2006-283: ENGINEERING CAPACITY BUILDING IN LATIN AMERICA

Lueny Morell, Hewlett-Packard

LUENY MORELL, M.S., P.E., is a member of the University Relations staff of the Hewlett Packard Company. She is responsible for relations with universities throughout Latin America and the Caribbean. Before joining HP, Lueny was full professor of Chemical Engineering at the University of Puerto Rico - Mayagüez where she held positions at the Campus and UPR system level, including director of the UPRM R&D Center. Recipient of the 2006 US National Academy of Engineering Bernard M. Gordon award, her work in curriculum, research, accreditation and economic development activities has been published in more than 40 papers, book chapters and journals.

Alice Abreu, OAS

ALICE ABREU, PhD, former Director of the Organization for American States (OAS) Office of Science, Technology and Education.

Marta Cehelsky, InterAmerican Development Bank

MARTA CEHELSKY is Senior Adviser for Science And Technology in the Department of Sustainable Development of the InterAmerican Development Bank, where she has spearheaded a initiatiative to strengthen the effectiveness of the Bank's S&T. Previously, Dr. Cehelsky served as Executive Officer of the Presidentially appointed National Science Board, responsible for policy of the National Science Foundation and for advising the US President and Congress on national science and technology. She served in a number of senior policy positions at NSF, NASA, and on the staff of Senator Ernest Hollings (D-SC). She was a member of the faculty of Brooklyn College, CUNY and the University of Houston and holds a doctorate from Columbia University in political science.

Russel Jones, World Expertise LLC

RUSSEL C. JONES is a private consultant, working through World Expertise LLC to offer services in engineering education in the international arena. Prior to that, he had a long career in education: faculty member at MIT, department chair in civil engineering at Ohio State University, dean of engineering at University of Massachusetts, academic vice president at Boston University, and President at University of Delaware.

Dan Marcek, Hewlett-Packard

DAN MARCEK, Deputy Director of HP University Relations, is responsible for development of HP strategy for and engagement with select university partners worldwide. Dan has been involved in managing HP university relationships since 1997 and is responsible for a wide range of institutions – from small, Ivy-league campuses to some of the nation's largest publics. He is also focused on exploring international opportunities for partnership among government, industry, academia, and NGO's to develop higher education systems, based on quality assurance mechanisms, that foster systemic improvements that create new business opportunities for HP.

Teofilo Ramos, Instituto Tecnologico de Monterrey

TEOFILO RAMOS, PhD, is currently Director of Institutional Effectiveness of the Monterrey Institute of Technology System in Monterrey, Mexico. He has served in Monterrey Tech for over 30 years as Chairman of the Electrical Engineering Dept.,(1976-1982) Dean of Engineering and Architecture (1983-1997), and Dean of Research and Extension (1998-2000). He was President of the Mexican Association of Schools of Engineering (1994-1996) and with IEEE he has been a member of the Awards Board, Educational Activities Board, Fellow Committee, EAB Accreditation Policy Committee, EAB Planning and Review Committee, Admission and Advancement Committee and Director of the IEEE-Monterrey Section. In 1998 he received the

IEEE-EAB Meritorious Achievement Award in Accreditation Activities "for leadership in establishment of the engineering accreditation system in Mexico" and in 1992 an ABET Award "in recognition of distinguished leadership in engineering education accreditation in Mexico".

Luiz Scavarda Do Carmo, Pontifical Catholic University of Rio de Janeiro

LUIZ C. SCAVARDA DO CARMO is Vice Rector of the Pontifical Catholic University of Rio de Janeiro (PUC-Rio). He received his BS degree on telecommunicaton his PhD degree in Physics and has publsihed more than 50 scientific and engineering articles. Prof. Scavarda was Dean of Engineering and Natural Sciences of PUC-Rio and has devoted part of his time to support and dvelopt the Engineer of the Americas initiative.

John Spencer, Microsoft Corp.

JOHN D. SPENCER, Manager, Microsoft Research, External Research & Programs has the responsibility for strategic initiatives in the area of software engineering and secure software development worldwide. John was the lead manager in establishing Microsoft's university relations program in Latin America and is currently involved in those strategic initiatives. Over the past several years his responsibilities has been to partner with top tier institutions and government organizations worldwide, and to promote research, innovation, and academic excellence.

Jorge Yutronic, Conicyt - Chile

JORGE YUTRONIC is currently Executive Director of the Chilean Fund for the Promotion of Scientific and Technological Development (FONDEF) (since 1991), Member of the Directive Council of Fundación Chile (since 1997), President of the Executive Committee of the EXPLORA Program of CONICYT for the Diffusion of Science and Technology (since 1995), Director of Development and Programs of CONICYT (since January 2002), President of KYBER (since 1999) and Movilmaster (since 2002). He was President of the Instituto de Ingenieros de Chile (2002-2003) and a Member of its Board of Directors (since 1998). In the engineering field, he has served as Manager of the State and Government Division of SONDA (1996-1999), the main chilean company in the field of information technology business, General Manager of the Company SONDA Automation (1992- 1996), Manager of Systems Division of SONDA (1985 – 1992), Engineer in ENDESA (Chilean Electricity Generation and Transmission Company) (1974 – 1976). As research and development manager he has served as Director of PROSCOM (Organization belonging to the Universidad de Concepción for the Development of Technological Projects with Industry) (1976 – 1985). He also vas Associated teacher of the Universidad de Concepción (1976 – 1984), Associated teacher of the Universidad de Chile (1975 – 1977). He is also consultant for international organization and member of boards of directors of universities and companies.

Engineering Capacity Building in Latin America

Abstract

The widening, intensifying, speeding up, and growing impact of worldwide interconnectedness, better known as globalization is forcing countries and regions develop strategies to enhance their economies to better compete worldwide. Science, technology, engineering and innovation play a fundamental role in the creation of wealth, economic development and in the improvement of the quality of life for all citizens. This paper addresses the role of capacity building and engineering education as foundations to develop national/regional economic development strategies in Latin America. Contributors from various sectors (academia, non-governmental organizations, industry and government) share their roles, viewpoints and perspectives.

Introduction

There are many definitions of globalization. It can be thought as the process in which geographic distance becomes a factor of diminishing importance in the establishment and maintenance of cross-border economic, political, and socio-cultural relations or it can be thought of as the widening, intensifying, speeding up, and growing impact of worldwide interconnectedness [1]. But regardless of definitions, most agree that globalization has fundamentally transformed economies around the world. In this era, economic networks rather than political boundaries are the building blocks of prosperity and change.

In the ***World is Flat***, Tom Friedman [3] suggests how the world is in its 3rd globalization wave, one that is governed by people and communications. He states that the flattening of the world happened at the dawn of the twenty-first 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 countries and those in development think about effective and efficient strategies that will advance their economic and social development agendas. Many countries around the world have made significant strides in the past ten years in laying the foundations for market economies and democratic societies to flourish. For many of them, that progress is now recognized worldwide. Countries like Taiwan, Singapore, and Ireland come to mind.

Economic Development and Knowledge-Based Economies

Economists and social scientists agree that economic development is a concept that is not easy to define, but most would agree that is relates to the restructuring of an economy to enhance social and economic well-being of a community, region, state, or nation and its citizens [1]. Competing in global economy demands that policy makers understand a new geographic scope and the predominant new drivers of growth: innovation and entrepreneurship. Countries whose economies have embraced these drivers can be thought as knowledge-based economies. A knowledge based economy is one that employs a region's knowledge and educational resources to gain economic advantage across the whole value chain in the global economy. Thus, building

a region's capacity to adapt and create new technologies and opportunities is the underlying business strategy for competitive advantage [1]. In today's world, engineering and technology are at the very basis of the kind of capacity building that is required to position nations as competitive, companies to adapt, and people to gain economic and social advantage.

Pillars of Knowledge-based Economies - The Role of Capacity Building

Knowledge-based economies around the world have similar characteristics and national/regional strategies. One, they heavily invest in education at all levels in order to build the human capital necessary to develop an educated and skilled population that is needed to create, share and use knowledge. Two, they create an appropriate set of economic incentives and institutional regimes to create an enabling environment, including a regulatory and economic environment that enables the free flow of knowledge, supports investment in Information and Communications Technology (ICT), and encourages entrepreneurship central to a knowledge economy. Three, knowledge based economies build a national information infrastructure and promote access to and use of ICT's, by fostering competition and private sector investment, developing regulatory mechanisms to manage systems and protect public interests and by creating flexible legal and regulatory regimes for new forms of economic and social activity. And four, they create a strong and effective national innovation system, promoting research and development (R&D) to bring innovations to market, thus rationalizing government funding for R&D, improving support for innovation and networking, and encouraging greater cooperation and interaction of the various stakeholders: industry, university government and private research organizations, as well as foreign counterparts.

The World Bank recommends non EU countries [9] consider several critical elements for non European Union countries in their quest for their candidacy for accession to the European Union. These guidelines hope to provide a framework, and resources, for their continued efforts to reform their economic systems, reduce and adapt the role of the state in the economy, and restructure inefficient and uncompetitive sectors. These guidelines should help them create the policy frameworks, economic incentives, human capital, infrastructure and innovation capacity that will permit them to compete regionally and globally and thus create sustainable economic growth that benefits all sectors of their society.

In the pursuit of a more secure, stable and sustainable world, developing countries must seek to enhance their human, institutional and infrastructure capacity. In a coordinated approach, UNESCO and the World Federation of Engineering Organizations (WFEO) are mounting major efforts at technical capacity building in developing countries. Their aim is to develop a solid base of technologically prepared people that can compete internationally and will effectively improve their economies and quality of life. Such a base will facilitate the infusion of foreign capital through attraction of multinational companies to invest in the developing country, assist in making the most of foreign aid funds, and provide a basis for business development by local entrepreneurs [4,5].

Engineering and Engineering Education for the 21st Century

In its 2005 report, ***Science, Technology, Engineering and Innovation for Development, A Vision for the Americas in the Twenty First Century*** [8], OAS highlights how crucial it is that that all countries, large and small, rich and poor, take advantage of science, technology and innovation as fundamental elements for their development strategies, poverty reduction and the construction of a knowledge society. With the input and collaboration of distinguished scientists, experts and government officials from the Americas the report aims to contribute in the formulation of this new approach, focused on capacity building, which if developed and strengthened in the region's countries, will greatly favor their advancement, position and integration to the world. It is envisioned that the development and maintenance of a national science and technology capacity will allow countries in the Americas to be more than just consumers of other nations' technological exports and allow citizens to actively participate in generating global economic growth.

Engineering educators, professional associations and accreditation organizations are also concerned with their role in the development of the kind of engineer that can work in this globalized world. The US National Academies of Engineering have recently completed its Engineering 2020 Report. Phase I report of the Engineer of 2020 Project [2], ***Visions of Engineering in the New Century,*** identified the attributes and abilities engineers will need to perform well in a world driven by rapid technological advancements, national security needs, aging infrastructure in developed countries, environmental challenges brought about by population growth and diminishing resources, and the creation of new disciplines at the interfaces between engineering and science.

To ensure that future engineers have these capabilities, they must be educated to be not only technically proficient, but also ethically grounded, global citizens who can become leaders in business and public service. NAE's Phase II report provides recommendations to guide engineering educators, employers, professional societies, and government agencies as they reengineer the "system of systems" called the engineering education process.

But not only enhancement of engineering education is required to reengineer the education process. Development and enhancement of quality assurance mechanisms, harmonization of degree patterns and portable measures of standards and abilities are also needed if credentials are to be understood. In addition to providing accreditation of engineering programs in Canada, the Canadian Engineering Accreditation Board (CEAB) also plays a key role in international activities, by assessing the equivalency of the accreditation systems used in other nations relative to the Canadian system, and by monitoring the accreditation systems employed by the engineering bodies which have entered into mutual recognition agreements with the country. Through CEAB's activities, the Canadian criteria and procedures for accrediting undergraduate engineering programs are now recognized around the world. The US counterpart, the Accreditation Board for Engineering and Technology (ABET) has similar collaborations.

What is the status of higher education and engineering education in Latin America?

Higher education in Latin America is very diverse. Simon Schwartzman [7] in his position paper titled Prospects for Higher Education in Latin America, provides an excellent summary of higher education in the region. As of 1994, enrollment rates vary from 39 percent (in Argentina) to 11 percent in Brazil, Honduras, and Nicaragua. There's also a wide range of private enrollment in the region, as Figure 1 presents.

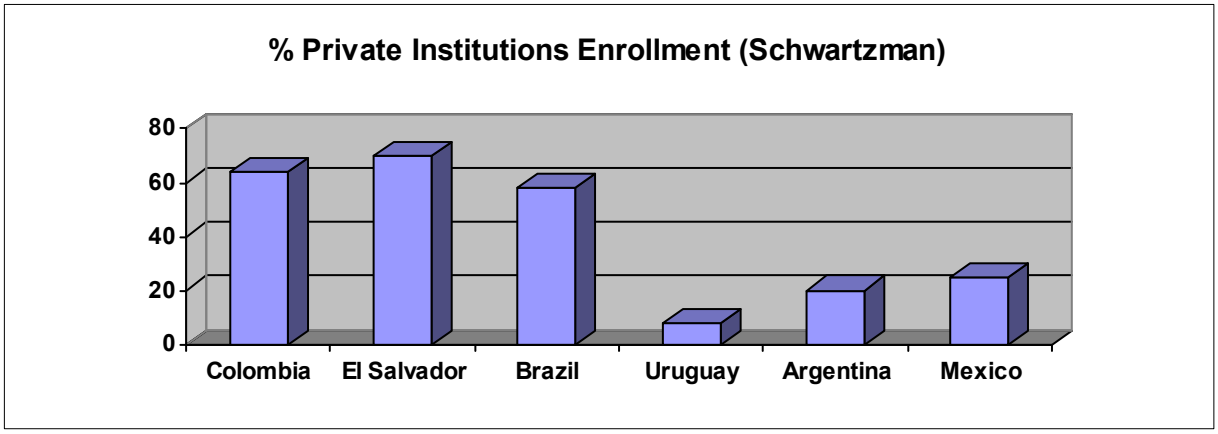

Figure 1 Percent Private Institution Enrollment

Concerning language, Peru, Bolivia, Paraguay, and Mexico have large native populations that speak their own languages, in contrast with Argentina and Uruguay, which do not. Brazil, Cuba, and the Dominican Republic have significant populations of people of African descent, and Haiti is a country of blacks who speak French.

There's also another dimension of diversity in Latin American higher education institutions. Old Catholic universities in Spanish America were created in the 16th century, while the first universities in Brazil date from the 1930s. In some countries, private universities cater to the elite, while public universities are poorly supported and populated by students with few resources and with modest educational backgrounds. In others, public education is highly selective and of good quality, and poorer students have to look for places in low-cost, low-quality institutions, such as night schools.

The first wave of higher education globalization in the New World occurred in the early 19th century, as the old Spanish and Portuguese empires crumbled. Their colonies had to become modern states, so that forced universities to be created to train military officers and lawyers who could build the new nations. The global model in those years was France, which exported to the New World the Napoleonic model of the centralized state and bureaucratically controlled institutions, together with the conflicts between church and state. Then, in the 20th century, and more so after the Second World War, people flocked from the country to the cities, mass communications spread, and governments were called upon to provide the protection and services required by growing populations. The region progressed in some places more than in others. However,, political and economic woes have affected the region significantly during the last half of the last millennium and many countries in the region still have to develop the necessary levels of income, education, and work to enjoy the benefits of modernization.

For the next century, another global trend may occur in higher education. Public higher education institutions will come under strong pressure to produce more, in quantity and quality, for the same amount or fewer resources; the private system, as it moves in to fill the gaps, will press for public subsidies and be questioned about the worthiness of its products and services. Institutions will require understanding their role in their countries' economic development strategies and they may have to look outside their walls for answers. The pressure for reform higher education will fall upon both the public and the private sectors. In addition, there will be a growing demand for transparency, thus, quality assurance systems and accreditation, which are so common in Europe and the United States will grow in importance and will have to be enhanced and/or developed.

The most difficult challenge for this century has to do with content and its delivery. There could be always a place for professional education in the traditional mode, and for graduate education and research, but the main question is how to provide a meaningful content and work opportunity for the large majority of new entrants in such an unequal system. Questions like what are the programs and courses needed in the region or country? What are the teaching and learning methods most appropriate to enhance learning effectiveness? What are the roles of stakeholders (like industry and employers) in the development of curricula and the assessment of outcomes?

> *"A completely new environment for higher education may emerge in the region from these trends; wider use of evaluation and external assessment; introduction of new organizational structures and a more managerial culture; expansion of technical, vocational, and general education; and extending overall access. Some countries and institutions will respond better than others to these changes. Those that succeed will likely be better able to use another feature of globalization in the new century--that is, the easy access to information, communication, technical assistance, and exchange on a truly global scale." [7]*

Although differences along Latin America must be observed and understood, it is important, nevertheless, to underline commonalities within the region. Most Latin Americans speak either Spanish of Portuguese and have a common background of Iberian culture. Local variations were developed from the presence of distinct indigenous populations and immigrants from Europe, Africa and Asia. The consequent result is a rich diversity, based on an easy communication that facilitates approximation and integration. A further approximation with North America is also based on historical commonalities that make the Hemisphere of the Americas a unique region in the world where most of the population may interact with the use of only three languages: English, Spanish and Portuguese. Differences on the social and economic state of development within the Hemisphere of the Americas is, nonetheless, a serious impairment to advance the process of hemispheric approximation, calling for a clear local development as the main goal of any program for capacity building within the Hemisphere.

Engineering and science education have been of great importance in the region, many programs with world recognized academic and research activity. To ensure quality, several countries have successfully established systems of accrediting their engineering programs. For example, in Mexico the Consejo de Acreditación de la Enseñanza de la Ingeniería (CACEI) accredits engineering programs in the country and has developed substantial equivalency with its US agency counterpart, the Accreditation Board for Engineering and Technology (ABET). Other countries and regions (like the Caribbean), are moving to create and enhance their accreditation

systems in an effort to have their engineering human resources recognized worldwide. More recently, the Western Hemisphere Initiative announced by ABET, the Canadian Engineering Accreditation Board (CEAB), CACEI, and the Peruvian Engineering Accreditation Board aimed at further assisting Latin American countries in the development of effective engineering accreditation systems, and furthering regional mutual recognition efforts has been created.

This century has seen universities play a major role in Latin America. Both private and public universities have paved the way for the gradual expansion of cultural elites and established the foundations for national research and development systems. Furthermore, these universities have facilitated social mobility, served as political socialization channels and, in general, fostered the development of national cultures and common markets (Mercosur, which was created by Argentina, Brazil, Paraguay and Uruguay in 26 March 1991, was set up with the ambitious goal of creating a common market/customs union between the participating countries on the basis of various forms of economic co-operation that had been taking place between Argentina and Brazil since 1986. It has since then, grown to include Chile and Bolivia, and more recently Venezuela developing agreements with other parts of the world). Capacity building will continue to be a critical pillar in the development of the economies of the region.

Engineering for the Americas (EFTA) Initiative

Stimulated by the globalization of the engineering profession and industries that it supports, and by increased interest in trade between countries and regions in the American hemisphere, a grass-roots movement to enhance engineering and technology education in the hemisphere has been gathering momentum over the past four years. The movement has been dubbed "Engineering for the Americas (EFTA)", and it involves educators, industry representatives, government officials, and professional groups as partners in its evolution. The basic concept calls for engineers to be educated in high quality institutions in each country of the hemisphere with quality assurance systems in place to guarantee consistently high caliber graduates. Mutual recognition of such engineering graduates across national boundaries, combined with cross-border trade agreements, will facilitate the flow of work and human resources throughout the hemisphere to optimal locations – enabling distributed regional economic development. This open mobility will then form the basis for a knowledge-based, hemisphere-wide economy, which will be competitive in the overall global economy. Each country in the hemisphere, as well as the sum of all countries in the hemisphere, should benefit.

The concept of Engineer for the Americas was conceived to foster professional mobility within the Hemisphere of the Americas and also to generate a local workforce that stimulates the economic development through the attraction of multinational industry. The development of supra-national economic regions (or meta-national companies) with strong cross-border ties is a reality of the present day and introduces a new vision for human resource development, particularly in the area of engineering [6].

Recognizing the importance of this movement, the Office of Science and Technology of the Organization of American States is working with the previously established ad-hoc group to formalize the "Engineering for the Americas" concept and program. A hemispheric initiative with this title was developed in meetings convened by the OAS in mid-2004, and incorporated in the Declaration of Lima and the Plan of Action of Lima, which were adopted by the meeting of

Ministers and High Authorities of Science and Technology in November 2004. The initiative that the Ministers strongly endorsed calls for enhancement of engineering education specifically, development of quality assurance mechanisms, harmonization of degree patterns, fostering of innovation, and government commitment to providing necessary upgrading to engineering and technology education. Subsequently, Engineering for the Americas has also been endorsed by the Presidents in the Fourth Summit of the Americas in Mar del Plata, Argentina in November 2005.

With the support and participation of organizations like OAS, USTDA, the InterAmerican Development Bank, companies like Hewlett-Packard, Microsoft, National Instruments, CEMEX, NYCE and Neoris, and thought leaders in engineering education and accreditation from the Americas, a major workshop was held in Lima, Perú early December 2005 to address effective implementation of the Ministerial plan of action. Around 300 attendees met to discuss the definition of the productive sector's needs, understand needs and opportunities in enhancing quality assurance for engineering education, plan for appropriate processes in each country, and gain understanding of how to finance needed enhancements. A plan for sustainability of the Engineering for the Americas movement was also discussed.

The importance to seek solutions and financing with medium-and long-term policies and plans, developed with the active participation of the various sectors involved was strongly emphasized during this event, as well as the potential benefits that a regional approach to capacity building may offer, which, inter alia, would enhance the Americas' countries presence on the world stage and render them less dependent.

Figure 2 EFTA Symposium, Lima Nov-Dec 2005

The Engineering for the Americas movement continues to grow and expand, and plans are being developed by the partnership to facilitate and finance regional and country activities that begin to enhance engineering education and create quality assurance mechanisms.

Government View - Engineering Capacity building in Chile

Chile is a country under a relevant transformation process. In less then 15 years, it has rebuilt the nation democratic system and more than doubled both its GDP and the number of students in universities. Huge efforts and investments have been deployed to reach those results. The country is in the transition process to be a developed country in a new context, the knowledge society. Creating wealth is the main challenge now, not only for government but also for industry, institutions and people as well. Improve the quality and productivity of work, improve education to prepare people to be able to create value, fight against poverty and favour social mobility and protection, are some aims of this challenge.

Chilean economy is mainly based in natural resources (mining, agribusiness, forestry, fishing, aquaculture) and services (telecommunications, energy, financial resources, transportation). In the last decade, the main Chilean companies have triplicated their exportations to more than 160 countries, amounting about 30% of GDP, competing with world class operators. Those kind of activities are a very good opportunity for engineering and innovation, not only because the well known international specialization of Chile in high quality natural resources processing, but also for the local conditions that are appropriate for that purpose.

Companies that compete in international markets require better technologies continuously. More and more, Chilean bigger companies are demanding improvements in technologies (equipment, processes, and services) from other companies, usually smaller and technology based ones. These tech companies, more oriented to innovation, are the seeds in the market for the transition to a knowledge economy. They are working as components of clusters linked to leader companies in each economic sector, developing competitive value chains. That entrepreneurship constitutes interesting partners for foreign companies looking for market and investment opportunities. Investment is one of the main drivers in the engineering capacity building process.

Chilean universities and technological institutes have been the base for research and development in the country. Chile invests 0,7% GDP in R+D, about 70% of that financed with public resources and mainly executed in these institutions. About 27% of total is financed by industry and other is 5% is financed by international institutions. Hence, the challenge in the Chilean knowledge creation process is to increase the investment, particularly by the private sector. The Chilean government, conscientiously, created some mechanisms to foster the links between universities and companies and to attract investment from industry. A very important one is the establishment of the Bicentennial Science and Technology Program for the Knowledge Society and the Fund for Innovation and Competitiveness. These mechanisms also favour the participation of institutions and companies from other countries, creating an effective opportunity for international cooperation and developing alliances to participate in competitive markets. One of the mechanisms established in this program is the competition for technology based consortia formation among companies and universities and technological institutions, from Chile and abroad.

The main science and technology fields in which Chile is investing (both public and private) are information and communication technologies (ICT) and biotechnology (BT). ICT has been playing a relevant role in government modernization (e-government), education (ICT tools),

company management systems, automation and networking. BT has been playing a relevant role in the natural resources processing in several fields in the Chilean economy: forestry, food production, agribusiness, etc. Both ICT and BT provide a realm of opportunities for advancement of country economic competitiveness and people quality of life. From that perspective, ICT and BT are the right base for value creation in a country that transits to the knowledge society. Those seeds will grow in a new scheme under development, based on: policy framework and economic incentives to knowledge creation and transfer; human capital development mainly through education; strengthening and evolution of the Chilean innovation system; development of the information and communication infrastructure.

Engineers play a relevant role in the evolution of the Chilean industry, both in the professional activities and top management. Engineering careers have a huge reputation in the country and attracts best talents consistently every year. Engineering careers have similar curriculum and teaching practices than in other countries and in the last years have been in a accreditation process. Nevertheless, it has been established a lack of innovation in Chilean engineers. Innovation is now the main field in which the Chilean system is starting to focus in the engineering capacity building process. In the last decade, the amount of students in engineering careers has increased a lot because the emergence of private universities. Besides, engineers from others countries come to Chile to practice their professions. Then, there is an increasing amount of engineers working in Chile.

University Perspective – Brazil and Mexico

The concept of EFTA thrives on an environment of collaboration of distinct actors, centered in the School of Engineering. The interaction among industries and Schools of Engineering is a usual practice in North America, helping the wealth creation from knowledge. This interaction is less frequent in Latin America and the Caribbean.

University research is not a frequent practice in Latin America. According to the criteria of the Carnegie Foundation for the Advancement of Teaching, in 2003 Brazil had only 16 “extensive research universities”. Local governments finance most of the research carried on Latin American Universities, producing results mostly on basic research. Although these results are solid, they do not lead automatically to wealth creation, unless they become part of a larger ecosystem of knowledge creation involving the productive sector.

The Pontifical Catholic University of Rio de Janeiro – PUC-Rio and the Federal University of Rio de Janeiro – UFRJ, both in the Carnegie Foundation list, are located in the petroleum rich state of Rio de Janeiro. These institutions have very much benefited from their interaction with PETROBRAS, the Brazilian petroleum company, in developing high-level applied research. In the State of São Paulo, well-established lines of research are already the results of interaction of the universities and the local industries. These are a few examples and not the rule in Latin America. The presence of meta-national high tech industries may help to transform the realities of research in Latin America, helping and collaboration with local industries to foster practices of research to be disseminated in Latin America and the Caribbean.

The importance of universities in the economic development of the communities they serve has become increasingly clear over the past few decades, since prosperity is currently based on knowledge, a preponderantly intangible resource, rather than natural resources and labor. The Monterrey Tech in Mexico has always been characterized by its clear-cut vision of its role as a higher education institution, making it a unique leader in the region. In 2005, Monterrey Tech's vision was redefined for the next fifteen years, prioritizing the motivation of the knowledge economy. This vision, which is sensitive to the challenges of the 21st Century, is founded in several fundamental dimensions on Monterrey Tech's activities.

Education is the fundamental core of Monterrey Tech. The impact on the economy through its graduates is the main way in which Monterrey Tech participates in the community, apart from offering society professionals who are internationally competitive in their fields. Monterrey Tech has created new undergraduate, master's and doctoral degree programs, based on disciplines and sectors that are strategic for attaining global competitiveness in knowledge economies, such as mechatronics, industrial design, biotechnology, and information technologies, among others. Furthermore, Monterrey Tech has adopted a philosophy of world-class quality that not only affects its graduates, but also allows the institution to influence and assume the leading role in education in Mexico, backed by its international programs for transferring the knowledge, experiences and cultures of work of the world's foremost universities

Research and technological development are pivotal activities. Through its research centers and national and international network of researchers in disciplines that have been defined as a priority, Monterrey Tech generates knowledge by means of patents, innovations, technological development, and social development in the different areas of the economy. At present, the institution has invested resources in 59 research chairs nationwide, mainly focusing on topics concerning the new economy.

The creation and attraction of companies based on knowledge and new technologies. Apart from the renowned business incubation model developed by Monterrey Tech over the past 15 years, the institution's main concern has been to generate management models and incubators for technology-based companies in order to form new knowledge-based business models that can compete with global firms and guide the driving forces of the regional economy toward the new sectors, thus leading to greater prosperity and a stable future. This effort rests mainly on the entrepreneurial program, the business incubator network, the programs for attracting capital risk, and the formation of technology-based companies, all of which have an influence on the business community. The creation of centers that specialize in business incubation and the acceleration of new technology-based companies, design centers, and innovation and technology parks that will act as catalysts for developing and attracting state-of-the-art knowledge-based companies in order to boost the transformation of the regions' economic model.

Conclusions and Recommendations

The widening, intensifying, speeding up, and growing impact of worldwide interconnectedness, better known as globalization is forcing countries and regions to develop strategies to enhance their economic position to better compete worldwide. Science, technology, engineering and

innovation play fundamental roles in the creation of wealth, economic development, and in the improvement of the quality of life for all citizens. Economic success in knowledge-based economies depends largely on the capabilities of people, credentialed in meaningful, consistent ways. Engineers are the central group in taking knowledge and generating output that results in sustainable economic growth. Thus, as a top hemispheric priority we need to address engineering education and quality assurance together through the building of strong, multi-stakeholders partnerships and a sustained commitment to developing the human talent necessary to compete in a globalized world.

Countries, with the help of industry must encourage innovative approaches to education and share success models. Such programs that involve experiential learning as well as those that promote and encourage entrepreneurial activities and risk taking must be encouraged. It cannot over-stressed that utilizing technology and research to solve economic, environmental, and social issues can provide vertical, multi-solution success in the hemisphere. The sharing of success models and solutions cannot be over-stressed.

It is recommended that countries and regions in the hemisphere consider developing partnerships to jointly address these challenges. Industry and government have to recognize the role of education, capacity building and innovation as the first and most important step in economic development. Members of the EFTA initiative could facilitate meetings and workshops to create awareness and urgency to act among the various stakeholders. Governments and multilateral funding organizations need to allocate funds to support development of strategies to address these issues.

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