Education Driving Innovation

Forum 2007

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DR. SUSAN HOCKFIELD: There are any number of important issues facing the nation's higher education institutions. And I could have chosen, probably six or eight of them that would have been good to discuss with you today. But, I decided that what I wanted to talk with you about is a topic on which MIT has a particular perspective. That perspective is not necessarily unique, but it is a special one from where MIT sits. It's an issue that impacts all of us in higher education and in the nation.

That topic is the role for the research university in innovation in America, in the world, and the challenges that we face today. Now, this isn't a new role for higher education, but it's not an ancient role, either. It's one that has particular importance as we think about the distinctive features of American higher education and about America's ability to compete in education and also to compete in industry. It is, in important ways, paradigmatic for the role of higher education in the larger society and the economy.

The roots of this role go back to a vision for higher education that really began to take form in the middle of the 19th century in the United States. That vision has grown in strength over the intervening 150 years, but now it is seriously threatened. There are concerns about higher education in public discussion. In many of these discussions, we hear some concern about the research side of what I consider to be the inextricably intertwined dual mission of education and research. So there have been expressions that the research side somehow should be left behind.

There have been funding shortfalls for both education and research. In my view, there is a declining national resolve and a declining passion for leadership in innovation and for the fundamental elements that support it. Make no mistake: the inextricable intertwining of research with education has produced the greatest educational institutions of the present day.

That education system has produced many of the most productive innovators. It's produced world transformers, certainly in science and technology, but also in business, economics, in government and urban planning, across the entire spectrum of human endeavor.

It's also, not entirely by coincidence, provided the starter fuel for an innovation economy that, because of its success, we now see spreading around the world. What I want to talk to you about is to give you a little bit of history. Where did this remarkable enterprise come from? And of course, what does it need to flourish?

To set the historical perspective, I want to tell you something you probably know. Robert Solo is one of MIT's Nobel Prize winning economists. He did a study of the economy after World War II and determined that fully 50 percent of America's economic growth after World War II is derived directly from technological innovation.

Technological advance has been the single most important driver of economic growth in this country. Any number of analyses have demonstrated the critical importance of higher education in the nation's and each individual's success.

Today, higher education plays a vital role in the innovation economy. Of course, through research that advances knowledge and through the research that translates into the marketplace, but importantly, also through education, providing people with the knowledge and the skills needed to sustain innovation. And, also to sustain the perpetual reinvention and reinvigoration of a successful and productive life.

This wasn't true before the Civil War. Before 1860, science and advanced scholarship had very little role in American higher education. Higher education in the U.S., up until the middle of the 19th century, took place in a small number of colleges. These colleges were established early, and they were a small number, though there were surprisingly many of them considering the economic situation of the United States when they began. They reflected a drive, a passion, and a commitment to education, which is part of our nation's founding legacy.

It is our good fortune that along with the extraordinary invention of American democracy, our commitment to education began as a requirement for an educated and responsible citizenry. This has served us extraordinarily well. While these colleges took form early in our nation's history, by the middle of the 19th century, there was a brain drain.

It was going a different direction from today's brain drain. America's students were leaving the United States to go to Europe where they could engage in advanced scholarship. This brain drain was depriving our still-young nation of the intellectual independence that was necessary to support and strengthen our political independence.

In response, graduate education came to America. The first graduate school, graduate studies were established at Yale University in 1847 and rapidly, other schools around the nation followed that model.

In 1861, MIT was founded after many, many years of hard thought and very concerted effort by our founder William Barton Rogers. MIT and other land-grant institutions/universities came to be. Our founding president envisioned a new kind of academic institution that would serve the times and the nation's needs, as he said it.

He was talking about the nation's needs in a time of rapid industrialization. Now of course, we view MIT's mission as serving the times and the world's needs. MIT has been an engine of innovation ever since. I could list a thousand things that MIT pioneered but let me just give you a sense by a couple. The development of synthetic penicillin happened at MIT, and the invention of public key cryptography.

In addition to practical innovations that find their way into the marketplace, at MIT we're committed to exploring the unknown; that is, doing very basic research. Because we know that the answers to the great questions about the universe will provide insight to the world's problems in ways we cannot yet predict.

Everyone knows that at MIT we educate students in engineering, but we also educate students across the range of classical disciplines -- in biology, physics, math, geoscience, social sciences, humanities and the arts, architecture, and management.

In everything that we do, in all of our education, we also educate our students in entrepreneurship, in innovation, and in leadership. MIT has a very strong tradition of national service. It was demonstrated in the development of radar during World War II, and it continues today at our Institute for Soldier Nanotechnologies.

At the ISN, all of the work that's done is not classified. Totally non-classified research. It's basic research in advanced materials that will bring benefits to military and civilians. Smart uniforms and more efficient, lighter weight technologies.

MIT does not stand alone. It is only one example of the contributions that universities have made to technological development and to economic growth. These contributions depend on three fundamental enabling conditions.

The first is a robust public K-through-12 education system that provides high-quality education for all. The second is farsighted national investments in research and in education. And the third is an attitude and policies for openness; that we can serve as a talent magnet for the brightest and most ambitious people from around the world.

Unfortunately, all three of these fundamental enabling conditions are challenged today. I'm going to talk about all of them. First, I hardly need to describe to this audience the challenges around public education, and particularly math and scientific literacy.

Many of us of a certain age remember growing up under what we call the Shadow of Sputnik. But, it wasn't the Shadow of Sputnik. It was that bright beacon of the race to the moon, the Apollo Project. At that time, science and math were vital. They were fun. They were exciting, and many of us are products of the nation's enthusiasm, but also the nation's investments. Those investments catalyzed education reform, and it also built the personal commitments that many of us have brought to our careers in science.

Today, K-through-12 education is failing many students. In 2005, less than a quarter of American 12th graders were performing at or above grade level in science or math. And at MIT, which is a little unusual, where 85 percent of our undergraduate degrees are in science or engineering, we're not typical. Across the United States, about 16 percent of bachelor's degrees are awarded in science or engineering. In the United Kingdom, it runs about 50 percent; in Japan, 80 percent; in China and

Taiwan, about 60 percent. The United States isn't graduating scientists and engineers the way our competitors are.

Thirty years ago, the United States ranked third in the number of bachelor's degrees awarded in science and engineering around the world. We now rank seventeenth. I would say the data from these other countries is actually very good news. It reflects an acceleration of education in other parts of the world. It reflects their understanding of what a powerhouse the American system has been. But it also creates a situation of greater competition for us, and it's my view that we have to be sure that we're doing what we need to compete.

American children need to get the message that science and math are exciting and that careers in these fields will allow them to participate in the invention of the future. It requires first-rate teaching in the fields. If we don't do this, we're going to be closing off the pipeline of the innovation economy before it even begins.

People often ask me, "How can we at MIT, people in higher education, help?" Obviously at MIT, we're not experts in K-through-12 education, but we can help. My view is we must help communicate the excitement, the importance, and the joy of contributing to one of the greatest adventures of humankind.

We send lots of students and faculty into the public schools. We have over 48 K-through-12 outreach activities. We send our students and faculty out. We bring in students and teachers. We need to send the message that the future is ours to invent.

One of our most powerful ways of communicating what we do and sharing how we do is it OpenCourseWare. OpenCourseWare celebrated its fifth birthday just last year, and for those of you who don't know about it, I would recommend just checking out the website.

OpenCourseWare was a commitment on the part of MIT to put materials for all of our courses online, available for free. This fall we're going to be celebrating an important milestone when 1,800 of our courses -- that's essentially all of our courses -- will be available through the OpenCourseWare site. Some courses are there in full video; some simply have the syllabus. But everything is there for people around the world to see.

The use has been astonishing. There are about 40,000 visits a day to the main site and probably another 15 or 20,000 a day to the mirror sites. OpenCourseWare was invented as a way of sharing what we do with college and university teachers around the world. It ends up that half of the users to OpenCourseWare are independent learners.

We've discovered that high school students and high school teachers use OpenCourseWare. Some school systems feel they no longer can afford programs for the talented and gifted. These are people who are hungry for knowledge, and they're turning to OpenCourseWare. So this fall, along with the celebration of our 1,800 courses that are going to be on OpenCourseWare -- we're also launching a new portal. It's called Highlights for High School.

That's designed expressly for students and teachers in high school. There will be some high school specific content but it'll also provide a map, a set of links, so that high school students who are taking AP courses can link from the particular topics in that course to relevant parts of OpenCourseWare.

The second factor that was absolutely critical in supporting the innovation economy in the years after World War II was public investment and research and education. The model of the research university in America that we see today took form after World War II. During the war there were massive federal investments into research. Those investments produced some of the technological triumphs of the 20th century. Technological tour de forces. Radar at MIT. This is considered by most to be the technology that won the war. The science and the engineering went into the bomb also was extraordinary. The war-ending technology. But out of this came many other technologies, many inventions, and a new way of thinking about how federal investments could be turned to the human good.

It produced products for the marketplace. The World War II work on radar, for example, was critical to subsequent developments in television transmission. Cathode ray tubes became TV screens and computer monitors. Telephone systems came out of the work in the war. Satellite communications and, of course, computing.

World War II also produced a change in viewpoint -- that advances in science and technology were central to American competitiveness and to national security. After the war, a blueprint for the United States future was laid out by Vannevar Bush. Bush had been a dean of engineering at MIT. His treatise was called "Science, the Endless Frontier," and it was indeed a blueprint for post-war science. The critical part of this blueprint was investing federal research dollars in universities so that research and education would happen at the same place.

After the war, there was also an important commitment to funding education. The GI bill marked a transformational effect for individuals and for the nation. The collaboration between government, the universities and industry has contributed to economic growth, national security, and human health. It's also produced a new and newly effective educational structure.

Elements of Bush's blueprint were federal funding supporting research and education in the same place by the same people; that is, investments and universities. It's produced great innovation and also the next generation of innovators and scholars. There were other elements to it. Merit-based peer review. While those of you know how much we complain about it, it's very much like Churchill's view of democracy. The worst form of government except for all the others that have been tried. I feel that way about peer review.

It's been a system that's permitted young independent scholars and faculty to do their very, very best work. Federal investments in partnership with the private sector have moved ideas from the lab to the marketplace. After World War II, spin-off companies began to move university innovations into the marketplace. And critical to technology transfer, modern venture capital developed, and that started in Boston. The pioneer was a group called American Research and Development.

It was founded in 1946 by one of my predecessors, MIT's President Karl Taylor Compton; a professor from the Harvard Business School George Dorio; Ralph Flanders was at the Boston Federal Reserve Bank; and there was a mutual fund executive, Merrill Griswold. Together they formed this really new way of thinking about moving things from the lab into the marketplace.

Their goal was to commercialize innovations from MIT, from Harvard, and other universities. ARD had a lot of successes. The Digital Equipment Corporation was one major one. Their example led to the development of an entirely new approach to early-stage investment.

If we fast-forward to the next real transformational government decision, the Bayh-Dole Act of 1980 has had a very powerful effect. It transferred to universities the intellectual property rights and products of federally funded basic research. This has been a powerful stimulant to tech transfer.

I will just indulge myself in one aside about what has happened in universities after World War II: the miracles of World War II, radar and other inventions, were the product of a convergence between the physical sciences and engineering that were possible, because of the physics that was done at the beginning of the 20th century.

Entirely new industries came out of it -- the electronics industry, the computer industry, the information industry. These truly transformed our world.

This century, we're looking at another convergence. It's the convergence between the life sciences and engineering. This is taking place because of the life science discoveries that were made following World War II. This transformation is going to affect health care, a lot of biomedicine, but it's also affecting a lot of other things. Energy. We talk about bioengineered crops for biofuels and then the bioengineered yeast that will digest them.

On our campus, we have people working on viruses that self assemble into batteries. I can't tell you the names of the industries that are going to come out of this century's convergence, but I guarantee you that it will be as transformational as those that came out of the 20th century's.

The economic power of the federal investments in basic research have been huge. These are data that any of you can pull from the NIH website or from one of Elias Zerhouni's speeches. The NIH has invested $44 per person per year over the last 30 years. These investments have resulted in an increase of life span of six years.

We've spent about $15 billion to date on research for AIDS. There's no question that's a lot of money, $15 billion. But, that investment has saved us $1.4 trillion in health care costs. If NIH hadn't done its work, right now we'd have hundreds of thousands of people in U.S. hospitals dying from AIDS.

It was NIH fundamental research that has helped us to avert a social disaster. There's been a similar extraordinary return on investments in the physical sciences -- DARPA, this brilliant agency that created the foundational elements that have led to the computer industries. Those technologies truly transformed our lives. The Internet, personal computers, semiconductor advances, supercomputing. All of those can be traced back to DARPA funding.

Let me get back to the main line of my argument, is that the dual inextricably intertwined research and education mission of American higher education has served us well. It has had a powerful educational outcome. It puts the latest innovation into the classroom. The faculty who teach our students are at the forefront of their fields. At MIT, our Nobel Prize winners are really in the classroom. One of our Nobel Prize winners loves advising freshmen. They teach. They advise our students, and our students do research. A critical part of an MIT education is a student actually getting into a research lab. It gives them a practical sense of how knowledge advances. It also gives them very direct experience with faculty and more senior students.

Having the people who are inventing the future in the classroom makes the classroom come alive. It teaches our students the evolutionary nature of knowledge and critical understanding. That understanding prepares them to be lifelong learners, which is a key to success in the workplace, but also for individual satisfaction. It also produces the next generation of innovators. This model has worked extraordinarily well, and we see it being avidly copied all around the world.

Even as this educational engine has been firing, through tech transfer of the inventions that have happened on our campuses, we've moved product into the marketplaces through start-ups in licenses. It's fueled America's innovation economy.

Now, there are challenges. Research investments in R & D aren't what they have been. Within industry, sadly there's been a diminishment of industry research labs like Bell Labs, which makes the role of universities more important than ever.

Government investments in research are stagnant or declining. Over the last four decades, federal investments in research as a percentage of GDP has declined from about 2 percent of GDP in the mid-1960s to less than 1 percent today. The decline has been steepest in the physical sciences, engineering and mathematics, which have been flat as far as funding goes for 30 years. I know you all are aware that funding for research in the life sciences has begun to look just like the funding in the physical sciences, because even though the NIH budget doubled between 1998 and 2003, it's now been flat or declining.

We have to continue to encourage federal investments in research as powerfully as we can, but at the same time, at universities, we're turning increasingly to private philanthropy in industry support.

The second very big issue is openness. This is an essential prerequisite for universities. For our service to be effective in education and to contribute to an innovation economy, we have to be able to attract the most talented people to our campuses.

There are two sides of this. The first is we have to keep higher education open to the best and brightest young people in the America. This is another important legacy of the post-World War II period where huge investments in education captured the talents of returning GIs and they fueled our nation's economy.

They proved to be incredibly productive investments. But, we have to remember that it takes the talents from our entire population to sustain the nation's strengths and to fuel the innovation economy. Talent, brilliance, and tenacity aren't restrictive across our population. They transcend geographic, ethnic, and racial boundaries. This is the key reason why diversity is an important goal for universities. We simply cannot afford to lose the willing and the able of any gender, any race, or any ethnicity from the innovation army. And that, for me, has been the real issue at stake in all of our many public discussions about the place of women and minorities in academic science, engineering, and medicine.

Of course, we always feel that change hasn't been fast enough, but I pause at this moment to reflect on just how fast -- how much has changed in the last 25 years. Women are now serving as presidents of one-half of the Ivy League universities, and one of them is an African-American.

In the corporate world, we have CEOs of major companies. Anne Mulcahy at Xerox, Meg Whitman at eBay, Kenneth Chenault at American Express. In politics, Nancy Pelosi as Speaker of the House. The governor of Massachusetts, Deval Patrick, is an African-American. How much can we recognize that things have changed when two of the leading candidates for president are a woman and an African-American. This is not your grandfather's leadership team.

The message here is a very simple one. The hard work of the generations that came before us made it possible that I and other women and members of underrepresented minorities could be in the positions we are today. We need to place an unrelenting focus on determining what impediments still exist and repair them. Among our most important responsibilities is to ensure that there will be even better and newer opportunities for the next generation.

The second face of openness is our need to continue to attract the best and the brightest from around the world, or we will be the losers. U.S. universities and industry have benefited from the talents and skills of immigrants. Let me just give you a couple of MIT facts: Since 1990, nine members of the MIT faculty have won the Nobel Prize. Some of them were born in the United States. But others were born in Germany, in Mexico, in Japan, in India.

About three-quarters of the twenty leaders of our School of Engineering, which is ranked as the best school of engineering in the world, we have twenty department heads and lab and center directors. About three-quarters of them were born outside of the United States.

Now, visa restrictions have eased a lot since 9/11. That's gotten much better and we see the number of applicants to our graduate programs of international scholars increasing. But many international students and scholars find it difficult to enter the United States and even more difficult to stay here.

The third really critical element is access. There are, I think, very appropriate and widely discussed concerns about rising tuition costs. But, as I read the newspaper reports on these, rarely is the full story of financial aid considered thoroughly in these discussions.

Tuition has risen rapidly, but the true cost of education at universities and colleges has also risen very rapidly. Why is that? Well, at MIT we have to have the best faculty and we have to provide cutting-edge laboratories so that we can teach students about what's going on at the frontier. This is very expensive.

In education, there aren't opportunities for efficiency that you might find in the manufacture of other kinds of goods. Ultimately, the very best education is a one-on-one experience. It's me talking to a student about my field and explaining how something was discovered and where the frontier lies. So one-on-one is pretty inefficient. And that may be best. But one to ten, one faculty member and ten students, is pretty good, too. I can tell you that one to a hundred or one to a thousand doesn't give the same kind of educational experience.

It's also important that our students get the very best education because these are the students who are going to be inventing our and the world's future.

Increases in tuition at MIT have been far surpassed by our increases in financial aid. People throw around these terms: sticker price versus net price, and it reflects a very poor understanding of our model. Our model is based on individual need. At MIT for decades, we have practiced need-blind admissions and entirely need-based aid. MIT awards no merit aid. It's all based on need.

We're committed to meeting the full need of all of our admitted students. At MIT this really does mean something because over 15 percent of our students come from families with annual incomes of less than $45,000 a year. We spend $60 million of MIT funds on financial aid and about 60 percent of our students are receiving some kind of MIT scholarship.

As government aid programs have failed to keep pace with inflation, MIT has made a substantial institutional commitment using our endowment to supplement student aid.

Herb Allison [TIAA-CREF President] mentioned our new Pell grant matching system. We had to do that, because over the last several years, Pell grants have been stagnant, even though tuition and other costs of education have risen. So we started a new policy of matching Pell grants dollars one for one. These are among our most needy students, and we have to help them as much as we can.

For the 60 percent of our students who are on financial aid, this support has held the average net tuition for this group to around $8,000 a year. That's a very good price for an MIT education. 20 percent of our students pay no tuition at all. At the end of their undergraduate study, some of our students graduate with loans, about 45 percent of them. But the average loan they're graduating with is about $18,000. Any number of studies has shown that four years of college anywhere increases the average salary by about $20,000 in just one year. My view, this is a very, very good investment. American colleges and universities are the most powerful economic elevator we know.

We've analyzed what happens to MIT students when they leave. We can see what their salaries are five, ten, twenty years out. We know what kinds of income families they came from in the socioeconomic scale. I can tell you that it doesn't make any difference where these students come from. After they leave MIT, they all track along the same salary curve.

The good news is that tuition at our schools is a progressive tax. Those who can afford pay the full amount; and those who can't, we make it possible for them to attend. American higher education is the vehicle by which the American dream comes true. Here in the United States we have the recipe for a highly productive higher education system. It's one that creates a future of opportunity for individuals and for the society at large.

We need to understand very clearly the key elements that drive success for institutions and for individuals. I've outlined for you today some of the key elements to keep the innovation pipeline full, and keep it full of people and full of ideas and inventions so that the industries can flourish and our nation can continue to grow.

As I've suggested, I think there are three foundational elements that support the research education mission of higher education that has fueled the innovation economy -- high-quality K-through-12 education for all of our young people; national investments in education and research; and an openness to all those with the ability and the ambition to succeed in the extraordinary environments that we've created for them.

Even with the challenges I've outlined, I have to confess, I have huge confidence that we will figure out how to invent our way to another era of strength. How can I be optimistic? Well, perhaps it's not surprising that I see a very bright future as I watch it being invented by the astonishing faculty and students at our wonderful institutions of higher education. My optimism is reinforced every day by the students. They have an unquenchable passion for solving the world's most pressing problems.

The modern research university is a relatively new species. In the United States, it dates to the great federal investments in science and general research and in an education that began after World War II. But the model of the research university is going to have to reinvent itself in this new century.

Getting the basic elements right is going to be critical to our success, and I deeply hope we'll be able to do it.