or entity to encourage minorities to enter STEM careers?

A1. The NSF ATE program is an excellent federally-funded program that encourages minorities to enter STEM educational/training opportunities that lead to STEM oriented careers. My direct familiarity with the Center for Systems Security and Information Assurances (CSSIA), an ATE funded regional center located at Moraine Valley Community College (MVCC), has provided me with first hand experience related to STEM promotion through curriculum alignment, high school partnerships, and collaboration with community based organizations. CSSIA works closely with the Mirta Ramirez Computer Science Academy, a charter high school on the northwest side of Chicago, which is supported by Aspira, a National Hispanic Not for Profit Organization. This collaboration provides learning opportunities for students otherwise unavailable to inner city Hispanic and Latino youth. The funding allows Moraine Valley Community College to work with the students directly while also affording professional development opportunity for high school faculty and staff. The results are concrete and long term as specific student feedback indicates an increased awareness about technology careers, a desire to attend college in a technology oriented program and ambition to achieve educational and career goals. I fully support funding that enables secondary and post-secondary educational institutions to work this closely. I encourage all partnerships that work towards aligning STEM curriculum, providing transitional services for high school students and involve community based ethnic minority organizations.

Additional funding sources that have assisted in these efforts include the federal secondary and post-secondary Carl Perkins grant. This funding more specifically assists with program development, implementation and maintenance of the public high school and community college Career and Technical Education (CTE) and Tech Prep programs. These programs align more distinctively with engineering and technology programs. ATE funding has the ability to cast a wider net because in addition to technology programs, ATE encompasses science and math curriculum/programs in institutions other than community colleges. Nonetheless, Perkins funding and the benefit to students should never be underestimated with regard to STEM.

Q2. How can we help teachers do their jobs better to captivate kids and encourage them to pursue STEM careers?

A2. Captivating kids and drawing them into STEM careers takes concerted, continual and big picture effort. This effort needs to begin early and should be incorporated into a developmental guidance program. Educational institutions should focus on technological literacy that begins in the primary grades for all students. Focused career awareness activities that emphasis STEM careers should be incorporated at the middle school years and career plans tied to educational plans should be required in the high school years.

More so, kids today need to see STEM as cool. I have an eight-year-old boy and a nine-year-old girl. From this experience, I see kids most captivated in any activities that allow them to use their hands and solve complex problems. They are engaged in activities that incorporate music, creativity and competition. They best enjoy math and science when it fully relates to every day experiences, activities and situations. They use technology to have fun first not realizing they are learning too. Kids will be captivated with fun, engaging and interactive STEM curriculum. Teachers must have an opportunity to develop skills to deliver STEM in this way and teachers should be technologically savvy. This skill development and awareness should occur preferably during teacher training prior to graduation/certification or through concerted on-going professional development activities at the local level.

At the post-secondary level, namely the community college, teachers should have opportunity through funding to develop mentoring programs and tutoring assistance geared at retention of STEM students. Funding for curriculum development that incorporates the most up to date and effective instructional techniques for teaching STEM courses should be made available. A priority should be placed on understanding how individuals learn, on understanding learning styles and on incorporating the most favorable for STEM success into existing curriculum. Community college teachers need easy access to professional development for this purpose.