CUR Focus

John Mateja,
CUR Fellows Address

Undergraduate Research: Needed More Today Than Ever Before

I do not think there is a word in the English language that adequately expresses my feelings about receiving the CUR Fellows award; at least, I couldn't come up with one that I thought was appropriate. I consider it a tremendous honor to have received this recognition. I truly want to say "Thank You" for the award and for all that you are doing to change undergraduate education in this country.

It has been the tradition that recipients of the CUR Fellow award talk about their research and their students' involvement in that work. I'm going to break with tradition. I am certain I could have kept each of you spell bound and on the edge of your seats as I discussed nuclear quasi-molecular resonances, fusion cross-sections, and projectile fragmentation. That presentation will have to wait until another time. Today I would like to talk about a topic that I know you are passionate about or you would not be attending this CUR national meeting. I am going to talk about education at the pre-college, undergraduate and graduate levels; and how education plays into the future of this country.

In 1977, when I first suggested to my research colleagues at Florida State University that I wanted to go to a state-supported regional university to teach and engage undergraduates in research, my colleagues looked at me as if I had lost my mind. Despite my efforts to explain that I thought students at these institutions needed opportunities to enable them to realize their full potential, my research colleagues simply did not believe that a fundable research program could be sustained at this kind of institution using only undergraduate assistants. I believe the words they used were "professional suicide."

Hardly ever being one to take "good advice," I accepted a position at Tennessee Technological University. For me in those days, undergraduate research was about individual students. It was about Doug, Aaron, John, Joe and a number of other Tennessee Tech students. In the 65-70 year history of the physics program at Tennessee Tech, few students pursued advanced degrees and only 3 or 4 had gone on for PhDs. With the advent of the undergraduate research program that the other physics faculty and I worked to establish in the late 70s and early 80s, this would all change. Essentially all of our physics graduates went on to pursue advanced degrees. Doug, Aaron and John all have PhDs in physics today. Joe's compelling desire was to retire by age 40. He achieved that goal with a masters' degree but today, he is starting a second career in an MD/PhD program. All these students ever needed was an opportunity and a little encouragement. Over the decades prior to the initiation of our undergraduate research initiative, there can be little question that a lot of talent had been wasted.

But, that was then and this is now. In 1977, who worried about U.S. economic competitiveness and jobs? Excellent paying jobs that required little education beyond high school were widely available in many manufacturing sectors (automotive, commercial airline, and steel are but a few examples). Today, as Thomas Friedman describes it, the world is "flat" (Friedman, 2005). The playing field has leveled. In automobile manufacturing, one once talked about the "big three" U.S. automobile manufacturers – General Motors, Ford, and Chrysler. Today, it is the big six, with three Japanese companies – Toyota, Nissan, and Honda – holding center stage. While Boeing and McDonald Douglas once dominated commercial airplane manufacturing, today, Airbus commands a major share of the airline market. What this means, of course, is that many of the high-paying jobs that required little formal education are now gone.

The competition is intense not only in the manufacturing sector, but increasingly other countries are making inroads in science and engineering. As reported by the National Science Board in its report *Science and Engineering Indicators 2006*, there is considerable worldwide growth in research and development investments, international scientific publications have increased, and there is a significant increase in the number of science and engineering degrees being awarded in Europe and Asia (NSB, 2006). In India, Japan, China, and South Korea, for example, the number of bachelor's degrees in the sciences has doubled and the number of engineering bachelor's degrees has quadrupled since 1975. A comparison of the number of bachelor's degrees awarded in engineering annually in the U.S. (75,000) with the number awarded in India (350,000) and China (600,000) is clearly troubling.

One might ask what the near term job prospects will be in science and engineering in the United States. According to the Bureau of Labor Statistics' occupational employment projection to 2014 (Bureau of

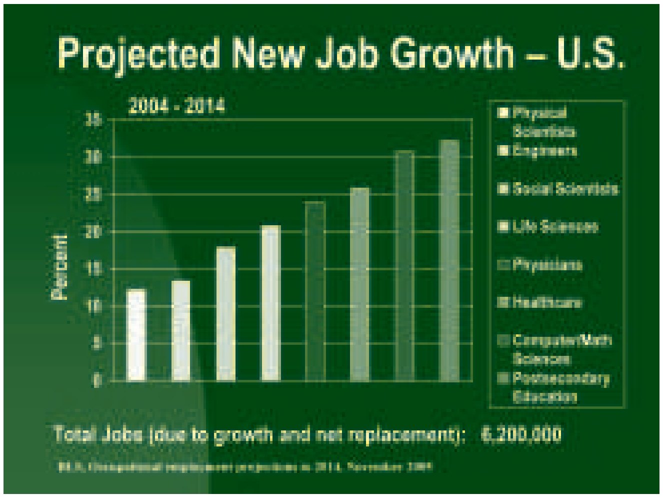

Figure 1. Bureau of Labor Statistics: Projected Growth (2004 -2014)

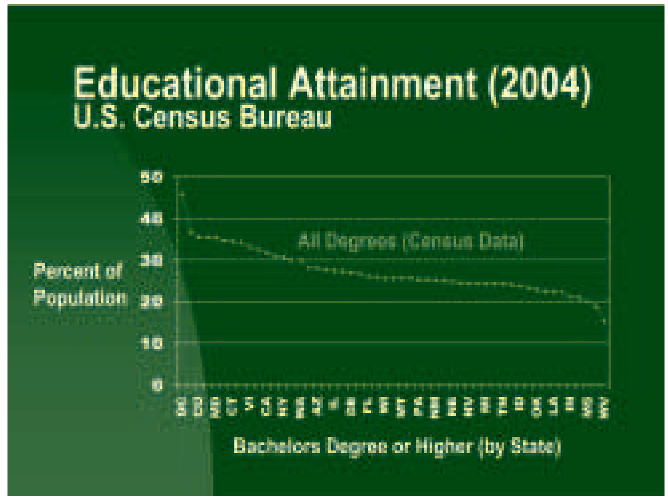

Figure 2. Educational Attainment (2004)

Labor Statistics, 2005), growth in jobs in science and engineering will range from about 12% in the physical sciences to a high of over 30% in the computer and math sciences (see Figure 1). In addition, numerous faculty positions will become available over the next decade. The total number of new jobs (due to new job growth and net replacement) in the areas included in the chart shown in Figure 1 is over 6 million.

In the past, the United States has simply relied on foreign-born talent to make up any shortfalls in our labor pool. Our future ability to make up labor shortages is certainly in doubt. First, 9/11 yanked out the welcome mat to many from other nations. While the welcome mat could certainly be rolled back out, the fact remains that there will be more opportunity for foreign talent in other countries, including these scientists' and engineers' home countries. China has an initiative to develop 100 new world class universities (Roe, 2004). With new opportunities like these and increased financial support at home, will Chinese scientists and engineers be as willing to come to the United States? There is also increased competition from Europe. To retain talent in Europe, the European Commission has doubled the funding for personnel in the Sixth Research Framework Programme that will make it less likely that individuals from these countries will come to the United States (European Commission, 2006).

It would therefore appear that we must become much more self-reliant and develop our own knowledge-based workforce. To what extent does this knowledge-based workforce already exist in the United States? Educational Attainment data from the U.S. Census Bureau is shown by state in Figure 2 (U.S. Census Bureau, 2004). Clearly less than 1/3 of U.S. residents have a bachelor's degree or higher in ALL disciplinary areas. The number with science and engineering degrees is a fraction of this total.

If the knowledge-based U.S. workforce does not exist today, it will be the responsibility of the education community to produce this workforce. So how are we doing? Since we are at the CUR conference primarily to look at undergraduate education, I'm going to leave that discussion for last. I will cover pre-college and graduate education first.

Since 2000, the Program for International Student Assessment (PISA) (Lemke & Gonzales, 2006) has looked at the math and science literacy

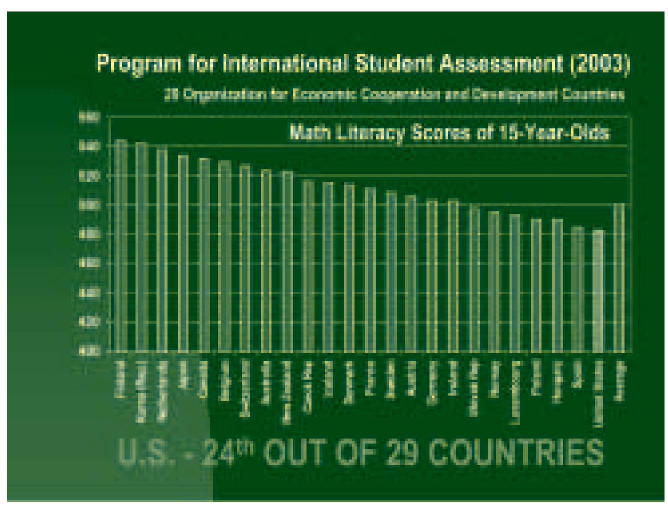

Figure 3. PISA Math and Literacy Score.

of 15-year-olds from 29 industrialized countries (countries belonging to the Organization for Economic Cooperation and Development[1]) and others. The PISA math and science literacy scores are shown in Figures 3 and 4, respectively. In math literacy, 15-year-olds from the United States placed 24th out of the 29 countries in the 2003 PISA study, badly trailing students from countries like Republic of Korea, Japan, Canada, and France. While performing slightly better in science literacy, students from the United States still trailed behind students from 18 of the survey's industrialized nations.

The TIMSS data for fourth and eighth graders from the OECD countries is not much more encouraging. From 1995 to 2003, there was either no change or, at the 8th grade level, a modest improvement in the math and science performance (Lemke & Gonzales, 2006).

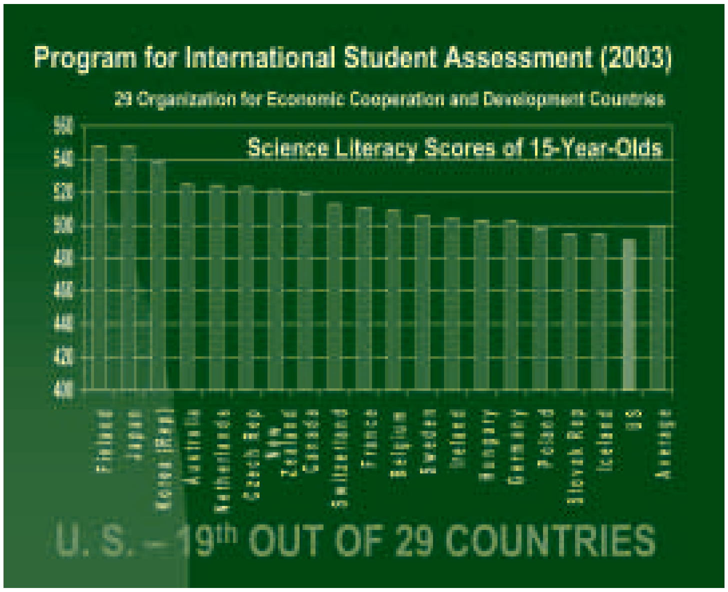

Figure 4. PISA – Science Literacy Scores.

Turning our attention to U.S. graduate education, we find that our graduate education programs are considered by most to be among the best in the world (Committee on Graduate Education, 1998). It is simply unfortunate that more U.S. students are not enrolled in our graduate programs. From 1994 to 2001, graduate enrollments in the U.S. increased, on the surface a positive indicator. However, enrollments in our graduate programs were increasing because foreign student enrollments in U.S. graduate programs increased by 25% over this period of time. U.S. student enrollments in graduate school actually declined by 10% over this period (National Science Foundation, 2003). Also troubling is the fact that in the United States graduate degrees in the sciences only make up about 13% of graduate degrees awarded in this country. In Austria and Portugal, 40% of the graduate degrees are awarded in the sciences. In Japan, South Korea, Sweden and Switzerland over 40% of the graduate degrees awarded in the sciences (NSB, 2006). Again, while our graduate programs in the sciences may be strong, too few American students are enrolling in these programs.

The numbers of undergraduates obtaining bachelors degrees in the sciences in the U.S. is hardly any better. In a report from the OECD (Organization for Economic Co-operation and Development, 2005) approximately 17% of U.S. students obtained bachelors degrees in the sciences in 2003. This contrasts sharply with the percentage of students – at or above 30% - who obtained bachelors degrees in the sciences in Finland, Sweden, Republic of Korea, and Germany. If one looked at the number of students in China in 2000 who obtained science and engineering degrees, the number was a stunning 52%.

A Public Broadcasting Service documentary entitled "Declining by Degree" (Hersh & Merrow, 2005) that aired in the summer of 2005 looked at undergraduate education at four U.S. institutions. The documentary seriously called into question many aspects of undergraduate education in the United States. In addition to being critical of the lecture format used in many colleges and universities, the documentary questioned admission practices that enrolled students who were marginally ready for college, the impact of this practice on maintaining high standards, and the minimal amount of work required in many of today's classes. As stated in the documentary, we have taught our students how to "tread water" for four years.

To recap the discussion to this point, we have seen that 1) today's U.S. knowledge-based workforce is not sufficient to meet future challenges, 2) foreign-born talent will become increasingly difficult to attract, and 3) the U.S. is not producing the knowledge-based talent – at any educational level – that it will need to meet tomorrow's challenges.

Do we know what works in college to interest students in learning and encourage them to seek advanced degrees in their chosen field? We do. Astin (1993) has interviewed hundreds of thousands of students at hundreds of colleges. His data are clear that what matters is 1) the nature of the students' peer group, 2) the quality and quantity of student interaction with faculty outside the classroom, 3) the level of student involvement, and 4) the amount of time students spend on task. Undergraduate research, as we all know, impacts a student in all of these areas. When a student joins our research team, we change his or her peer group. With individual student mentoring comes increased faculty-student interaction outside the classroom. A student's time-on-task and his or her involvement increases dramatically.

Additionally, there is the undergraduate research outcomes data of Hathaway et al.(2002), Rauckhorst, Czaja and Magolda (2001), and Loppato (2003) that clearly show, among other things, there are increases in intellectual development, greater retention and persistence, there is an enhancement in the number of students who pursue advanced degrees, and, very importantly, individuals are more likely to be involved in research in their career after they have left the academy. We know what works. What we need to do is to implement what works on a significant scale.

What should we do as individual faculty and administrators? First and foremost, we must increase our efforts to provide undergraduates at our institutions with faculty mentored experiences, and, as I have said many times, I believe this needs to happen in ALL disciplinary areas. Each of you needs to become a missionary for the cause, perhaps even a zealot, and recruit others to the enterprise. As faculty, I know your workload is not going to go away so it is up to you to find efficiencies that will allow you to find the needed time to meet this request. Can you reduce the number of committees you serve on? Can you teach multiple sections of the same course, thereby reducing the number of preps you have to do in a semester? Can you reduce the number of new classes you teach since new classes take considerable time to prepare? It is also up to those of you who are administrators in the audience to work with the faculty to help them find this time. Can you schedule a faculty member's classes to provide at least one day a week with no classes? Can you find the funds to hire a masters-level laboratory coordinator to reduce the amount of time your Ph.D. faculty are involved in lab prep? Can you reduce their number of preps and new courses?

What can institutions do to tackle the educational challenges described above? To begin with, we need radically different thinking. To meet the new challenges brought about by increased competition, we must change the undergraduate paradigm. We need revolutionary change; not evolutionary change. To reach the number of students who will become the innovators, critical thinkers, and problem solvers this nation will require, we need to do more than just add a few more undergraduate research opportunities on each of our campuses. At Murray State with the number of faculty we have, it is unlikely that we would ever be able to provide meaningful undergraduate research opportunities to more than 20% of our students. At Murray State, that leaves us with the question, "what about the other 8000 students?"

It is imperative that as institutions we begin to change undergraduate education to be research focused and NOT lecture focused. Undergraduate education should not be modeled after our pre-college programs where we are falling far behind many of our competitors; they should be modeled after our graduate programs where we are the world leader. Our students' first college class should be a research methods class and all subsequent classes should be research-based – regardless of whether the class involves writing or understanding the world's civilization and cultures or studying the biology of the world around us. The new undergraduate education formula must: 1) minimize seat time, 2) maximize hands-on experiences, 3) involve teamwork, 4) solve real problems, 5) be interdisciplinary, and 6) be for ALL students. Such a curriculum will involve a concerted effort on the part of the entire institution and I call upon those who are administrators to step forward and assume responsibility for this discussion.

There is another assignment for you today. With everything that has been presented above, one might guess that funding for STEM (science, technology, engineering and mathematics) education by the federal government would be skyrocketing, particularly at the National Science Foundation (NSF). As described in his remarks to the Business-Higher Education Forum on June 8, 2006 (Boehlert, 2006), Sherwood Boehlert (R-NY), House Science Committee Chair, said of NSF, "while small, NSF has a unique and crucial role in education because of its peer review process, its prestige, its history of laying the ground work for change and its connections to higher education." Boehlert went on to say, "in undergrad education, NSF is almost the only game in town." At the NSF, the Division of Undergraduate Education (DUE) is that game and DUE finds itself in a Directorate at the NSF, Education and Human Resources (EHR), that has suffered a 20% decrease in funding since 2004 (Bement, 2006). Let me say that again: the Education and Human Resources funding has been cut by 20%. The miniscule 2.5% increase in the EHR budget for 2007, does not begin to restore the education budget to its 2004 level. With growth in the 2007 NSF budget projected to be 8%, in the words of Representative Boehlert, "The Administration does not plan to have the Education Directorate share fully in the Foundation's expected growth and continues to shift emphasis to the Department of Education, which despite its current dynamic leadership, tends to be more bureaucratic, more political, more driven by distribution formulas, and which simply doesn't have the same focused education mission as NSF has had since 1950"

Table 1. Funding Rates of Key NSF Undergraduate Education Programs

PROGRAM	2003	2004	2005
Course, Curriculum and Laboratory Improvement (CCLI)	19%	14%	13%
Research at Undergraduate Institutions (RUI)	33%	30%	28%
Research Experiences for Undergraduates (REU)	53%	32%	27%
Collaborative Research at Undergraduate Institutions (C-RUI)			Suspended

(Bement, 2006). Over the past several years, what has happened to NSF programs that are critical to undergraduate education? Table 1 tells the story and it is not pretty (Private communication). Funding for NSF's Course, Curriculum and Laboratory Improvement (CCLI) program, for the Research at Undergraduate Institutions (RUI) initiative, and the Research Experiences for Undergraduates (REU) sites are down by from 15% to nearly 50% of their 2003 levels. All one can say is, "What are they thinking?"

Quite frankly, it really does not matter with whom the fault lies, with the Administration, the leadership at the NSF, or Congress. For me, they all share the blame. We also do not need additional studies to tell us there is a problem. In the 1990s there was the Boyer Commission's Report, *"Reinventing Undergraduate Education"* (Boyer Commission on Educating Undergraduates in the Research University, 1998 and 2002) and now we have the report *"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, 2006). The time for talking about the problem is over; the time for universal action is upon us. At the NSF, it is time for the agency's Division of Undergraduate Education (DUE) in the Education and Human Resources Directorate to assert leadership and to work to obtain the kind of support that is critical to changing undergraduate education on a national scale.

As Representative Boehlert did at the Business Education Forum, I call on you to contact the White House, the Director of NSF, and your members of Congress to let them know that education cannot be improved for free and that the NSF has a critical role to play in this effort. Contact information for the White House, Senate, and House of Representatives can be found on the web at www.whitehouse.gov, www.senate.gov, and www.house.gov, respectively. Contact information for the NSF can be found online at www.nsf.gov or you may write to the NSF Director at:

Arden Bement, Director
National Science Foundation
4201 Wilson Boulevard
Arlington, Virginia 22230

You need to contact these individuals now regarding the 2006 budget, you need to contact them in February 2007 when they are starting next year's budget process, and you need to contact them in June, 2007 as they begin to put the finishing touches on the 2007 budget.

As I spent approximately 1/3 of my career working at the Department of Energy, I would be remiss if I did not mention that other federal agencies have important contributions to make to enhance the undergraduate learning experience in the U.S. While NSF has the lead role in reforming undergraduate education, agencies like the National Aeronautics and Space Administration, Department of Energy, and National Institutes of Health have a role to play too. Your Congressional members and the White House need to know that too.

Undergraduate education, I believe, is the key to solving our education challenges. We are the gatekeepers. We prepare the teachers and we are responsible for preparing and sending students to graduate school. Either we do this job well or teachers will not bring the needed innovation to the classroom and our undergraduates will not pursue the advanced degrees necessary to meet tomorrow's STEM workforce needs. Despite these critical roles, undergraduate education receives far less attention than pre-college and graduate education programs. This is a mistake we cannot allow to continue. I call on everyone in the education community to urge our national leaders to provide the level of resources undergraduate education must have if we are to meet today's new international challenges.

As I close my remarks today, I want to say that for me undergraduate research will always be about the individual Dougs, Johns, Joes, and Aarons but today we must realize it is also about much, much more.

Footnote

[1] Information on the Organization for Economic Cooperation and Development can be found at http://oecd.org. Member countries include, in addition to those listed in Figure 3, Portugal, Italy, Greece, Turkey, Mexico and the United Kingdom.

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John Mateja

John Mateja is an experimental nuclear physicist with research interests in light heavy-ion reactions. After earning his B.S and Ph.D. degrees from the University of Notre Dame in 1972 and 1976, he was a post-doctoral research associate at Florida State University. Subsequently, he joined the physics faculty at Tennessee Technological University where he developed one of the first research programs in the nation to involve physics undergraduates in research. In 1988, he joined the staff at Argonne National Laboratory where he had oversight for the lab's undergraduate, graduate, and faculty programs, placing 700 participants at the lab annually. In 1994 he joined the staff at DOE to co-manage a new program to assist non-competitive states become more competitive for federal research funding. John assumed the position of Dean of the College of Science, Engineering, and Technology at Murray State University in 1998. During his three year tenure as Dean, his College successfully competed for an HHMI, NSF C-RUI, three NSF CCLI, and NSF EPSCoR awards. Today, he is the Director of MSU's Research and Scholarly Activity and McNair Scholars Program offices. He has been the President of the CUR and the Chair of the American Physical Society's Committee on Education. Over his career, John has been responsible for seeing that thousands of undergraduates have had the opportunity to participate in mentored research experiences.