Engineering Education, Globalization and Economic Development: Capacity Building for Global Prosperity

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In this paper, I use examples of an individual, a company and a country to illustrate how engineering is key to economic growth for developing countries, and to address the fact that engineering education must be reformed so that today's students are fully prepared to address the complex technical, social and ethical questions raised by emerging technologies in a knowledge-based economy.

I. Introduction: Globalization and Economic Development

The term "globalization" has gained considerable attention and force during the last few years. Some view it as a process that is beneficial—a key to world economic development—as well as inevitable and irreversible. Others regard it with hostility; even fear, believing that globalization increases inequality within and between nations, threatens employment and living standards, and thwarts social progress. According to the International Monetary Fund [1], globalization offers extensive opportunities for countries around the world but it is not progressing evenly. Some countries are becoming integrated into the global economy more quickly than others. However, in some of those countries that are becoming integrated, the divergence between the richest and the poorest in the country is widening, leaving the poorest even worse off. Still, there is general agreement that globalization is rapidly changing economic systems around the world.

What is globalization exactly and how is it related to engineering and engineering education? Globalization is often defined as the process in which geographic distance becomes a diminishing factor in establishing and maintaining cross-border economic, political, and socio-cultural relations. Thus globalization can be thought of as widening, intensifying, and increasing the impact of worldwide interconnectedness.

Knowledge-Based Economies are Key to Development
In a quest to address globalization and its economic challenges, the European Union (EU) set an ambitious target for itself during its March 2000 Lisbon Summit: that Europe "would become during the next decade the most competitive and dynamic knowledge-based economy in the world." Non-EU nations that want to be considered for inclusion in the EU realize that they need to develop their knowledge-based economies. Thus, the World Bank recommends that these nations concentrate all their efforts on four major areas [2]: education and training, information infrastructures, economic incentive and institutional regime, and innovation systems. The basic premise is that knowledge is becoming a primary factor of production, in addition to capital, labor and land. In fact, many economists now argue that knowledge has become the most important component of production. The belief is that a knowledge economy will lead to

improved quality, reduced costs, better response to consumer needs, and innovative products. However, there is an increasing digital, scientific and technological divide between developed countries that are exploiting knowledge, science and technology for economic well being--and those less-developed countries (and less-developed regions within countries) that are not fully participating in globalization.

In the *World is Flat*, author Tom Friedman [3] suggests the world is in its third wave of globalization, one that is governed by people and communications. He states that the flattening of the world happened at the dawn of the 21st century; and that countries, communities, individuals, governments and societies can and must adapt to the challenges that this "flat world" presents. Thus, globalization is making both developed and developing countries think about effective and efficient strategies that will advance their economies and social development. Many countries around the world have made significant strides in the past 10 years in laying the foundations upon which market economies and democratic societies can flourish. Examples include Taiwan, Singapore and Ireland.

The World Bank recommends that countries that want to develop their knowledge-based economies focus on four areas:

- **Education and training--**an educated and skilled population
- **Information infrastructure--**a dynamic information infrastructure--ranging from radio to the Internet.
- **Economic incentive and institutional regime--**a regulatory and economic environment that enables the free flow of knowledge, supports investment in Information and Communications Technology (ICT) and encourages entrepreneurship.
- **Innovation systems--**a network of research centers, universities, think tanks, private enterprises and community groups that can tap into the growing stock of global knowledge, assimilate and adapt it to local needs, and create new knowledge.

To "use knowledge for development" as the World Bank recommends, a country must ensure its people have the right set of knowledge, skills, competencies and values. It is people in the NGO, government, academic and private sector who develop the necessary information infrastructure, the economic incentives and institutional regimes, and the innovation systems. The United States has long set the world benchmark for building a knowledge economy, but the World Bank points to additional nations that have addressed these four points systemically and efficiently. Finland, Ireland and Korea are clear examples, where significant reform and investments have been made in science and technical education, and innovation systems.

Engineers are Key to Developing and Growing Knowledge-Based Economies

If technology and knowledge form the basis for meaningful economic development, given that globalization is radically accelerating the pace of change and raising the long-term stakes, it is clear that success in knowledge-based economies depends largely on the capabilities of people who are credentialed in meaningful and consistent ways. Further, the kind of knowledge countries need to develop is key: first, literacy of the general population, and then educating problem-solvers who can build the technical infrastructure for sustainable change. *Engineers are the ideal problem solvers.* When you consider that economic studies conducted before the information-technology revolution show that as much as 85 percent of measured growth in U.S. income per capita was due to technological change [29], a strong case can be made for seeing engineers as the key knowledge workers for capacity building and sustainable economic growth in emerging economies.

It follows, then, that to effectively compete in the knowledge-based economy, developing countries must invest in producing a large enough pool of high-quality and accredited engineering graduates. Of course, the pool will be drained somewhat because some of these graduates will leave for jobs in developed countries. However, many will choose to stay where family ties and native culture provide a comfortable environment and competitive quality of life. By building the technical capacity of their workforce, through quality engineering-education programs, countries can build a competent technical workforce, which can provide several paths to economic development: attraction of technically oriented multi-national companies that can invest in the country; effective use of foreign aid funds to build appropriate infrastructure projects, and then have the technically competent citizens of the country to operate and maintain them; and creation of small business startups by technically competent entrepreneurs who either live in the country, are living elsewhere but return home, or immigrate from other countries. Both the United Nations Educational, Scientific and Cultural Organization and the World Federation of Engineering Organizations are actively engaged in technical capacity building in developing countries [4].

II. The Imperative to Innovate and Reform Engineering Education

High-quality and pertinent engineering education, and quality-assurance mechanisms are imperatives for creating a knowledge-based economy. Engineering education must respond to local challenges as well as global opportunities. Quality-assurance systems with peer-review accreditation must be present to promote high-quality education programs and make degrees portable to other parts of the region and of the world. Quality-assurance systems can provide the basis for cross-border recognition systems, permitting the flow of services and goods across national boundaries and creating a net 'brain gain' for the country or region.

To innovate and reform engineering education, a country's educators need to understand what an engineer is, and what skills and competencies s/he must possess. Their education and professional development is not only about knowledge, but also about skills, values and competencies. Engineers face problems as a way of life. Engineers must not only be knowledgeable about science and technology but also have the skills, competencies and values to address problems and opportunities in effective and creative ways.

Higher education, in general, is responsible for formally preparing the next generation of business leaders, technical professionals, government officials and educators. Engineering education, in particular, plays a central role in our increasingly technology-based societies. The education of engineers must prepare them for the multi-disciplinary nature of the problems they will face.

But is engineering education preparing the kind of professional that's needed to solve local problems and face global opportunities?

The need to innovate and reform engineering education is vital and undeniable. In the United States, for example, prestigious organizations like the National Science Foundation (NSF), the American Society for Engineering Education (ASEE) and the National Academy of Engineering (NAE) have reported on the growing need for change in engineering education [5,6,7]. Sweeping changes in the context for engineering accompanied by significant changes in the challenges offered by the engineering workplace bring urgency to the need for broad change in the education of engineers.

But herein lays the problem: Engineering education has not traditionally concerned itself with the development of skills and competencies needed in the job market and workplace. According to Richard M. Felder, co-director of the U.S. National Effective Teaching Institute, "We're teaching the wrong stuff [8]." He argues that since the 1960s, the United States has concentrated almost exclusively on equipping students with analytical (left-brain) problem-solving skills, and that a) most jobs calling for those skills can now be done better and or cheaper by either computers or skilled foreign workers (and if they can be, they will be), and b) American workers with certain right-brain skills will continue to find jobs in the new economy. (For example, researchers, designers, entrepreneurs as well as other self-directed people, and people with strong interpersonal, cultural awareness and language skills.) Felder questions whether the U.S. education system is helping students develop the attributes they will need to be employable in the coming American and global engineering job market.

NSF Workshop on Restructuring Engineering Education

To better understand the programmatic implications of the broad changes needed in engineering education, in 1995 the NSF organized a workshop on restructuring engineering education [13]. The task was to address the curricular content (including experiential, contextual and service-learning activities) and the broad academic framework of an engineering education. Workshop attendees included individual investigators, engineering education coalitions, engineering societies, industry and students. They concluded that, to be restructured, engineering education must be examined from a different point of view, with new measures and expectations.

In their report, workshop participants called for diversity in all aspects of engineering education: diversity in pedagogy, curriculum, cross-disciplinary approach, faculty and students. Restructuring requires rewards and incentives designed to achieve the desired diversity.

Workshop discussions and recommendations focused on four dimensions deemed critical to engineering education reform:

- **Students are central to the educational process**. As such, they should be active participants in the educational transformation process. The educational experience should develop in students the motivation, capability, and knowledge base for lifelong learning.
- **Faculty** need to assume a more active role not only in delivering the educational experience but also in innovating and continuously improving engineering education to meet the new global challenges. Changes in assessment, recruiting and the reward structure are most critical for encouraging faculty changes.

- **The learning experience** must move away from lectures as the dominant mode and toward a higher level of active learning approaches, such as laboratory and internship experiences. These experiences should encourage world-class design, development and implementation processes for engineering. Cooperative learning approaches and other contextual and experiential learning must be integrated into the classroom.
- **Engineering curricula** should be broad and flexible, preparing students for leadership and specialist roles in a variety of career areas. Each curriculum should be designed to produce graduates who are life-long learners and contributors to the profession, fully capable of succeeding in a global, multi-disciplinary marketplace. The learning experiences should accommodate students with various learning styles as well as different cultural, ethnic, class, gender, age and racial backgrounds. Further, engineering education should provide an opportunity for non-majors to study engineering topics and concepts, and enable engineering discipline and approaches to inform other disciplines.

How to Prepare the Next Generation of Engineering Students – The U.S. National Academy of Engineers Report

In 2005, the National Academy of Engineering published its report, *The Engineer of 2020: Visions of Engineering in the New Century.* The report begins with the premise that for the United States to maintain its economic competitiveness and improve the quality of life for people around the world, engineering educators and curriculum developers must anticipate dramatic changes in engineering practice and adapt their programs accordingly. Written by a group of distinguished educators and practicing engineers from diverse backgrounds, the report includes various future scenarios based on scientific and technological trends. In addition to identifying the ideal attributes of the engineer of 2020, the report asks: “What should engineering education be like today, or in the near future, to prepare the next generation of students for effective engagement in the engineering profession in 2020?” The report recommends ways to improve training to prepare engineers for addressing the complex technical, social, and ethical questions raised by emerging technologies.

The Educator’s Role in Reforming Engineering Education

Traditional scholarly work (including engineering) centers on the professor, his/her course(s), and his/her professional career and research agenda. Teaching is often considered secondary, even a burden. Faculty is mostly rewarded for research activity and outcomes.

But the need and changes described in the NSF and NAE reports shared above will be an insurmountable challenge if education does not recognize and value the scholarship of teaching, in addition to the scholarship of discovery [9]. We need to ensure that the full range of scholarly activity by college and university faculty is recognized: discovery, integration of knowledge, teaching and service. We need to create a reward system that values faculty’s full range of scholarly activity**,** one that recognizes those who make an effort to bridge the ‘disconnects’ that exist between academia and the real world [10], especially in the teaching of engineering. Because as Richard M. Felder states “…College teaching may be the only skilled profession for which no preparation or training is provided or required” (http://www.ncsu.edu/felder-public/).”

If the key to economic development is people, the question arises, “What can one person do?”

As a Puerto Rican and a former university professor at the University of Puerto Rico-Mayaguez, and now a director in Hewlett-Packard Company's University Relations Department, I have been asked many times to discuss the role of engineering educators in meeting national and global challenges. It may seem a big responsibility to try to change engineering education. But it really begins with an individual's personal challenge and drive, and sense of accountability and social responsibility. One has to feel "responsible" for one's people, for one's country and for the world. Often, when we first undertake the challenges, we meet seemingly insurmountable obstacles. We sometimes try to find someone to blame [14]. We may become cynics. But someone once said, "A cynic is a disappointed optimist," so there is enormous untapped potential in the cynic as well as the idealist.

A first obstacle I encountered as a young professor at UPRM was the poor track record of my students in some courses – no worse than that of other professors' students, but no better, either. How could some of the best and brightest students in Puerto Rico be doing no better when I was so committed to teaching them and having them enjoy the experience? It took me several years to understand that the problem was not in the learner but in the teaching. I finally had my epiphany and came to comprehend – or rather, accept - that there was a mismatch between how people learn and how professors teach. That realization drove me to use non-conventional teaching and learning strategies in my classroom, including active and cooperative learning, hands-on learning and a focus on problem-solving skills instead of the usual tons of theory. It took me 25 years to re-define myself as an educator, and it meant going along paths different from those modeled by my former professors and mentors – a somewhat scary proposition at the time.

Here are some of the steps, projects and initiatives I have been involved with to improve engineering education:

Using Cooperative Learning in the Classroom [15]

After successfully using cooperative learning in my classes in the early 1990s, UPRM Chemical Engineering Professor Carlos Velázquez and I tried to prove the value of the cooperative learning strategy in one course that had an historical attrition rate of 50 percent to 60 percent. We departed from the traditional teaching method and instead used a cooperative approach that included think-tank/in-class problem-solving, joint quizzes, one-minute papers and study groups. In addition, we offered incentives for teamwork. The outcomes were extraordinary. Overall, 77.4 percent of the students participating in the cooperative learning experiment passed the course with a grade of C or better, compared to 28.6 percent of students in the control group.

Statewide Science, Math and Engineering Curriculum Innovation Initiative

I then was invited to join the University of Puerto Rico Resource Center for Science and Engineering. Here, several higher education institutions collaborated in a multi-year program under the NSF's Louis Stokes Alliance for Minority Participation Program (LSAMP). The program was known as Puerto Rico LSAMP, or PR-LSAMP. PR-LSAMP's core was to revise the curricula of science, mathematics, engineering and technology (SMET) courses to improve student performance. I led the curriculum innovation center. We were asked to identify, assess and reform SMET "gatekeeper and bottleneck" courses (those with high attrition rates); and describe successful reforms institutionalized at several institutions [16, 17]. Curricular revision and assessment was not limited to the classroom, and as a result, a scholastic community of SMET faculty was formed to document and publish educational research, strategies and results for the benefit of the academic community at large.

The Learning Factory: a Multi-Disciplinary, Active-Learning Program

In 1994, I began participating in a university-industry partnership called the Manufacturing Engineering Education Partnership (MEEP). Its aim was to integrate design, manufacturing and business realities into the engineering curriculum. This was an opportunity to extend curriculum, and teaching and learning methodologies across the Atlantic.

The MEEP team developed the Learning Factory, a multi-disciplinary program that provides real (industry-driven) projects; a curriculum in product realization; and a state-of-the-art, hands-on learning laboratory, with strong industry participation and integrated outcomes assessment. The Learning Factory began as the result of a joint National Science Foundation/Defense Advanced Research Projects Agency grant, and was undertaken by Sandia National Labs and three universities: UPRM, Penn State University and the University of Washington. This program, which integrates an outcomes, competency-based curriculum with assessment and industry partnership, continues to grow over a decade since it began [18, 19, 20].

The fundamental innovations of the Learning Factory that made the greatest impact at the universities are:

- **Facilities:** The Learning Factory <http://www.lf.psu.edu> is an open-access, active-learning laboratory, where students, faculty and industry from all disciplines can practice real engineering. It provides practical training and modern facilities for design, prototyping, manufacturing, testing and re-design. These facilities support numerous student design projects and competitions, enabling faculty to integrate engineering practice into their courses.
- **Industry interaction:** The Learning Factory provides an efficient infrastructure for actively involving industry in the educational process through capstone design projects, curriculum improvement and engineers in the classroom.
- **Curriculum:** The product realization minor, or manufacturing certificate, is comprised of elective courses in product dissection, concurrent engineering and engineering entrepreneurship; and required courses in manufacturing processes, quality control and capstone design.

In 2006, Jens E. Jorgensen (University of Washington), John S. Lamancusa (Penn State University), Allen L. Soyster (Northeastern University), José Zayas-Castro (University of South Florida) and I received the National Academy of Engineering's Bernard M. Gordon Prize -- a $500,000 annual award that recognizes innovation in engineering and technology education. We won, the academy noted, "For creating the Learning Factory, where multidisciplinary student teams develop engineering leadership skills by working with industry to solve real-world problems."

Replicating and Expanding the Learning Factory Model

Based on the Learning Factory model and with funding from the National Aeronautics and Space Administration, in 1998 I led UPRM's team to start the Partnership for Spatial and Computational Research (PaSCoR), an innovative interdisciplinary curriculum whose goal was to strengthen academic programs and integrate research in remote sensing and geographical information systems (GIS), at the undergraduate level, in various SMET disciplines. This project followed the model of the Learning Factory, and focused on the student's learning, with strong emphasis on hands-on activities [21, 22].

Quality Assurance and Outcomes Assessment

At UPRM, one of the most significant impacts of the Learning Factory was on accreditation and outcomes assessment [23].

Since the fall of 2001, educational institutions across the United States have had to assess and evaluate their undergraduate engineering programs to employ the philosophy and practice of continuous quality improvement., based on new engineering criteria approved by the Accreditation Board for Engineering and Technology (ABET). The first step is to develop program educational objectives – statements describing expected achievements of graduates in the early years of their careers as a result of their educational preparation. Usually, educational objectives are expectations of graduates' performance after they have been in the workforce for three to five years. The second step requires a more specific definition of program outcomes – skills, knowledge and behavior that is expected of students when they graduate. Fulfilling these steps requires considerable time and effort, not only to clearly define the program educational objectives and outcomes, but also to develop proper and continuous assessment methods and tools, documentation, processes, and the necessary culture and philosophy changes that would be introduced as a consequence of the cyclical processes.

Learning Factory Experience Drives UPRM Engineering Accreditation Strategy

UPRM's College of Engineering ABET 2000 accreditation strategy (www.abet.uprm.edu) was based on the Learning Factory experience. The strategy incorporated the outcomes assessment plan and tools developed under MEEP and PaSCoR. In order to institutionalize the assessment process as part of the various courses, the College of Engineering established an office called the System for the Evaluation of Education (SEED), with the goal of developing assessment strategies for the undergraduate engineering programs. In addition, the faculty involved industry and employers in its process, and conducted mock "accreditation visits" where industry members gave input about the programs. The UPRM ABET committee organized a series of one-day workshops that led to the development of a package of assessment tools and strategies. This was adopted for common use by all programs, with each one at liberty to modify or choose from among the recommended methods and tools. The package contains an outcomes assessment matrix; an assessment strategies matrix; and various assessment forms for integrating ethics, oral and written reports, teamwork, peer evaluation, course and project evaluations, internships, and a variety of surveys.

All six of the undergraduate engineering programs were evaluated in 2002. ABET's accreditation visit team commented: "The institution's systematic and innovative effort to introduce the culture of outcomes-based assessment to the College of Engineering community is especially noteworthy." As a result of these experiences, UPRM is expanding the quality assurance and outcomes assessment efforts institution-wide.

Sharing with Others: Outreach Small and Hemispheric

As the MEEP Learning Factory project was coming to an end, the UPRM team began working to share this model program with other faculty and institutions [21, 24, 25]. Grants from the NSF, Raytheon Company, Microsoft and Hewlett-Packard have made it possible for UPRM to hold more than 40 workshops around the world for hundreds of faculty and deans, many of whom have adopted or adapted this model program.[1]

The program has had an outstanding impact in many cases. The most noteworthy example is Chile, where the Engineering Deans Council sponsored workshops for more than 130 participants nationwide, resulting in curricular reform supported by government grants. UPRM workshop leaders are assisting faculty at the Universidad Federico Santa Maria in Valparaiso, Universidad de Bio-Bio, and Universidad de la Frontera, in their implementation efforts.

Engineering for the Americas

Recently, I've had the opportunity to be involved in engineering education innovation and assessment that became the "Engineering for the Americas" initiative. It was developed after a Learning Factory workshop was held in Rio de Janeiro in 1998.

This grass-roots initiative is being carried out by many organizations and in conjunction with the Organization of American States (OAS). It focuses on developing plans for enhancing engineering education and practice throughout Latin American and the Caribbean [27, 28]. The OAS ministers of science and technology issued a major declaration in support of this capacity-building effort during their meeting in Lima, Peru, in 2004.

A subsequent meeting held in Lima in 2005 attracted over 200 participants from corporations, universities, governments, and NGOs throughout the hemisphere. Funding provided by the U.S. Trade and Development Agency and several corporations, (including HP, the catalyst for its inception), was used to support attendance by over 100 of the participants. The Lima Declaration, as it is called, is the overarching achievement of the conference. It makes recommendations for defining the needs of the technology sector, taking the necessary steps for enhancing and ensuring the quality of engineering education, and developing financial initiatives for capacity-building efforts. A follow up meeting was held in Puerto Rico in 2006 at which committees were established to pursue the recommendations from the Lima 2005 conference.

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[1] Some of the sites where this workshop has been offered include:1998 & 1999 Frontiers in Education Conferences; 1999, 2000 ASEE Conferences; 2000 SUCCEED-GATEWAY conference in Greensboro, NC; UTEP; Tennessee State University; Southern University; North Carolina A&T; 1999 ICEE Conference; Texas A&M - Prairie View; Polytechnic University- Puerto Rico; University of P.R. at Bayamón; Worcester Polytechnic Institute; 2000 ADMI Conference; Hampton University, VA; University of Chile; Pontifical Catholic University of Chile; University of Buenos Aires; Universidad Tecnológica Nacional, Argentina; and Universidade Estadual de Campinas, Brazil; and more recently in 2005-2006 at Monterrey Tech and 2006 SEFI Conference in Uppsala, Sweden. Frank Stefan Becker, Director of Siemens Worldwide University Relations said of his experience July 2006: "it is probably the best workshop in all the SEFI conference".

Plans now include offering regional workshops on engineering education innovation and reform, quality assurance and assessment, and technology innovation, in addition to finding resources to support these initiatives. The Engineering for the Americas team is focused on creating a comprehensive partnership committed to advancing the mandate set forth in the Lima Declaration. It also is pursuing opportunities from government, academic, industry, professional societies, accreditation agencies, and a variety of funding institutions to invest in building engineering capacity and sustainable competitiveness throughout the Americas.

III. The Convergence of Engineering Education, Globalization and Economic Development

Where do engineering education and economic development meet, and does this convergence help achieve economic development? To demonstrate this, I will focus on work being done by the UPRM and Hewlett Packard Company's Puerto Rico site.

Puerto Rico

Puerto Rico became a commonwealth of the United States in 1952. It has experienced periods of impressive economic growth, which raised domestic living standards significantly. For example, GDP per worker rose from just 30 percent of the U.S. average in 1950 to 75 percent in 1980 [11], exceeding the standards in many Latin American countries. Currently, around 45 percent of Puerto Rico's GDP is based on manufacturing, especially pharmaceutical and biotechnology, as well as the information technology industry[2].

This growth is in large part due to the country's strategic investment in education at all levels. Lacking natural resources, Puerto Rico must rely on its highly skilled, educated and fully bilingual workforce. Currently, Puerto Rico universities graduate around 23,000 bilingual students each year, of which about half are women. A large number of women enroll in engineering programs. For example, 40 percent of the engineering students at UPRM are women.

Hewlett-Packard

Successful companies like Hewlett-Packard (HP) [30] know that ideas are a precious currency and innovation is an essential competitive strategy. Without innovation — turning good ideas into useful products and solutions that meet changing customer needs — companies, like countries, struggle to catch up or to keep from going under. An integrated approach to innovation is critical. To be a leader, companies like HP know that innovation must be fostered and managed across the company and the world. HP is a complex system of businesses, technologies, systems and capabilities, which together give the company a unique market position and competitive advantage. To make the most of its diverse parts, HP needs an integrated strategy and approach to innovation.

To get the most from its investments in innovation, HP builds on industry standards and focuses on areas where it can add unique value. The company does not try to be everything to everybody; rather, it leverages its multi-billion dollar investment in R&D and chooses to innovate in ways

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[2] The pharma/biotech industries combined represented more than $30 billion in annual exports for Puerto Rico in 2005.

that will bring unique value to customers and create a competitive advantage for HP. In addition, the company maximizes the return on its R&D investment — and executes on its strategy — by leveraging innovations across the company and partnering with top universities worldwide.

People are the key critical factor to make this happen, especially engineers and scientists who have the right kind of skills, values and knowledge to drive innovation. HP's facility in Puerto Rico is a part of this effort. For 35 years, HP has made significant investments in its manufacturing facilities in Puerto Rico. The site has currently approximately 1,200 employees and they include engineers and scientists from UPRM. Due to its multi-faceted relationships, including joint research, recruiting, sales and philanthropy, UPRM was selected by HP to be one of the company's strategic university partners worldwide. As one of HP's principal research academic partners, UPRM works with the company on research projects of international recognition, and in emerging technologies, such as digital publishing. As a result, HP has donated millions of dollars in equipment and resources to UPRM, and supports faculty and graduate students in areas of research of interest to HP.

University of Puerto Rico

The University of Puerto Rico was established in 1903. The Mayaguez campus originated in the school's College of Agriculture. In 1942, the campus was organized into highly autonomous colleges of agriculture, engineering and science. Expansion continued through the 1950s when many programs flourished in the university to support Puerto Rico's development from an agricultural economy to manufacturing and now a knowledge-based services economy. Today, UPRM continues its development. It is a co-educational, bilingual, and non-sectarian school with colleges of agricultural sciences, arts and sciences, business administration, engineering, and the division of continuing education and professional studies. There are 12,136 students, 1,336 regular staff members and 1,026 members of the educational staff. Programs are continuously assessed and evolved to help develop Puerto Rico's primary resource: its human capital.

UPRM has a history of excellence in its academic programs and higher education administration. For decades, UPRM's College of Engineering has had its programs accredited by ABET, and its graduates work for local companies as well as more than 85 multinational companies and organizations.

The UPRM-HP Partnership [12]
In partnership with the Puerto Rican government and thanks to government incentives, HP Puerto Rico is successfully responding to the challenges and opportunities of the global economy. An important example is the establishment of the HP Technology Center. In 2001 HP Puerto Rico decided to approach the government of Puerto Rico to partner in a new economic development strategy. Through the government's Industrial Development Company, HP received a five-year grant to establish the first bona fide R&D operation in Puerto Rico: the HP Technology Center. The main goals of the center are to enhance HP's value, enhance Puerto Rico's economy, focus on R&D of new technologies, and leverage and enhance HP's and partners' human capital and resource capabilities.

During its first two years, the technology center built an R&D organization of nearly 60 people and now has three research teams: software and hardware, e-services, and an Imaging and Printing Excellence Center. Invention disclosures currently range in the thousand, more than 85 patents have been issued, and about 40 new products or processes enabling almost a billion dollar of manufacturing revenue have been developed.

In addition to the R&D outcomes, HP Puerto Rico leaders are participating in the government of Puerto Rico's Science and Technology Roadmaps, Communications and Information Technology (C&IT) and life sciences (the most important technology cluster in Puerto Rico's economy), providing new opportunities for HP and Puerto Rico. Evidence of this is the end-to-end product tracking and authentication solution the technology center has developed for the pharma/biotech industry, a technology to track and authenticate products across the whole value chain. The solution is a breakthrough for the industry as well as potentially Federal Drug Administrations standards, capabilities and policies.

The technology center also has developed strategic alliances with HP Labs, the company's central advanced R&D facility, and with labs in the HP business units. It also has alliances with academia and other partners. This offers Puerto Rico's scientists and engineers the opportunity to partner with top research, development and manufacturing groups around the world. The center can most certainly help move Puerto Rico into a knowledge- based economy, and it is becoming a showcase that can attract further investments in Puerto Rico and other developing economies.

Conclusions

Using the examples of an individual, a company and a country, I hoped to demonstrate that engineering and engineering education are closely linked to globalization and economic development. Engineering education that focuses on outcomes and on producing engineers that society, regions, nations and the world need is an imperative, one that countries committed to bettering the lives of their citizens must address.

It's quite possible to go from small steps taken by individual faculty motivated to enhance learning and the classroom experience, to engaging in larger initiatives that enhance and prove concepts based on these success, as my case studies demonstrate. All it takes is the desire to change people's lives, and a caring attitude toward self and others. Eventually you can positively impact the world. Each of us need to help develop the skills of workers who will follow us and be our future leaders.

The path is rocky but very rewarding. For me, the greatest reward has been my students' feedback. A former student who now works for the U.S. Environmental Protection Agency, wrote to congratulate me on winning the Bernard M. Gordon award, and said: "Professor, congratulations on your award. You may not remember me, but you made a difference in my life."

There are many Sancho Panzas along the way, to help the Don Quixotes among us who some say are tilting at windmills. Together we can start with little things that are obvious and right in front of us, because these matter and soon lead to bigger things. Then suddenly one day, we realize that we have made a difference and things did change because of us. And with that accomplishment, we confirm my favorite line from St. Francis of Assisi: “Start by doing what’s necessary, then what's possible, and suddenly you are doing the impossible.”

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