ENGINEERING EDUCATION: MULTIDISCIPLINARY AND GLOBAL

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Abstract *¾ "Globalization" means that there are fewer resources and more competitors. It also defines new rules of the game. We must think locally and act globally. In the new Creative Economy, the most important force of the present change is the growing power of ideas. Ideas like germs and viruses are infectious. This is the exactly the university environment that must be protected, nurtured, and funded. Furthermore, synergy and ideas from multi-disciplinary activities must be encouraged by tearing down old divisions between colleges, schools, departments and alike. Global Engineering Education must prepare the future human resources for a rapidly changing environment, driven by the accelerated rate of technical innovation and opportunities; engagement in life-long learning; and collaboration across geographical, cultural and time domains. What is essential are teamwork, and creative problem solving skills. We are challenged by the fact that engineering knowledge becomes obsolete quickly making new professions appear and others disappear.*

Index Terms ¾ education, engineering, ideas, multidisciplinary, globalization.

1. INTRODUCTION: E-CHANGE

Information Technology (IT) or Information and Communication Technologies (ICT) have shortened effective time and distances, facilitating the exchange of products, ideas and services across geographical, cultural and time barriers. It is changing the world economy, society, and daily life. No country can ignore the benefits and opportunities to transform society that are available with the tools based on IT. For maximum benefit, adequate and appropriate policies in IT are essential requirements for productivity growth and development in the private and public sectors. This must take place with total participation from society in an equitable fashion. The risks of not reaching an equitable development can be counterproductive against the challenges of today.

What is change? One definition points to forces that cannot be controlled, forces that produce new businesses. Change comes in waves, originating with the new technologies, growth, and restructuring of the affected industries. Next come the changes in other businesses as they absorb those technologies. New businesses are started, and traditional practices are overthrown. Societies and governments try to adapt to shifts in the demands for goods and services, investment, skilled workers. All of us change our daily routines in work, recreation, and in the way we interact with others, as we adapt, willingly or under pressure, to the new opportunities. The struggle of daily business will be won by the people and organizations that adapt most successfully to the new world that is unfolding.

Awareness of change is one thing, but the ability to do something about it is quite another. Change identifies the management challenges we face in the new economy and explore good practices in greater detail. Briefly, we can identify three waves of technological change, the first being the Personal Computer (PC) wave, followed by the telecommunications wave, and presently we are in the net-sources wave. Several developing countries, the majority, have watched or are watching these opportunities pass by with few reacting to it. In addition, depending how these waves are added we can have negative or positive feedback. A second question is related to time, that is, when to react? Time is now! As many experts preach, it is better a poor decision than no decision at all.

For nations to compete successfully, it is imperative that they place at their disposal elements of IT. The degree of success that they experience in economic, social, and cultural development will be directly proportional to strategic investments in science, technology, information systems and human capital. Countries that do not adapt to the new technological paradigm will face difficulties trying to keep pace socially and economically with the rest of the world, and will be marginalized from the process of integration and globalization.

Positive or negative feedback, what should it be?

- Countries need a sound, aggressive, long-term, and flexible national policies in Science and Technology (S&T)
- Degree of success is directly proportional to strategic investments in science, technology, and information systems
- Countries that do not adapt to the technological explosion will not be able to compete

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- Need Center(s) of Excellence for S&T to enhance the capabilities of industry, government, health and educational institutions
- International cooperation
- New Leadership, Partnerships, alliances among industry, academia, government and international organizations
- Assured human and financial resources to sustain a systematic program in education of Science and Technology (S&T)
- Reform, adapt and enhance curricula considering the new tends in S&T to improve technological abilities. Education should be a life-long process and graduate programs should be increased.
- Increase capacity for Research and Development (R&D) and give incentives to the academia to promote national and international R&D projects
- Provide incentives and secure adequate funding and active involvement form private sector
- Enhance existing and create new infrastructures in Information and Communications Technology
- Make information universal and in real time

Clearly, IT is an effective indicator of the difference between developed and developing nations. More than ever, governments, industry, academia, and international organizations have a social responsibility to their citizens in reallocating resources to dedicate them to science and technology in order to rise standards in education, mobilize market forces and secure a better development for the new generations of the XXI century.

Like capital and labor, information is considered a vital factor to production. In the decade of 1980, the information sector amounted from 30-50% of GDP and employment in the developed countries of OECD. This sector will increase to 60% among the European Union countries. In the telecommunications context, this is considered a strategic investment to maintain and develop a competitive advantage at national, regional, and hemispheric levels. Countries and industries that do not have access to modern communications systems will not be able to participate effectively in the global economy, and will not fully develop economically or socially. This is a critical reality to those countries in the region that aspire to become developed (World Bank 1994).

In summary, an idea on the importance and necessity of IT for the development of a country and a region can be obtained by observing the following indicators. It is important to observe that the top 15% of the population are the beneficiaries of this technology, the info-rich or upper class.

TABLE I

Teledensity (telephone lines per 100 inhabitants):	
Industrialized countries	> 48 %
Countries of medium development	~ 10 %
Countries of lesser development	~ 1.5 %
World average	11.50%
Informatics Gap (PC's per 100 inhabitants)	
Industrialized countries	> 18 %
Countries of medium development	~ 2.3 %
Countries of lesser development	~ 0.01 %
Participation in the IT Market:	
U.S.A.	34.70%
Europe	29.30%
Japan	14.60%
Rest of the World	21.40%

2. E-Education: Case Study

"Globalization" means that there are fewer resources and more competitors. It also defines new rules of the game. We must think locally and act globally. In the new Creative Economy, the most important force of the present change is the growing power of ideas. In an economy based on ideas rather than physical capital, the potential for breakaway successes is far greater. That is because ideas, like germs and viruses, are infectious. This is the exactly the university environment that must be protected, nurtured, and funded. Furthermore, synergy and ideas from multi-disciplinary activities must be encouraged by tearing down old divisions between colleges, schools, departments and alike. The bad turn with ideas is that theft of intellectual property is lethal to innovation and funding.

Lets take the case of semiconductors; the push continues to achieve ever-smaller devices and increasing circuit density. Also, the use of individual molecules to fabricate device/circuit components (i.e., switches, wiring, etc.) has become attractive. Molecules are inherently nano-scale in size and highly uniform in nature. Organic and inorganic molecules can be synthesized with unique chemical, physical and biological properties that could be used to promote their self-assembly to one another and to specific surfaces, and to perform functions that can provide logic operations. It comes from the "bottom-up" in which the starting components are nano-scale in nature and are self-assembled into devices and circuits. The traditional semiconductor-based approach is from the "top-down",

starting with large wafers on which small components are fabricated and interconnected using lithography and other processing techniques. How do we transmit/acquire knowledge that involves Electrical Engineering, Ethics, Biology, and Business in the years spent in the University?

Initially, the training of an engineer in this discipline was mainly in chemistry and in special solid-state physics chapters. With the advent of the integrated circuit, the knowledge was expanded to include network theory and numeric methods for circuit simulation. Now, the level of complexity technologically achievable generates "systems-on-a-chip", requiring multidisciplinary knowledge, different from case to case, relying heavily on software and information technology for application development and design automation.

In this environment, a traditional University degree has a rapidly diminishing value, if it is limited to certifying that a graduate acquired, and was able to apply, a certain body of knowledge. Future graduates must have acquired the ability to learn continuously and rapidly, to function, and be productive, in continuously changing environments, to enter in, and take advantage of interactions with various groups, specialized in multiple disciplines, distributed across continents. The methods and style of teaching, the curriculum and the measurement methods must be changed. Some of these changes happen as a result of regulatory measures, such as the accreditation criteria for Universities in the USA, some others take place spontaneously, under social and economic pressures.

Recognizing the rapidly changes in the workplace of future engineers, ABET issued a series of proposed changes to the accreditation criteria. The spirit of the changes is to replace static rules, such as numbers of semester-credit hours for specific disciplines, with dynamic criteria, institutionalizing a process for continuous evolution and improvement, with the intent that the Academia will keep step with the rapidly changing realities in the working environment. Universities seeking accreditation must have in place a process by which educational objectives are defined and evaluated with the participation of academic and non-academic constituencies, the curriculum and teaching process are aligned with the objectives, and the results are periodically evaluated to improve program efficiency. Universities are thinking about their role in the society and the ways they organize and conduct their business. These institutions will undergo dramatic changes, paralleling the changes in the industry. Needless to say, the definition of a University is less related to a campus at a particular geographical location, and more a brand, featuring celebrity professors. To drive the process, not only Universities and Colleges, but also departments are installing Industrial Advisory Councils, involved in defining objectives and driving the continuous improvement process.

What about globalization? This is the new variable today and it also has a great impact on education. It is also bringing competition to the traditional university environment. Global Engineering Education must prepare the future human resources for a rapidly changing environment, driven by the accelerated rate of technical innovation and opportunities; engagement in life-long learning; and collaboration across geographical, cultural and time domains. What are essential now are teamwork, creative problem solving skills, and generation of ideas. We are being challenged by the fact that engineering knowledge becomes obsolete quickly making new professions appear and others disappear. Clearly, it is impossible to acquire all the skills and knowledge during the university years.

Can a university find a mechanism under which it can act locally but perform globally? Since its inception in 1990, the ISTEC Consortium has been a non-profit organization comprised of educational, research, and industrial institutions throughout the Americas and the Iberian Peninsula. The Consortium's mission is to foster scientific, engineering, and technology education, joint international research and development efforts among its members, and to provide a cost-effective vehicle for the application and transfer of technology. Currently ISTEC has a membership of almost 150 members in 25 countries in Ibero-America.

One of the four ISTEC Initiatives is "Los Libertadores". This initiative is a "common thread" effort that links together all of ISTEC's goals and objectives. It seeks to create a flexible network of telecommunication services (a hemispheric backbone for academic and R&D purposes), computing facilities, and teaching stations, known as "Centers of Excellence". Each country or region identifies needs that must be met, and then designs a Center of Excellence to address those needs. Each Center of Excellence brings together people from the private sector, the public sector, and the educational system to work together to find solutions to the problems of interest. Since those problems invariably have multiple facets, the solutions must involve multiple disciplines and the diverse contributions available from each sector. It is important that the Center be adapted to the needs of the country, identifying those areas that can be most beneficial for all the participants and finding effective methods of collaboration. Thus, the Center may not be a central building, but rather a network of capabilities distributed throughout an area. ISTEC is actively working with several governments, international funding agencies, and professional organizations to highlight the importance and critical nature of this effort in the economic, social, and cultural development of the nations in Ibero-America.

This IT Plan will support education, distance learning, research and development, intellectual property development, capital acquisition, project and program

incubation and will be a major source of revenue generation within the region, and to member universities, through the use of the Gateway/Portal by non-members, and others throughout Ibero-America who wish to access the databases and contacts within the region. It has captured the interest and enthusiasm of industry, financiers, entrepreneurs, foundations, and large-scale vendors who wish to contribute to the goals and objectives of the consortium. Among these major vendors, who are also members of ISTEC, are Microsoft, Sun Microsystems, Nortel Networks, Motorola, SCT, EpicEdge, Semio, Khoral Research, American Academy of Distance Education and Training (AADET) and SilverPlatter. Since massively improved telecommunication services within the region are a major aspect of the Los Libertadores project and the Portal, ISTEC has recently gained the support and interest of 4 major international telecom providers who wish to provide the major backbone(s) required for ISTEC to achieve its goals. Among these are IMPSAT, AMPATH, Merit and W4. In addition to these vendors, there are at least 2 financial groups who invest solely in telecommunication solutions who are interested in assisting ISTEC expand and develop a telecom footprint that will truly reach the masses within the Region. We have created a structured plan to incubate and capitalize future high-tech companies, which emanate from or through ISTEC academic members, as well as provide full assistance to successfully bring an idea from the laboratory into the commercial marketplace in a timely and efficient manner. This effort translates in the identification of new opportunities, talent, venture capital, management, technology assessment, IP protection, and marketing.

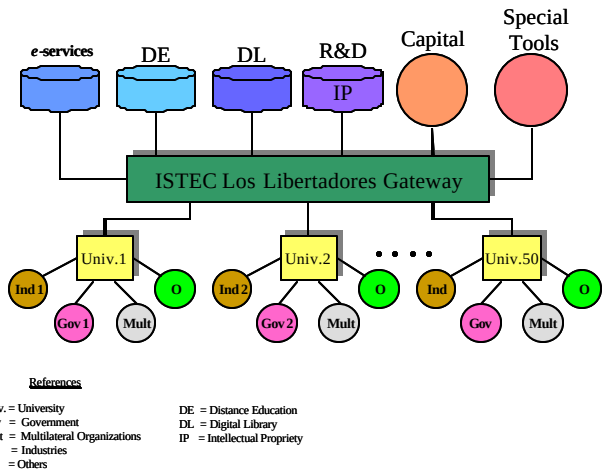

FIGURE. 1
ISTEC LOS LIBERTADORES GATEWAY PROJECT

We have been working closely with the Government of the Rio Grande do Sul, Brazil, in the creation of the Ibero-American Center for Advanced Electronics Technology (CEITEC) Center of Excellence. This Center brings together the Software, Electronics and Telecommunications industries. CEITEC will bring Ibero-America to a leading role in Microelectronics and nano-technology. Clearly, efforts built on the strength provided by Strategic Alliances among academia, industry, government agencies, and multilateral organizations will bring a region into the new highly competitive global economy.

At a local level, the Electrical and Computer Engineering Department (EECE) at the University of New Mexico, where the ISTEC Executive Office is hosted and the Consortium was founded, has decided to take innovative steps. The EECE department is currently developing the plan to launch in 2002 with several ISTEC academic members via distance education, graduate dual-degree programs. The areas currently identified are Wireless Communications, Software Engineering, and Microelectronics. The State of New Mexico with a Hispanic population of almost 50%, long and strong ties with Latin America and Spain, and hosting the largest scientific community in the world, because of the world-class national laboratories like Sandia and Los Alamos, is a natural environment to lead this type of effort.

3. E-People and their E-ideas

As was stated above, the most important force is the growing power of ideas, which forms the basis of the Creative Economy. Because of globalization and ideas, the definition of Intellectual Property (IP) and ownership is changing. The best that organizations can do is to create an environment that makes the best people want to stay. The advanced organizations have gotten so efficient at producing physical goods that most of the workforce has been freed to provide services or to produce abstract goods, that is, data, software, books, music, entertainment, advertising, that is, digital content. For instance, new competition for academia is coming from industry expanding into Distance Learning, creation of content and ideas. The bad turn is that theft of intellectual property is lethal to innovation. But overly strict enforcement of IP protections can dampen innovation as well as lazy IP owners. Organizations will have to strike a delicate balance: reward mechanisms, enforce patents, copyrights, trademarks, and non-compete clauses to preserve the incentives to create, but not so much that it suppresses competition.

Education is likely to become even more essential to prosperity in the future. The five fastest growing occupations are computer-related. Organizations facing a shortage of talent are likely to respond through a combination of training, exporting work offshore, and looking for ways to de-skill certain jobs. A chronic shortage of skilled help will be accompanied by a change in the mix of people in the workforce. The long-term trend toward earlier retirement has recently been reversed, and the ethnic

mix of the workforce is changing because of the influx of talented immigrants. That translates into more women and minorities in the workforce. To retain employees corporations will begin providing services that in other times were provided by the government (child and elder care). Employees will handle more work matters at home and more personal matters at work. Presently, Web-based education in the US is expected to grow from $197 million in 1997 to $6 billion in 2002. In Latin America and the Caribbean the exponential growth in Web-based education can also be seen, from almost $0 to $2.5 billion in year 2000. Clearly, education via the Web is great business but we must be careful. What now must be addressed are Quality Control issues in education in general. In addition, curricula reform is essential for development. Education must become a dynamic process instead of the current static model. Teamwork must be encouraged as well as working in multidisciplinary environments where opportunities are created, ideas generated and entrepreneurship fostered.

Lack of professionals translates into a dead weight for the economy. There are 850,000 potential job openings for IT workers in the US, and universities are producing 1/6th of what is needed. In Europe the number of potential IT workers is 1.2 million. The question to be asked then is: – where will industry turn to find the talent that is needed?

The globalization and integration of the world's markets will lead industries to search for this talent in other parts of the world, particularly in Latin America and the Caribbean. According to trends and studies conducted by American industries, the next decade points to Latin America and the Caribbean. The Latin America and the Caribbean markets are subject to this process of globalization, and in order to ensure more suitable development, these markets must be restructured. Various governments, educational institutions, research facilities, and industrial firms have great interest in establishing efforts of cooperation in technical fields. The identification of areas of common interest is also crucial for the investment in appropriate resources. In the next ten years the population of Latin America and the Caribbean will have a workforce of 120 million, another 120 million will be in schools, and the amount of people in poverty will be 140 million. Clearly, hands-on education, research, and technology transfer in state-of-the-art technology and science is critical for the success of Latin America and the Caribbean. More importantly, Latin America and the Caribbean must take advantage of their second chance to integrate among themselves. Like the US, Europe and Japan, LAC should launch efforts to increase academic and R&D resources, in order to develop and avoid an unnecessary technological dependence.

4. E-GOVERNMENTS AND E-POLICIES

Industries and societies that can make the transition to the new models of creating wealth and value will have greater chances of being successful in the new and volatile world market. A key concept there is that of community. Relations among businesses, businesses to consumers, are key as long as businesses learn to develop themselves among businesses communities that are on-line. These new relationships demand transparency, efficiency and effectiveness. Not only businesses are feeling the pressure of the digital age but the public sector as well.

Citizens from all over the world wish for an inexpensive, transparent and efficient government. The message is simple: is not enough to make small changes, it is necessary to reinvent it. What is needed is designing a network to improve its performance. Government programs can be distributed over the net and thus improve the quality and reduce costs. Access to public information must be made available to make governments more open, develop a truly participative democracy, regain the confidence of the citizens, and eliminate bureaucracy. Transparency, efficiency and effectiveness should be the new metrics for public organizations. Furthermore, positive effects can be amplified and negative consequences can be mitigated through a participative democracy, with a new sense of responsibility and consciousness, to the exercise of rights and duties, and to the education of all people. Transparency and universal access to information are necessary for interactive creativity and world solidarity. The technological and humanistic perspectives need to be reconciled. One of the great benefits of the Internet is that is the new equalizer; it democratizes, brings accountability, and eliminates intermediaries.

What does reinventing government mean? It refers to a change in quality imposed by the new reality. This new reality is based and determined by ICT, a new economy, reformed international policies, advances in world regionalizations, and a more globalized and interdependent world. Once again, this marks the characterization of the 21st century. This new governance brings agility, accountability, new mindset and leadership, more equity, and solidarity to bridge the digital divide. It must confront head-on the Digital Divide and turn it into Digital Opportunities with Information Technology (DD to DO IT!).

Some of the most significant and immediate courses of actions are up-to-date legislature to foster Science and Technology, protect intellectual property, provide investment incentives, systemic education reforms, facilitate and strengthen regional efforts that eventually will lead to the creation of economies of scale and integration. Latin America and the Caribbean region must create/strengthen its regional effort to present a competitive regional group to

other existing regional projects in today's competitive global economy. New dynamic collaboration, funding mechanisms, and agencies must be established. These agencies must promote project identification, partnering and funding to diversify and expand the capabilities of projects. They must be savvy to play with the new rules of the game called "strategic alliances". Strategic alliances (consortia) among academia, industry, government agencies, and international organizations are essential. If done correctly, these alliances will improve the profile of its members by increasing the quantity and quality of innovation, and participation and organization of international forums. These alliances are also important to promote and raise the awareness on the need to create/enhance ideas, sustainable policies and infrastructure. They also must be horizontal, multidisciplinary, reaching across boundaries, aggressive, fostering synergy, and effective, efficient and transparent. These alliances overcome the old model of public versus private.

How can the generation of ideas be fostered and sustained? Where can resources be found? With the appropriate and forward thinking legislature where IP is protected, critical for innovation, an unlimited number of possibilities are possible. We list below a number of possible sources.

- National and International Foundations
- National Agencies for International Development (USAID, JIKA, IICA)
- Venture Capital, Angels
- Multilateral Organizations
- Rotating Funds
- Fiduciary Funds
- Congressional Delegations, State and Federal Governments
- National Science Foundations
- Non-government Organizations
- Forums, Conferences, Tradeshows
- Alumni
- Strategic Alliances, Associations, Joint Ventures
- Industry Incentives
- Intellectual Property Protection
- Entrepreneurial Centers, Incubation
- Donations, Grants, Contracts, Credits, Conventional and non-conventional finance
- Community Funds
- National Laboratories
- Industry R&D Centers

5. CONCLUSIONS

Competition, markets and opportunities are now global in nature, even for the smallest Internet-based organization. Thus uncertainty, ambiguity and stress are feelings that are global too. New directions need to be identified so that the next historic period is one where promises have been implemented and dangers have been mitigated. Industry and Academia face together the challenges of a world in rapid change, in which the education of newer generation must respond rapidly to new demands. Cooperation is the only effective way to raise to the challenge.

The lesson for 21st century leaders is not just about clever applications of the latest software; it is also about culture and mind-set. The new organization is a learning organization that shares ideas across its many boundaries. Technology not only gives the ability to make an organization more efficient but it also provides the potential to spark transformative change and the Internet empowers such creativity and innovation. It flourishes if unconstrained by government bureaucracy and where there is vision and when businesses are freed from legacy business models. Innovation is independent of who you work for, what rank you have, and it comes from the best ideas. In this new millennium, new governance must confront head-on the Digital Divide and turn it into Digital Opportunities with Information Technology (DD to DO IT!).

Furthermore, by integrating regions through Science and Technology like the ISTEC Consortium in Ibero-America, we are placing this region in a leading role and provide a response to the challenges from other regions, as well as creating economies of scale to foster regional economic, social, and cultural development.

6. ACKNOWLEDGMENTS

The existence and growth of the Ibero-American Science and Technology Education Consortium is due to the individual efforts of the dedicated personnel at member institutions. These people continue to invest time and energy in the activities of the Consortium, knowing that this investment will result in improved opportunities for all Ibero-America.

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