Fueling the Economy: Exciting, Inviting, and Preparing the Next Generation of Innovators

As prepared for delivery by
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I am delighted to be able to join my fellow educators here today, as well as the students of this fine institution. I would like to talk about the role universities like ours have in answering the great challenges of our day, especially as it relates to scientific discovery and technological innovation.

Clearly, environmental and social challenges such as climate change, energy security and health care are calling out for new approaches and new technologies. Many of these will be born in university classrooms and laboratories. So, too, will be many of the answers to our most pressing economic challenges, including the immediate necessity of recouping the 7.6 million jobs lost in the Great Recession.

The history of America's prosperity since World War II is one of discovery and innovation, which, over and over, have yielded new industries that lead the world. Even in this last year, when we felt the full force of a global downturn that began in the American housing market, the World Economic Forum ranked the American economy number two in terms of global competitiveness. Its report cites "structural features" that make our economy particularly productive, especially our "highly sophisticated and innovative companies" and "an excellent university system that collaborates strongly with the business sector in R&D." I would add to this recipe for productivity, the substantial investments by the government in basic research that have produced such civilization-enhancing technologies as the Internet.

If we, as a nation, intend to remain economically competitive, our focus must be on scientific discovery and technological innovation. Certainly, a number of developing nations are imitating our strategy for prosperity. Research and development expenditures worldwide doubled between 1996 and 2007. And developing countries are investing substantially in higher education in science, technology, engineering, and mathematics — the STEM fields.

Consider the case of China. The number of students earning first university degrees in the natural sciences and engineering in China increased from 239,000 in 1998 to 807,000 in 2006 — more than three times as many as in the United States. By 2007, China had 25% of the world's researchers and by 2008, had moved to second in the world in its publication of peer-reviewed research, behind the United States. China has observed, also, the degree to which America has benefited by attracting brilliant foreign-born students, and retaining them after they complete their education, and is working hard to persuade senior Chinese scientists educated here to return home.

Recently, there has been considerable fear expressed in the press about the possibility of China, in particular, eclipsing the United States as a scientific and technological power. However, I have to take issue with such defensiveness: Scientific and technological progress is not a zero sum game. A world with more scientists and engineers can be only a better world.

At the same time, the United States cannot afford to lag behind, if we hope to create millions of high-value jobs in the near future, in emerging fields such as renewable energy, nanotechnology, and personalized medicine. Yet, we are suffering a loss of focus nationally when it comes to innovation. We do not always capitalize on our opportunities. For example, because we did not put incentives in place over the last decade to create a vigorous market for clean energy, the preponderance of leading solar panel and wind turbine companies are now located outside the United States.

Business and government have both grown excessively cautious in choosing which research projects to support, preferring less risky short-term projects, rather than the long-term, high-risk basic research that yields the most transformative innovations. And possibly most worrisome of all, we have a gap between our economy's need for scientists, mathematicians, engineers, and technologically skilled professionals and our success in producing them. I know that the University of Illinois is addressing this latter problem forcefully, through its Illinois-STEM (I-STEM) initiative. However, before I offer a few ideas about enriching the human capital necessary for our innovation economy, I would like to place the need for that human capital in context.

The United States emerged from World War II as the world's greatest scientific and economic power, thanks to an energetic wartime partnership between industry, academia, and government. This partnership is still powerful, yet promising ideas often fail at the interstices between the three sectors. It is time to re-knit together our innovation economy at key points, in order to create an innovation ecosystem that transforms scientific discoveries into new industries.

History and the lifecycles of technologies suggest that four elements are necessary for such an ecosystem: First is a strategic focus on our greatest national challenges, which clearly include the need for clean energy, and advances in both the policies and practices of our health care system.

Second is the generation of transformative ideas. Basic research plays an indispensible role in generating such ideas — though their eventual application may lie far afield from the initial purpose of the inquiry. It was basic research at the Defense Advanced Research Projects Agency (DARPA) that gave birth to the Internet, as well as microwave technologies developed for missile detection that now are used in cancer treatments.

Universities are increasingly the locus of basic research, and basic research unites seamlessly with our mission to educate. However, that means business and government must support, and not merely draw from, universities. We are fortunate that the Obama Administration understands the significance of basic research, and even in a time of soaring deficits, intends to provide the seed corn for our future prosperity by funding it. When we back basic research, we are backing serendipity, and no innovation ecosystem can survive without it.

The third element comprises translational pathways that bring ideas into the world, for applied, commercial, and societal use. Universities must adopt a sensible approach to their intellectual property, balancing the virtues of commercializing new discoveries, with the free sharing of key ideas to allow further innovation while taking account of the ethical and security issues inherent in technologies that can be used for good or for ill.

We also need to support the fledgling start-ups that grow out of university research, and network them into the innovation ecosystem. At Rensselaer, we created one of the first university-based incubators in the country – to help start-ups bring their products to market. Today, we are in the process of refocusing our efforts on targeted innovation in key areas. The University of Illinois also has devoted considerable energy to the question of how best to support these new businesses, but this is a topic which should be addressed on a national scale.

The fourth necessity is capital to make the system run: financial, infrastructural, and human. Financial capital is a challenge, particularly for new technologies requiring seed or early-stage investments. IllinoisVENTURES — a venture capital firm conceived and launched by this university — offers a very interesting solution. We also may need more early stage government support for potentially transformative technologies that cannot find industry backing.

Infrastructural capital is also crucial. It may include research facilities, as well as computational centers, instrumentation, robotics, clean rooms, and fabrication facilities — facilities that no single company can afford. While universities may possess such critical infrastructure, an institution of higher education cannot become simply an early-stage platform for business. Such engagement on university campuses is fraught with potential conflicts that may interfere with a university's core mission to educate (or with its tax status).

What are the alternatives? Such infrastructure could be developed by industry consortia. It could be created, also, at universities or federal laboratories in arms-length entities with infrastructure specifically to be shared with nascent industries.

Finally, but critically, an innovation ecosystem must have human capital. Yet the United States is not educating enough scientists and engineers. While job growth in science and engineering fields has been vigorous, at about 4.2 percent per year since 1980, growth in science and engineering degree production has been comparatively weak, at about 1.5 percent per year.

We have compensated for that gap by attracting foreign scientists and engineers. Indeed, many of the science and engineering degrees themselves are awarded to foreign students. The fact that the United States still draws the best and the brightest from around the world is a great competitive advantage. We must do everything possible to ensure that it continues.

At the same time, we are failing to inspire sufficient numbers of American children with the wonders of the natural world, mathematics, materials, and machines. I call this the Quiet Crisis, since it can take a generation to manifest itself fully in our economy, because it takes decades to educate a world-class scientist or engineer.

Just as nitrogen is the limiting factor in the productivity of an agricultural field, human capital is the limiting factor in the innovation capacity of our nation. If we want the most advanced industries to be conceived in the United States, to take root here, and to generate the tens of millions of good jobs our economy requires, we must have an educated population well-prepared to work at science and technology's leading edge. Clearly, universities increase the capacity of our innovation ecosystem by educating bright, motivated young people, such as those in the audience today.

Our challenge is to do more, even as the Great Recession affords us fewer resources. We need to reach out to a new majority — that made up of women and minorities — which, traditionally, has been under-represented in the sciences. We have made some progress: The share of science and engineering degrees awarded to minorities has increased somewhat in recent years. Women now earn half or more of bachelor's degrees in the biological sciences and chemistry. However, in the fields of computer science, mathematics, and engineering, the proportion of young women is — almost inconceivably — shrinking. While women earn approximately six out of ten bachelor's degrees, they earn just two out of ten degrees in engineering, computer sciences, and physics.

We must move more aggressively, to excite, invite, and prepare more young people to pursue STEM careers. The solution is not merely to recruit more women and minorities for such majors, but to operate our universities with the most expansive possible definition of talent. Depending on our institutional missions and capabilities, that definition could include not-so-young people returning to the workforce after raising families — as well as people displaced by the current recession, who are moving into science and technology in mid-career.

At Rensselaer, with the support of the Bill and Melinda Gates Foundation, we are working to design a strategic roadmap for New York State – for increasing the number of students, from all backgrounds, aspiring to STEM disciplines. Obviously, the process of creating investigators and entrepreneurs has to begin long before young men and women even consider coming to our campuses. Any attempt to encourage more minorities to become scientists, for example, must address a high-school drop-out rate that can be called, quite fairly, a national scandal: Four of ten African American and Hispanic teenagers fail to graduate from high school on time.

Clearly, there is a mismatch between the needs of our high-tech economy, and the quality of the K-to-12 education we offer our children. American elementary and secondary students do not perform as well as they should on international tests of mathematics and science. Particularly troubling is the performance of American 15 year-olds in the Organization for Economic Co-Operation and Development (OECD) Program for International Student Assessment (PISA) tests, which measure practical problem-solving abilities. In 2006, with 25 nations participating, the United States students ranked near the bottom in both science and mathematics.

Education research increasingly demonstrates that more than the right curricula or facilities — more than any other factor — the quality of the teacher determines the success of students. Training superior STEM teachers is clearly a significant focus of the College of Education here. One rough measure of teacher quality is whether the teacher has a degree or certificate in his or her field of instruction. In middle and elementary school, STEM teachers often do not. Clearly, universities must encourage STEM majors to consider the crucial work of inspiring and educating the young.

Teachers need the right preparation. They need, also, the opportunity for continuous learning. They need to be invited, by universities, to join the community of scientists and mathematicians, in order that both their knowledge and their enthusiasm for their subjects constantly are refreshed. Teachers need greater public recognition, also, for extraordinary performance in making a gift of their own passions. I am very grateful, personally, that, for me, a high school teacher named Marie Smith so loved mathematics that she helped me see beyond mere equations, and understand that mathematics is a particularly beautiful way of looking at the world.

Fortunately, as the two other essential partners in our innovation ecosystem — industry and government- — also address STEM education, there are signs that the Quiet Crisis may resolve itself into a Quiet Revolution. A recent survey found that two-thirds of corporate philanthropists in the field of education consider STEM a high priority. The National Governors Association is working to increase interest in STEM education at the state level. At the federal level, the Recovery Act included a $4+ billion "Race to the Top" fund, which encourages states to compete for support by developing innovative math and science programs, and recruiting and developing effective STEM teachers.

However, improving what occurs in classrooms is only part of the solution. It was a great honor for me, this past April, to be appointed by President Obama to serve on the President's Council of Advisors on Science and Technology (PCAST). During his remarks at the National Academy of Sciences' annual meeting, where he introduced the Council, President Obama threw down the gauntlet to the assembled scientists. "I want to challenge you," he said, "to use your love and knowledge of science to spark the same sense of wonder and excitement in a new generation."

Such a thing needs to be asked more broadly of our discoverers and innovators. One of greatest challenges we face is cultural. It is a strange paradox in a nation whose economy so depends on scientific and technological progress, that scientific illiteracy is common and acceptable. Many Americans have an easy intimacy with electronic devices, yet are at loose ends when asked to describe an integrated circuit or semiconductor.

We must evolve our national culture to celebrate the spirit of inquiry that yields the iPhone and the Xbox, as well as the devices themselves. Teachers alone cannot effect such a change. Scientists, engineers, mathematicians, and entrepreneurs also must find a way to communicate the joyous aspects of their work to the young. Artists, too, have a role to play here — which is why at Rensselaer, we have created one of the finest experimental media programs in the country, where art and technology of the highest order are able to intersect.

Fortunately, we are in the midst of a great age in science and technology — one that, if we meet the education challenge, could prove easily as exciting to children as the Space Race was to my generation. The merging of the life sciences and engineering in recent years, in particular, has opened up astonishing possibilities for humanity — astonishing enough to rival any magic performed at Hogwarts. These include the distinct possibility that we may soon be able to resurrect extinct species like the woolly mammoth — and engineer microbes to manufacture biofuels or medicines.

Let us not forget, also, that when beams of protons meet within the Large Hadron Collider at CERN, they will generate 100,000 times the heat at the core of the sun. In doing so, more secrets of the universe will be revealed. In the future, we may be able to stave off the worst of global warming by brightening clouds. At Rensselaer alone, our scientists have developed the world's darkest material, produced a paper battery, and are unlocking the secrets of photosynthesis in hopes that we, someday, may use solar energy as efficiently as does an oak tree. To describe such advances properly, one is compelled to borrow the vocabulary of a fifth grader: They are awesome. And any fifth grader would appreciate such awesomeness instantaneously, if only she or he had the chance to hear about it.

We are in some sense fortunate that the great challenges of our day are amenable to scientific and technological solutions, including climate change and energy security. Because of this, science is becoming part of our national dialogue. However, as every parent is well aware, children often are more eager to take their cues from popular culture than from adult conversation. It is interesting to note that the film Avatar, which recently became the highest grossing movie of all time, is an environmental fable, with a scientist as one of the main characters. Moreover, the plants and animals on the fictional planet this movie proposes are imagined so carefully, that even biologists are enraptured by it. Science clearly can be big box office. Indeed, a number of media companies are partnering with the White House on an "Educate to Innovate" STEM initiative, which includes design contests for the most compelling video games featuring STEM subjects.

Of course, the communications challenge here is not limited to expressing the wonders of science and nature, and the delights of inquiry and innovation. We need to help more children see that they, too, could become discoverers and innovators. Sociologists Neil Gross and Ethan Fosse recently considered a question that is somewhat irrelevant to our conversation, namely, why are university professors often left-leaning politically. However, their conclusion is relevant: Typecasting has much to do with it. In other words, liberal students are attracted to a field that has a reputation for liberal politics. Commenting on the study in the New York Times, Stanford education professor Mitchell L. Stevens suggested that there is a dearth of women physicists for similar reasons. The profession has been typecast as "male," so girls do not bother to audition for roles in it.

Nonetheless, some of us do persist in becoming physicists, preferring to pursue work that inspires us, rather than to look "just right" for a less interesting part. Women scientists and engineers can accomplish something significant simply by becoming visible to young girls, so girls can see that fields like physics are not exclusively male preserves. The same is true for minority innovators: They can do a great deal of good simply by making their presence known to children. I have had the great honor of adding to The HistoryMakers' interviews with African American scientists — and I believe that by assembling an archive of the stories of innovative African Americans in many fields, The HistoryMakers is doing important work.

That is why I am so pleased and honored to be here to participate in tonight's conversation with my good friend, mentor, and fellow physicist Dr. Walter Massey. I also congratulate the National Science Foundation for its wisdom in funding a HistoryMakers' project to bring the oral histories of even more African American scientists to schoolchildren, in hopes that those children may be inspired to follow a similar path.

Ultimately, when we talk about an innovation ecosystem, we are really talking about the benefits that radiate outwards from bits of human imagination like the ripples from a pebble thrown into a pond.

To be capable of generating transformative ideas, children require nothing more than a solid footing in mathematics and science, and confidence enough to ask penetrating questions. But the results can be mighty indeed. Our task here is to help more children understand that they, too, have the power to change the world.

Thank you.