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Engineering 2.0: Rekindling American Ingenuity

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Technological innovation has long been key to American prosperity, especially when it is applied to cutting-edge manufacturing, and the centerpiece of such innovation is engineering.

Investments in scientific research produce indispensable knowledge, but it is by applying that knowledge through rigorous engineering and practical development that people and nations produce wealth, thereby achieving economic strength, and national security. That the United States has fallen behind in this "translational research", to convert its own discoveries and inventions into homemade high-tech products, can be seen in its growing trade deficits in the high-tech sector. Between 2000 and 2013 U.S. trade in Advanced Technology Products grew from surplus to $92 billion deficit.

In order to reverse these negative trends, we need greater clarity on their causes. While conventional wisdom points to low labor costs abroad, it doesn't account for Germany's manufacturing prowess despite its 40 percent higher wages than the U.S. Some would like to believe that job losses are due to increases in American productivity, ignoring the fact that in the last decade productivity and manufacturing output in 15 out of 19 manufacturing sectors has actually decreased.

A core problem lies in America's failure to maintain one of its historical core strengths: engineering. Distinct from science, engineering means not just analysis and discovery but synthesis and innovation aimed at turning abstract ideas into tangible products.

The U.S. scientific community continues to lead the world in basic research, measured by publications and citations. Being the world's best in science is crucial to our success but it is not sufficient to survive in the global economy. We must innovate — that is, transform promising ideas and emerging technologies into practical solutions at a scale sufficient to meet some societal need. That demands world-class engineering.

Engineering educators today struggle mostly with questions of how to balance between hands-on experience versus analytics, or how engineering schools might attract and graduate more women and minorities, and even whether they should include "soft" humanities courses to make engineering more wholesome and palatable. Even more telling, engineering researchers have adopted the scientific model of "publish or perish' over the development of a new product, or process to solve a societal challenge as their primary measure of success. And they insist, first-and-foremost, that a student be mathematically gifted to even consider pursuing an engineering discipline. Some of these real issues and false beliefs can be resolved to a great extent if we step back and examine the perceptions and realities of today's engineering education and research. Since the Sputnik era, the engineering community in the U.S. at large has placed science on a pedestal while ignoring the real world value that is inherent in engineering creativity.

Science is not engineering

We must begin with an assertion that science is not engineering and they are distinctly different occupations. Science attempts to explain the world through experimentation and analysis, whereas engineering creates new technologies through creativity and synthesis. Most of what we perceive as "rocket science" is actually "rocket engineering". This seemingly innocuous generalization of science to subordinately include engineering has had real consequences in our investments and outcomes. How a government allocates its resources is both a reflection of and an influence on the prevailing national mindset. Of the $1.3 billion devoted to STEM (Science, Technology, Engineering and Mathematics) education, NSF spends barely more than 1 percent on engineering education. Between 2001 and 2011, overall federal research expenditures have increased by 8.1 percent, although more so in life sciences than in others. Engineering, on the other hand, is the only field where research expenditures actually decreased by 4.3 percent.

In 2010, Lux Research benchmarked various countries on their nanotechnology activity and technology development strength. Germany, Japan, South Korea, Taiwan, and the United States all ranked high in nanotechnology — but the United States ranked lowest of those five in technology development strength and we have been falling farther behind ever since.

NSF's Annual Science and Engineering Indicators measure "research outcomes" in terms of numbers of publications, citations and patents. Certainly, publication is the true currency of science disciplines, and is why academics live by the "publish or perish" model. However, in engineering, which takes place through the application of knowledge, publication should be less important. Dissemination of knowledge can even be counter-productive before an emerging technology or a product idea is at least partially developed and the intellectual property can be protected with a patent. In Engineering, we simply cannot afford to "publish and perish."

National Science Foundation employs the same yardstick to measure the "intellectual merit" and "broader impacts of research" of proposals submitted to its engineering programs as it does to evaluate proposals submitted to its science programs.

Following the priorities of these funding agencies, the vast majority of current U.S. engineering research programs explicitly emphasize the scientific aspects of a problem, showing a purely analytical bent and focusing on publication. Some engineering researchers resist drawing a distinction between science and engineering, and some of them would argue that, nowadays, "engineering science" is the best term to describe their engineering research.

Surely, science can be foundational to engineering and the associated analysis is an inevitable step to discover and learn how certain parameters affect the outcome of a system or how a given material behaves under particular loads so we can optimize the design. Engineering science and dissemination of analysis results are only intermediate steps to the ultimate goal of engineering - that is creating/synthesizing a "better mouse trap" to address a societal need.

"Bell Labs" Model

To rekindle true American "know-how", we need to put the "&" back in "R&D." The scientific discoveries at Bell Labs that led to such inventions as the transistor, the laser, solar cells and satellite communications showed what scientists and engineers could do when they worked together: transform scientific breakthroughs — the 1 percent "inspiration" of Edison's formula for "genius" — into the engineered solutions that arose thanks to the formula's 99 percent "perspiration."

Compared to "Bell Labs" of yesteryear, the scope of corporate R&D today is on achieving incremental improvements through applied research rather than engineering the "next big thing." The average time Wall Street investors held a stock has dropped from eight years in the 1960s to four months in 2010.

To capitalize on our scientific breakthroughs, we must invest in translational research that matures emerging technologies and their manufacturing readiness. President Obama's national manufacturing innovation institutes, as public private partnerships, are meant to bridge precisely this innovation gap between our inventions and manufacturing-readiness.

Inspiring Future Engineers

To re-establish our strength as creators and producers of advanced technology values, we need to inspire our youth and revitalize our engineering community.

While U.S. high schools commonly require students to dissect a frog, hardly any require students to disassemble a power tool. No matter their age, empowering students to take things like power tools apart can engage them in design, materials, manufacturing, and safety challenges by tapping into the curiosity and creativity that many children naturally have.

Such exposure to real-world engineering will inspire our youth to attend a four-year degree college to become an engineer or pursue vocational training, without feeling like a second-class intellect, and to master the advanced manufacturing trades (ex. CNC machining) that are desperately needed in industry.

Once inspired by the ultimate prize of becoming an innovator or an entrepreneur, these empowered students will learn and excel in the foundational math and analysis they require as stepping-stones to create their new products and processes.

The recent emergence of the "Maker Movement" is having a phenomenal influence on American youth. Maker Faires bring together science, art, crafts, and engineering in a fun, energized and exciting public forum. FIRST Robotics is an outstanding example of an extracurricular program that has inspired thousands of middle and high school students to pursue careers in science and engineering by teaming up to build robots for their competitions. We need to bring this type of education and experience into mainstream K-12 curriculum.

Olin College, a newly minted small engineering college in Massachusetts with a highly integrated interdisciplinary engineering program, focuses on engineering as a creative discipline and prepares students to be engineering innovators. It has a 44% female enrollment compared to a 22 percent representation rate for women in engineering nationwide. Women constitute 50 percent of a typical graduating class at Olin College - underscoring the fact that if engineering is portrayed as a creative discipline that can make the world a better place, young women no less than young men, will be naturally attracted.

If we educate our engineering student researchers to place value not just on analytical rigor, but also on physical reasoning and the creative aspects of their work, they will be inspired to create the "next big thing."

Only when the United States starts to generate a new pipeline for a skilled workforce at all levels — from skilled production workers to talented engineers equipped with hands-on and analytical skills — will the country regain its lock on its position at the forefront of technological innovation and high-tech manufacturing and foster future economic and national security.