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United Nations
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Regional Bureau for Science
in Latin America and the Caribbean

ISTIC-UNESCO-WFEO Workshop on Science, Engineering and Industry: Innovation for Sustainable Development

ISTIC-UNESCO-WFEO Workshop on Science, Engineering and Industry: Innovation for Sustainable Development

Pablo J. Bereciartua and

Guillermo A. Lemarchand (editors)

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Dedication ceremony of the ISTIC-UNESCO-WFEO Workshop on Science, Engineering and Industry: Innovation for Sustainable Development, Buenos Aires, October 16, 2010. From left to right: Jorge Grandi, Director of the UNESCO Regional Bureau for Science in Latin America and the Caribbean, Mario Telichevsky, President of the Argentine Union of Engineering Associations (UADI) and Conrado Bauer from the Argentine Engineering Centre (CAI).

"ISTIC-UNESCO-WFEO Workshop on Science, Engineering and Industry: Innovation for Sustainable Development"

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Prologue

In October 2010, the Science Policy and Sustainable Development (SC PSD) and Basic and Engineering Sciences (SC BES) programmes of the UNESCO Regional Bureau for Science in Latin America and the Caribbean, sponsored the organization of the ISTIC-UNESCO-WFEO Workshop on Science, Engineering and Industry, in association with the International Science, Technology and Innovation Centre for South-South Cooperation (ISTIC), the Argentine Engineering Centre (CAI), the Consejo Argentino de Relaciones Internacionales (CARI), Instituto Tecnológico de Buenos Aires (ITBA), the Argentine Union of Engineering Associations (UADI), the National Ministry of Education, National Ministry of Science, Technology and Productive Innovation and the National Ministry of Foreign Affairs of Argentina. This workshop was conceived as a pre-conference event of the World Engineering Congress: Argentina 2010, organized by the World Federation of Engineering Organizations (WFEO).

It is a great pleasure for me to present in this volume the proceedings of that very fruitful workshop.

Engineers are responsible for the development and innovation of a whole range of technologies that will be vital if we are to meet the challenges of climate change mitigation and adaptation and transition to a lower carbon economy. This includes such areas as agriculture and primary production, industrial development, housing, water supply and sanitation, energy, transportation and other aspects of infrastructure, especially the infrastructures that will be necessary to support increasing urban populations around the world. They also play a key role as a bridge between science and industry.

The applications of science, engineering, technology and innovation (SETI) work as an agent of industrial, economic and social development. The promotion of cooperation between SETI knowledge producers in universities and R&D institutions and users in industry and in the private sector is vital in the process of innovation and commercialization of R&D. This is especially important at a time of globalization and changing work organization in engineering, science and technology.

The overall goal of the UNESCO University-Industry Science Partnership Programme (UNISPAR) is the promotion of interactions between universities and the productive sector, through a number of UNESCO Chairs; particular attention is given to the setting-up of science and technology parks to promote S&T innovation and commercialisation of R&D, scientific and engineering education and continued professional training. A focus of the UNISPAR Programme is the production of information, learning and teaching materials, to promote human resource development, capacity building and institutional strengthening of innovation and development through cooperation between universities, research centres and industry in SETI.

Particularly, our Regional Bureau for Science in Latin America and the Caribbean, in collaboration with the Division of Science Policy and Sustainable Development in Paris, and other UNESCO field offices in the region, have promoted the organization of training courses for S&T Park leaders.

Recently, we have also been promoting the establishment of a strategic regional programme on science, technology and innovation for sustainable development, in cooperation with the Ministries of Science and Technology of Argentina and Brazil, CONACYT of Mexico and other S&T national agencies from different countries in LAC. The bases of this programme are reflected within the text of the Buenos Aires Regional Declaration, proclaimed in September 2009 and later presented at the Budapest IV World Science Forum.

In August 2010, we also launched our Science Policy Information Network (SPIN) platform (http://spin.unesco.org.uy). SPIN is a revolutionary cluster of databases equipped with powerful graphic and analytical tools that has been devised for decision-makers and specialists in science, technology and innovation (STI).

The new context of knowledge-based economies has highlighted the importance of human capital to sustain the countries' innovative dynamism. Education and capacity-building have come to be central to technological development strategies of countries and companies.

The major obstacles to innovation in LAC are: shortage of qualified staff, reduced access to financing innovation and incipient SETI public policies. According to a study recently published by our Regional Office for Science, out of the total graduates in the region, less than 15% pursue careers related to engineering or technology. This figure has remained constant for over 20 years and is negligible when compared with graduates in social and human sciences over the same period, representing 63% of graduates in Latin America and the Caribbean. The disciplinary distribution of Master and Doctoral degrees shows similar patterns.

On the other hand, Brazil generates over 70% of all Doctorates in LAC, followed by Mexico with more than 20%. Thus, two countries alone, with only 50% of the entire population of the region, account for more than 90% of the production of new PhDs in science and engineering. This should call planners and other decision makers to reflect on the urgent need to implement new tools and mechanisms to stimulate the production of new highly qualified human resources in science, engineering and technology.

These and other topics were discussed during the ISTIC-UNESCO-WFEO Workshop on Science, Engineering and Industry, held at the Argentine Engineering Centre in Buenos Aires. A selected group of one hundred government, academy and industry representatives, from almost 20 countries presented different points of view to develop a better strategy to foster the relationship between academy and industry in our developing countries.

It is with great satisfaction that we include these proceedings in our new collection "Science Policy Studies and Documents in LAC".

Jorge Grandi,

Director,
UNESCO Regional Bureau for Science
in Latin America and the Caribbean

Montevideo, February, 2011

Background

Since the middle of the 20th century the technological advances and experience gained during the Second Great World War have made possible a more careful and comprehensive view of human society and its relation with our planet.

Artificial satellites and new observation, measurement and information processing systems have shown with greater precision the physical deterioration of the Earth and its ecosystems and the increasing effects of the global warming process. Together with this and beyond, the changes in habits and human relations, and in the ways of life and systems of economic and political organization and operation, have been as or even more rapid and impressive. However, the complexity, fragility and ephemerality of human life seem to be maintaining the capacity of our human race to survive and adapt to the very changeable conditions that shape it, encouraged and protected (or, in many cases, attacked) by scientific advances, artistic and recreational developments, and philosophical and religious interpretations.

Within this disturbing and uncertain context and still with doubts about the confidence in our rationality, solidarity and charitable efforts, the United Nations Organization and its agencies have endeavored to set some guidelines to outline alternatives and choose possible ways towards a safer future development.

In this sense, immersed in a number of meetings and activities, it is worth mentioning the three major world summits organized by the United Nations: on “human environment” (Stockholm, 1972), on “environment and development” (Río de Janeiro, 1992) and on “sustainable development” (Johannesburg, 2002). This series of summits points out the evolution of ideas towards a better understanding of human and social aspects as key factors to assess the effectiveness of development, thus going beyond the unsuccessful confidence placed exclusively on economic growth as the indicator and main instrument to improve people’s living conditions worldwide. This explains the evolution towards the paradigm of “sustainable development”, adopted in Rio and ratified in Johannesburg, and it is in line with this concept that we are nowadays moving forwards, with the aim of achieving the “Millennium Development Goals”, decided upon in New York in 2000 by 189 world leaders who met together in an extraordinary meeting at the beginning of the third millennium.

According to the Rio Declaration, human beings are at the center of concern for sustainable development, entitled to a healthy and productive life in harmony with Nature (Principle 1). It also established that development should be achieved taking into account the fulfillment of human and environmental needs and requirements of present and future generations (Principle 3) and therefore environmental protection, that constitutes a relevant part in this development process, cannot be considered in isolation from it (Principle 4).

While “development” implies the improvement of physical, economic, cultural, ethical and spiritual conditions of all human beings and their societies, its “sustainable” achievement requires that the advances that take place should be long-lasting, that they should not suffer setbacks. “Sustainable development” requires the integration of economic growth and social and cultural betterment so as to eradicate poverty, ignorance, discriminations and inequalities present today among groups, countries and regions, trying to advance towards an equitable and peaceful world community, "healthy and productive, in harmony with the environment", as claimed at those international meetings.

Adhering to the aforementioned process and in compliance with what has been unanimously agreed by all the nations of the world, as the Workshop organizers we raised the following questions, particularly focusing on developing countries: what is the role science, engineering and industry play in today's scenario and; what should their joint work and interaction with each other be in order to contribute better to the sustainable development process and to the accomplishment of the millennium goals. This is a concern that has always been present, with its temporal variables, and that should be constantly reconsidered, updated and discussed in the light of the changing global scenario that impacts on the three aforementioned areas: science, engineering and industry, which are key actors since their activities extend throughout a wide sector of people's actions.

The reconsideration and discussion of these topics by distinguished scientists, engineers, businessmen and government authorities was the main purpose of organizing the Workshop on "Science, Engineering and Industry: Innovation for Sustainable Development". The date chosen, Saturday October 16, 2010, was decided upon in order to dsseminate the Workshop conclusions immediately, introducing them to an important and numerous audience of engineers who were to participate in the World Congress "Engineering 2010-Argentina" that was to be held on in Buenos Aires from 17 to 20 October, 2010, sponsored by WFEO.

The Workshop

The UNESCO Regional Bureau for Science in Latin America and the Caribbean, with headquarters in Montevideo, together with the Argentine Union of Engineering Associations (UADI) and the Argentine Engineering Centre (CAI), with headquarters in Buenos Aires, on behalf of the World Federation of Engineering Organizations (WFEO) were institutionally and executively responsible for the workshop organization. The meeting had the support and active participation of the International Centre for South-South Cooperation on Science, Technology and Innovation, under the auspices of UNESCO, with headquarters in Kuala Lumpur (Malaysia), of the Consejo Argentino de Relaciones Internacionales (CARI), the Technological Institute of Buenos Aires (ITBA) and three Ministries of the Argentine National Government: Foreign Affairs, International Trade and Worship (its special Group for Technological Issues, in Spanish GETEC); Science, Technology and Productive Innovation (its Secretary of Technological and Scientific Articulation and its Research Center CIDIVI); and Education (its Secretary of University Policies). Several universities and productive enterprises also contributed to the organization and holding of the Workshop. The Workshop Organizing Committee included Members of these institutions.

According to the organizers' proposals and to what has already been stated in section 1, it was decided that the objective of the Workshop would be to plan actions so as to encourage mutual cooperation between productive enterprise, and science, technology and engineering. This implied, among other aims, that of promoting the process of corporate acquisition of new and better technologies, those related to organization and selection as well as to goods and services production.

To accomplish these objectives, a priori it seemed advisable to encourage business managers to get accustomed to requiring, supporting and financing (or at less to get to know about) the scientific achievements and proposals obtained as contributions of research and development (R&D) processes. By analyzing the needs and possibilities of trading new systems, goods and services resulting from scientific and technological activities, they could then turn them into concrete works, i.e. productive innovations that would enhance the efficiency and competitiveness of their corporations. It was thus agreed that the workshop would aim at, on the one hand, encouraging businessmen to take an innovative and progressive attitude, and, on the other, within certain reasonable limits without restricting creativity, at adjusting research and development supply to demand, to the pursuit of solutions to issues and problems arising from the intention of improving production processes or of meeting people's needs and aspirations, responding to market possibilities and requirements.

To make this view of mutual cooperation possible, professional engineers should be required to consciously take on the duty of articulating the corresponding process. In this sense, they should stress their potential as promoters and actors of technological research and development in the sector of goods and services and they should also pass on to the business sector the advances of applied science and those inventions arising from their own productive search.

It was therefore clear that one of the objectives of the workshop was to discuss how to lead and encourage engineers' professional activities in order to enhance their role as a link between science and invention, and their applications as entrepreneurial innovations. This urges engineers to improve their knowledge, attitudes and technical and humanistic skills and to maintain themselves updated and informed, so as to act as solid facilitators of initiatives, and to participate, dialogue and proactively contribute to adjust the search, selection or generation, and adoption and production of new technologies, to business and market characteristics: their physical and environmental conditions, availability of inputs, the likely management and evolution capacity, idiosyncrasy and economic and social features of the place where engineers offer their proposals or projects. In general terms, insisting on this latter point, it is worth noting that, to compare and assess possible proposals, particularly those aimed at less developed communities or with very traditional life-styles, well-established processes should be found and analyzed carefully since their continuity, improvement or substitution should be subordinated to the circumstances of the need and willingness to change under consideration.

The purpose of the workshop has therefore been to discuss the aforementioned basic ideas and their application. To this aim, key international experts from the various sectors involved were invited to prepare white papers expounding experiences, ideas and proposals that could enhance and enrich the discussion and the conclusions to be reached.

Several months were necessary for the organization of the workshop and the production of white papers, their exchange among the authors and their distribution to those who would be taking part in the debate to ensure that participants were informed in advance of the ideas and proposals.

The full-day workshop took place in Buenos Aires, at the headquarters of CAI, on Saturday October 16, 2010, according to the scheduled program. Nearly sixty people participated in it, including the authors of white papers, the members of the organizing committee and some invited guests: well-known experts, government authorities, businessmen and a group of young engineers.

This publication comprises the content of the "Conclusions and Recommendations" of the workshop as well as the white papers which the debate focused on, the list of members of the Organizing Committee and the Workshop program. The event was successful and very inspiring for all its participants, encouraging the commitment of future action to disseminate its proposals and promote their effective accomplishment.

Conrado E. Bauer
Argentine Engineering Centre (CAI)
Buenos Aires, Argentina

A group of institutions behind the same goal

The origin of the Workshop can be traced back to two independent proposals. The first one was promoted by the Committee on Science and Technology of the Consejo Argentino de Relaciones Internacionales (CARI) and its chairman, Mario Mariscotti. During 2009 they started work trying to foster the link between industry and academy, in order to improve the quality of life in developing countries. To that end it was thought necessary to stimulate a stronger and more active participation of engineering, a creative and reality world shaping activity, to better link and motivate both industry and the national STI system, by letting the latter know the needs of industry for newer and better goods and services, and the former to get acquaintance with the advances in research and development and the potential uses of new technologies for new products and services. This idea was also shared by two distinguished members of the Ministry of Foreign Affairs in Argentina: Juan Eduardo Fleming, former Ambassador to Prague, and Raúl Dejean, representative of the Argentine Ministry of Foreign Affairs for the organization of the World Congress of Engineering 2010 – Argentina. In November 2009, the group contacted Conrado Bauer, the Academic Director of Engineering 2010, with the idea of holding a Workshop right before the beginning of the Congress in order to make it possible to communicate its conclusions. That same month, CARI under the leadership of Mario Mariscotti, held a meeting with the participation of several Argentine personalities. The conclusions made an excellent basis for the organization of our Workshop and also for Engineering 2010. Pablo J. Bereciartua who participated in this meeting would later become the Chairman of the Organizing Committee.

Independently, in October 2009, the UNESCO Regional Bureau for Science in Latin America and the Caribbean at Montevideo, under the leadership of Jorge Grandi, and through its regional programmes on Basic Science and Engineering (SC BES) and Science Policy and Sustainable Development (SC PSD), at that time under the responsibility of Guillermo A. Lemarchand, came up with a similar idea. They had proposed to the SC BES and SC PSD Divisions at UNESCO HQ in Paris, to organize a SC PSD Workshop on Engineering and Industry and a SC BES Graduate School, in coincidence with the World Congress Engineering 2010 – Argentina. Both activities would have an interesting impact on the promotion of engineering and innovation for sustainable development.

Finally, the two independent proposals coincided at the ISTIC Governing Board meeting held in Budapest in November 2009, within the IV World Science Forum, organized by UNESCO. Dato Lee Yee Cheong, WFEO past-president and ISTIC Chairman, Conrado Bauer, Jorge Grandi and Guillermo Lemarchand took part of that meeting. Given the common interest of ISTIC on these issues by promoting south-south co-operation within science, technology and innovation, and taking into account that they had planned to have their next board meeting in Buenos Aires together with the World Congress Engineering 2010, the board of ISTIC also approved the proposal to organize the workshop and committed their efforts to promote it.

In January 2010, Jorge Grandi, Director of UNESCO Regional Bureau for Science in Latin America and the Caribbean, sent a formal letter to the organizing committee of the World Congress Engineering 2010, proposing the organization of two parallel activities within the Congress: (1) A graduate regional school on engineering for sustainable development, and (2) a workshop to focus on the relations between science, engineering and industry. His letter emphasized that "the goal will be to promote the linkage among researchers, engineers and the industrial sector of Argentina and the region. To this purpose the regional programme on Science Policy and Sustainable Development will allocate funds for the workshop organization and will collaborate with logistic details".

A month later, Guillermo Lemarchand, SC BES and SC PSD Consultant from the UNESCO Regional Bureau for Science in LAC, visited Buenos Aires to meet with Luis Di Benedetto, President of CAI, Conrado E. Bauer, Pablo Bereciartua and other members of the local and international organizing committees of Engineering 2010. At that time, cooperation between UNESCO, ISTIC, CAI, WFEO was agreed on and soon afterwards the corresponding organizing committees for the Workshop and the Graduate School were established.

The workshop organizing committee comprised a distinguished and diverse group of people, representing science, engineering, governments and industry. Pablo Bereciartua, who was at that time, president of the Young Engineers Forum at Engineering 2010 was proposed as Chairman. The organizing committee carried out an intense and fruitful labor with several regular meetings, they selected a distinguish list of authors for the "white papers" and were able to obtain financial support from some major companies and institutions, among them ITBA, which functioned as the counterpart to the UNESCO Regional Bureau for Science in LAC and the Ministry of Science, Technology and Productive Innovation of Argentina, handling the administrative and financial side of the organization.

All these actions resulted in a successful Workshop that was held on October 16th, 2010. The workshop developed as planned, including some relevant contributions, outstanding participants, and special guests.

Workshop structure and functioning

To understand the key role that engineering plays in the promotion of sustainable innovation enabling economic, social and environmental development, with particular focus on less developed countries, we started our work with the identification of three lines of inquiry: 1) The role of science, engineering, private companies and governments in the promotion of applied R&D activities for the development of new products and services; 2) The role of engineers in the creation of technology-based new enterprises; and 3) Engineering education and its relation with industry's demands and requirements.

In addition to the preparatory meetings of the organizing committee, we developed an online platform with the specific purpose of enabling the remote participation of those members of the committee without the possibility of physically attending the meetings. Special attention was given to shaping a committee which would reflect a balanced composition representing science, engineering practice and education, government and industry.

A group of distinguished authors that could contribute with their experience and original ideas for the seminal papers were identified during the initial phases of the work. During the previous months, the selected "white papers" were published on the web for open discussion among the workshop participants. This approach was taken in order to increase the active exchange of ideas during the workshop itself.

The workshop was held during one day and split into two sessions. During the first session, all the papers were presented and some time was assigned for short questions and answers. During the afternoon a second session took place to draw the workshop's main conclusions and recommendations (see Appendix).

It is important to note that beyond the articles included in these proceedings, the workshop has greatly benefited from insightful presentations given by the following members of the ISTIC Governing Board: Jorge Yutronic from Chile; Edward Kofi Omane Boamah, Deputy Minister of Science and Technology of Ghana; Ahmad Zaidee from Malaysia; A. K. Poothia Inn from India; and a presentation by Johan Gorecki, SKYPE founder from Sweden. Their contributions were also enriching for the visions presented in these proceedings.

Main conclusions and recommendations

The conclusions and recommendations of the ISTIC-UNESCO-WFEO Workshop on Science, Engineering and Industry: Innovation for Sustainable Development, were included within the final declaration of the World Congress "Engineering 2010 – Argentina" and presented at the meetings of the Young Engineers Forum Chapter, the Engineering Education for Sustainable Development Chapter, and the Professional Engineering Practice Chapter. Last but not least, they were included within the general Conclusions of the Congress and, as such, read to all the participants of at the final ceremony by the World Federation of Engineering Organizations (WFEO) authorities. Both the Congress and the Workshop conclusions and recommendations are also included in this book.

In order to give further follow up to the conclusions and recommendations of this Workshop, it is necessary to rise the importance of these issues needs to be addressed within the framework of WFEO, ISTIC, UNESCO and institutions related with engineers globally. To this end it was proposed to bring to the attention of the WFEO General Assembly schedule for September 2011, the initiative of creating of a WFEO Committee on Science, Engineering and Innovation able to further the initial work carried out in Buenos Aires and to advance towards higher goals in the future.

Finally we want to emphasize the need for support some of the main conclusions and recommendations of this Workshops, such as: 1) to promote the participation of governments of less developed countries in order to consolidate stronger and more able National Innovation Systems (NIS), by reviewing institutional frameworks and linkages between public and private actors, and by giving particular attention to the role of engineers; 2) to promote higher levels of investment in applied technologies and engineering projects from international and multilateral banks and financial institutions with global impact; 3) to convey to the preparatory meetings for the UN "Rio + 20" Conference, to be held next 2012 in Brazil, the importance of stimulating productive innovation particularly in less and intermediate developed countries as a sustainable strategy for growth and development, paying particular attention to the differences with the more advanced countries, searching for valid alternatives to foster capital risk investments in technology-oriented projects. This idea could even be extended towards a proposal for developing a set of millennium goals for innovation in less developed countries.

Pablo J. Bereciartua and
Guillermo A. Lemarchand
Guest Editors

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The publication of this volume has been possible thanks to the proposal, enthusiasm and constant support of Jorge Grandi, Director of the UNESCO Regional Bureau for Science in Latin America and the Caribbean and Ernesto Fernández Polcuch, SC BES and SC PSD Senior Programme Specialist. We must also highlight the constant work, enthusiasm, professional input and help of Gabriela V. Bordoy, from the Escuela de Ingeniería y Gestión (EI+G) at the Instituto Tecnológico de Buenos Aires (ITBA). We also want to express our acknowledgements to Paula Santos, Assistant to the UNESCO Natural Sciences Programme, who collaborated in the various stages of the project. This volume could not have been published without two colleagues from the Publications Department of the UNESCO Bureau for Science in Latin America and the Caribbean: María Noel Pereyra who made an excellent job of designing and diagramming it, and the professional work done by Silvia Diez in correcting the texts.

ISTIC White Paper

Dato Ir. Lee Yee Cheong[1]

Abstract. A description of the main South-South, North-South-South cooperation activities in science, engineering and technology (SET) at international level is presented as well as the role of ISTIC. A proposal to develop a SET agenda for the forthcoming UN Rio+20 Summit is made.

Resumen. Se presenta una descripción de las principales actividades de cooperación Sur-Sur y Norte-Sur-Sur a nivel internacional en ciencia, ingeniería y tecnología (CIT), así como el papel de ISTIC. Se propone desarrollar una agenda CIT para la próxima Cumbre de las Naciones Unidas Río +20.

1. Introduction

The most critical and urgent challenges in this century are twofold: (i) combating global poverty and (ii) combating climate change. Merely confronting the environmental and ecological challenge is not sufficient to achieve sustainability on earth. We must at the same time address the equally urgent problem of global poverty.

According to Professor John Holdren, then Harvard now Science Advisor to US President Obama, world population in the dawn of this century exceeded 6.0 billion and could be classified in three categories: (i) the rich (0.8 billion),(ii) the transitional (1.2 billion), and (iii) the poor (4.0 billion); based of the criterion of GDP in US$ per capita (Purchasing Power Parity adjusted): (i) more than 16,000, (ii) 4000-16,000, and (iii) less than 4,000 respectively. The rich had nine times the wealth; eight times the energy consumption, and the eight times the carbon emission of the poor. 20% of the richest enjoyed 86% of the world consumption of energy and materials, whereas 20% of the poorest, only 1.3%. This glaring disparity resulted in (i) 1.3 billion lived in abject poverty on daily income of less than US $1.00; (ii) 3 billion had daily income of less than US$ 2.00; (iii) 800 million suffered from food insecurity; (iv) 50 million were HIV positive; (v) 1 billion suffered from water scarcity; and (vi) 2 billion had no access to commercial energy.

Looking ahead to 2050, it has been estimated by the UN that world population will reach 9-10 billion. Since the population of the developed world is already declining, most of the increase will occur in developing countries and in their urban slums. This daunting population increase will greatly aggravate the global challenges of climate change and poverty eradication.

Yet according to Professor Bill Clark of Harvard University, there had been much betterment of the human condition in the second half of the 20th century. He quotes the following statistics: (i) life expectancy at birth is up from 50 to 64 years; (ii) infant mortality is down from 13% to 6%, (iii) access to safe drinking water has improved from 35% to 65%, (iv) literacy rate is up from 50% to 70% , (v) GDP/capita in developing countries has increased from US $900 to US$2900, (vi) living standards of more than 3 billion people have improved.

1 Chairman, ISTIC Governing Board. E-mail: lyeec@pc.jaring.my

The above improvements can largely be attributed to advancements in Science, Engineering and Technology (SET). However, it must be acknowledged that SET have also contributed to the despoiling of the environment and to widening the wealth/poverty gap in the 20th Century, including the provision of military hardware for colonisation, two world wars, and wanton exploitation of world resources.

In the face of the great challenges confronting humankind in this century, SET must work closely together to reverse the current profligate use of the earth's limited resources and become the crucial leader in humankind's march to sustainability.

This is ISTIC's rationale for today's workshop on science, engineering and industry, representing technology. It must also be noted that ISTIC's vantage point is from the South.

2. Current Status of SET Collaboration

There is increasing recognition that investment in scientific research has not resulted in commensurate innovation in technological systems, products and services that benefit directly human society, especially in the developing world.

ISTIC is one such example. The second summit meeting of G77 + China in Doha, June 2005 urged UNESCO to develop and implement a programme for south-south cooperation in science and technology to realise the fruits of scientific research for social and economic development in South countries.

The newly established European Institute of Technology and Innovation (EIT) is another example. EIT is an Institute of the European Commission to promote creativity and innovation with an initial funding of 300 million Euro. With the promotion of 3-4 Knowledge Innovation Clusters in EU, funding will be increased to 3 billion Euro in 3 years' time.

Even the Academy of Sciences of the Developing World (TWAS), arguably the summit organisation of the scientific community in the developing world, is balancing science and technological innovation in its promotion of the Consortium of Science, Technology and Innovation for the South (COSTIS). TWAS was instrumental in getting the first G77 Summit in Havana, Cuba, April 2000 to establish COSTIS. COSTIS was launched by the meeting of the Ministers of Science and Technology of G77 in Rio de Janeiro, September 2006. Professor Mohamed H.A. Hassan, executive director of TWAS briefed the 30th Ministerial Meeting of the Ministers for Foreign Affairs of G77 in New York September 2006 on the rationale for COSTIS thus "COSTIS represents a unique blend of political power and scientific and technical expertise. COSTIS' main focus will be to promote science-based economic development in developing countries and encourage international cooperation in science and technology. COSTIS' flagship activity will be to convene periodic South-South forums on science, technology and innovation for development that address topics of critical concern, including the development of appropriate and affordable technologies for increasing access to safe drinking water, energy, and information and communication technologies. Many successful science-based economic development initiatives have been put in place in developing countries such as Brazil, China and India. As a result, we now have a great deal to learn from one another." Membership of COSTIS is proposed to be derived from three main streams: (i) Ministers of Science and Technology of G77; (ii) SET Academies, Academia and STI Research Institutions; and (iii) STI Industries and Corporations. Unfortunately due to various reasons, COSTIS is still work in progress. This also highlights the great difficulties in forming a top level troika of science, engineering and industry.

In my own experience as the President of the World Federation of Engineering Organisations (WFEO), a founding Board member of the Inter Academy Council (IAP) and as a role player in private sector in the electric power and energy arena, there are deeply entrenched barriers in effective SET collaboration.

Firstly, there exists an almost universal misconception that the necessary path to economic development in developing countries is through more emphasis and investment in science and scientific research. This view has consistently been championed by development banks and by the scientific communities in developing countries themselves. Postgraduate research departments of universities and basic scientific research institutes have been set up prematurely in developing countries with their graduates and researchers finding no local gainful employment and migrating to the developed world, aggravating the brain drain!

Secondly, though much has been made of science/industry or university/industry linkage advocacy and promotion, not least by UNESCO, the result in developing countries has been unsatisfactory. Scientists and academics with scientific bend are convinced that scientific R&D will automatically prosper industrial enterprises. Most have little or no firsthand experience as investors in such enterprises and cannot understand the deep concern of the industrialists and entrepreneurs about the bottom line. Such concern is fundamental to the survival of enterprises but is frequently taken by scientists as anti-progress conservatism. On the other hand, industrialists are wary and weary of research scientists asking more money for fundamental research with little development prospect.

Thirdly, in the public view, research and development are intertwined in that same order. There can be no development without research. The mass media has also played its part in attributing all SET successes to Science. When a rocket sends a satellite into orbit, it is a scientific success, but when it explodes, it is an engineering disaster! The scientific community bathes in such public acclaim and seldom acknowledges that a rocket shoot is basically an engineering and technological enterprise with heavy financial risks.

We in engineering have been promoting the fact that engineering is the crucial bridge between scientific discoveries and technological products and systems. Unfortunately engineering is too close to industry. Governments and global communities prefer to interact with technological industry rather than engineering organizations. Industry has greater clout and has greater impact on employment and wealth creation. At the other end of the bridge, engineering academies and organizations seldom reach out to scientific academies and organizations to get them closer to industry. It is a bridge without traffic!

In public perception, scientists claim the moral high ground. In most surveys amongst civil society and especially amongst the young, scientists almost always come top as the most admired professionals. Scientific academies and organizations receive much funding from philanthropic foundations and governments to promote their causes. The International Council for Science (ICSU) has the head office building given by the French government and received 500,000 Euro annually from the French government as well. ICSU received US$ 750,000 from the Packard Foundation for workshops and publications for the World Summit on Sustainable Development (WSSD) September-October 2002 Johannesburg.

TWAS receives annually 500,000 Euro from the Italian government. They are more frequently consulted by governments and policy makers. IAC was commissioned by then UN Secretary General Kofi Annan to carry out studies on global S&T capacity and on African agriculture. IAC was commissioned by UN Secretary General Ban Ki Moon this year to review the procedures of the Intergovernmental Panel on Climate Change (IPCC). It must be gratefully acknowledged that the impactful research and study by IPCC has been undertaken by scientists and their institutions. In my meeting with ICSU President Elect Nobel Laureate Dr. Lee Yuan Tseh in Penang Malaysia early September 2010, he informed me that ICSU is already raising money for participation in Rio+20 in 2012. He asked me whether WFEO is doing likewise.

Whatever our different and divergent interests, the great challenges confronting the world will be much more easily met if science, engineering and industry representing technology work more closely together than is hitherto the case. We must maximize our strengths and minimize our weaknesses in the service of humankind.

3. Conclusions

ISTIC hope that this workshop will delve into overcoming the abovementioned and other barriers to effective SET collaboration by making policy makers in intergovernmental organisations like the UN and UNESCO, national governments, the scientific and academic communities in developing countries, realize that scientific knowledge per say does not create wealth and employment. It is the application and commercialization of knowledge, scientific or otherwise, into useful devices, installations, services and systems through engineering and technological innovation that create wealth and employment. Therefore there must be much more balanced resource allocation between science, engineering and industry representing technology in line with national needs. National and International Governments and Agencies must endow the SET community with more resources to help them overcome the great challenges of this century.

The next great opportunity for SET community in worldwide outreach is the UN Rio+20 Summit meeting in Rio in 2012. It would be most fitting if this workshop in Buenos Aires can come up with the appropriate SET agenda for Rio+20.

Science, Technology, Engineering & Enterprise Nexus in LAC: An Innovation for a Sustainable Development Strategy

Jorge Grandi[1] and Guillermo A. Lemarchand[2]

Abstract. A description of the Basic and Engineering Sciences (SC BES) and Science Policy and Sustainable Development (SC PSD) programmes at the UNESCO Regional Bureau for Science in Latin America and the Caribbean is made. An account is presented of innovation patterns and the relationship between science, engineering and industry in LAC, based on a recent study performed by the UNESCO Montevideo Office, together with the results obtained with the SPIN Platform. The need for a regional STI strategic framework to focus on regional opportunities and threats is analysed.

Resumen. Se realiza una descripción de los programas de Ciencias Básicas e Ingeniería (SC BES) y de Política Científica y Desarrollo Sostenible (SC PSD) de la Oficina Regional de Ciencia de la UNESCO para América Latina y el Caribe. Basados en un reciente estudio de la Oficina de la UNESCO en Montevideo y de los resultados obtenidos con la plataforma SPIN, se presenta una descripción de los patrones de innovación y de la relación entre la ciencia, la ingeniería y la industria en ALC. Se analiza la necesidad de introducir un marco regional estratégico en CTI focalizado en las oportunidades y amenazas regionales.

1. Introduction

In 1999, the National Academy of Sciences of Córdoba (Argentina) organized a similar symposium on "Science, Technology and Enterprise" dedicated to the memory of an Argentine pioneer in STI policies, Jorge A. Sábato (Academia Nacional de Ciencias, 2000). A decade later we are discussing the same topic but this time focused on an element that was absent at the previous meeting: "sustainable development," which is now a key issue of the new social contract of science.

The UNESCO Regional Bureau for Science in Latin America and the Caribbean (LAC) through the Divisions of Basic and Engineering Sciences (SC BES) and Science Policy and Sustainable Development (SC PSD) undertook in 2009 a series of activities aimed at analysing progress made and results on science, technology and innovation policies achieved during the past decade and to propose future action towards fulfilling the agreements contained in the documents of the World Conference on Science (WCS), held in Budapest (Hungary) in June 1999.

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We were able to observe throughout the consultations carried out among the 33 Member States and 4 Associate Members of UNESCO in our region that many of the goals set out in the Budapest WCS were still far from being attained. Ten years after Budapest, the highest rate of generation and absorption of scientific and technological knowledge continues to be concentrated in the developed countries. This has contributed to increasing the technological gap between the latter and those countries that are still developing. It was also acknowledged that stepping up globalized relations and internationalization of scientific and technological production continues to be limited by restrictions in the circulation and dissemination of the knowledge produced.

Through the organization of two Regional Fora on STI Policies in LAC: Towards a new social contract of science, held respectively in Mexico and Buenos Aires, and a meeting of the drafting committee in Rio de Janeiro; the LAC Member States endorsed a Regional Declaration that was presented during the IV World Science Forum in Budapest (November, 2009). The Regional Declaration identified the strengths and weaknesses found in LAC and on this basis put forward a series of actions that should be developed in order to implement a regional strategic plan.

UNESCO's priority axis is the planning of strategic interventions to build up sustainable science and technology through the establishment of policy networks, the strengthening of research and the promotion of learning to guarantee a knowledge society. These networks will facilitate the exchange of information, data, experience and essential expertise to promote understanding of natural systems, preservation of biodiversity and a sustainable socio-economic development.

Some particular characteristics of our region such as: high rates of biodiversity loss, vulnerability to natural disasters, accelerated degradation of coastal and basin ecosystems, the strong contrasts in social imbalance within the region, the increased concentration of population in cities, which increases the demand of energy, worsening the loss of cultural identity, social exclusion and inequality, urge the design and establishment of a new type of innovation strategy based on long-term sustainability.

We need to move from narrow preoccupations with R&D to broader understandings of innovation systems – encompassing policy practices, institutional capabilities, organisational processes and social relations. There is acknowledgement of the crucial roles of a wider set of institutions and interactions, including laboratories, firms, funders, governments, international agencies and civil society organisations. This helps move us away from a simple model of technical progress, to an acceptance of a broader range of interactions behind innovation of all kinds –ranging across local and global scales (STEPS Centre, 2010).

Here on we will present a short analysis of the recent patterns of innovation behaviour in LAC and then we will present some actions taken by the UNESCO Regional Bureau for Science in Latin America and the Caribbean towards the design of a new STI regional strategic framework.

2 Innovation patterns in Latin America and the Caribbean

Within Latin America and the Caribbean (LAC), the pattern of productive specialization has remained linked to the so-called static comparative advantages (SCAs). For example, the Southern Cone continues to base its economy for the most part on activities that exploit natural resources in an intensive way, while Mexico and Central America are characterized by exporting labour-intensive goods, with low salaries and a strong presence of sweatshop-assembly lines. In the Caribbean, there is greater specialization in tourism and financial services. These patterns have remained in force at least over the past two decades.

Labour productivity, that is to say added value generated by each manufacturing industry worker, may be considered as an approximate measure of the sector's capacity to incorporate technological progress and improve the sector's efficiency.

Between 1980 and 2005 recently industrialized countries, such as South Korea and Singapore shortened the productivity gap with the Unites States which, in this case, represents the technological frontier. The gap remained constant with the first industrialize countries (the United Kingdom, Japan, France, Germany), while with LAC this gap grew. An ECLAC study (2008) observes the low dynamics of technological learning in Latin America and the Caribbean over the last decades. Labour productivity of this region has shown a downwards trend since the sixties. For example, at the end of the nineties in the four countries of LAC having the major development of science and technology (Argentina, Brazil, Chile and Mexico) the labour productivity gap with the United States had increased by 25% with respect to 1980. Although between 2002 and 2007 the region went through a period of relative bonanza, this difference in productivity increased another 10%. Labour productivity in countries such as Bolivia, Nicaragua and Honduras is 30 times less than in the United States.

Katz (2009) considers that in Latin America and the Caribbean, the concept of competitiveness is usually associated with the capacity of a country to maintain and increase the fraction of the international market on the basis of the application of lower production costs. This traditional model is totally inadequate in the context of the new techno-economic paradigm of the knowledge society. ECLAC studies (2008) show that the knowledge economy of the SCAs enabling lower costs and prices should be replaced by the concept of "dynamic comparative advantages" (DCAs) which generate new products, processes and markets. The new competitiveness pattern includes advantages based on knowledge, science and technology, while competitive advantages based on opportunities have considerably declined. For example the global demand for high technology goods has doubled over the past decade, and is now almost 25% of global trade.

The only way to promote dynamic comparative advantages (DCA) is through the development of innovation capacities that will ensure the participation and long-term permanence of the countries in international markets. In this way, the technological and welfare gap between developed and developing countries could be reduced.

Total-Factor Productivity (TFP) should be considered in any analysis attempting to interpret the influence in long-term evolution of science and technology on the productivity of nations (or regions). TFP is the difference between the growth rate of production and the weighted increase rate of the factors (labour, capital, etc.). TFP is a measure of the effect of scale economies, in which the total production grows more than proportionally on increasing the quantity of each productive factor (capital or labour). It is considered that technological improvement and increased efficiency are two of the variables that most contribute to TFP. Technological improvement generates positive externalities that indirectly contribute to increased production. It is interesting to observe the performance of TFP in LAC as compared to TFP in the rest of the world. Assigning a TFP index with a unitary value for the year 1960, figure 1 shows the evolution over time of TFP for LAC and for the rest of the world respectively. While as from the mid-seventies in the rest of the world TFP has grown in a parabolic manner, in LAC it has dropped in the same way. This fact has made the difference of TFP between LAC and the rest of the world increase in an almost linear manner. Over 46 years, this difference has increased by a factor of 250.

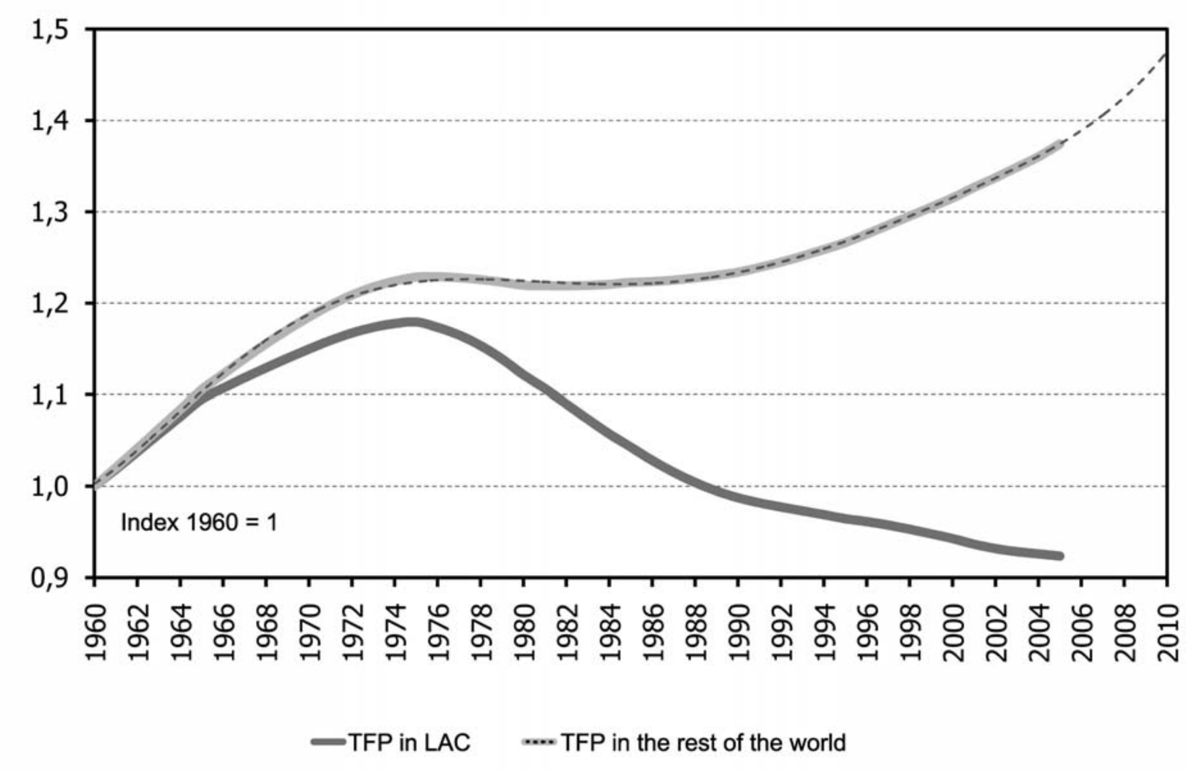

Figure 1: Evolution over time of the difference in Total-Factor Productivity (TFP) between LAC and the rest of the world between 1960 and 2006. Source: Based on Lemarchand (2010: 81) on the basis of data provided by IDB (Kawabata, 2009).

The manufacturing industry comprises very different productive sectors regarding skills and technological demands. One of the most usual classifications in recognizing inputs to the total added value of manufactured products is the identification of sectors making an intensive use of natural resources, labour and technology. Although it is true that in all industries techno-economic paradigms are reshaping the dynamics of production, this classification and its assumptions continue to be valid.

In most of the LAC economies the weight of the sectors making intensive use of technology is below 10 % of the added value generated in the manufacturing industry, while in industrialized countries these values are closer to 50% and in some extreme cases, reach 70%. Figure 2 represents, on the horizontal axis, manufactured products as a percentage of the total of exported products, versus the percentage of high technological content as compared to the total products manufactured and exported which is shown on the vertical axis. In this case the data provided by the World Development Indicators correspond to the year 2005. Here it is obvious that most of the countries of Latin America and the Caribbean are placed on the side showing the least proportion of manufactured products and less technological content. On the opposite side, we find the Philippines, Malta and Malaysia with the highest proportion of manufactured products of high technological content.

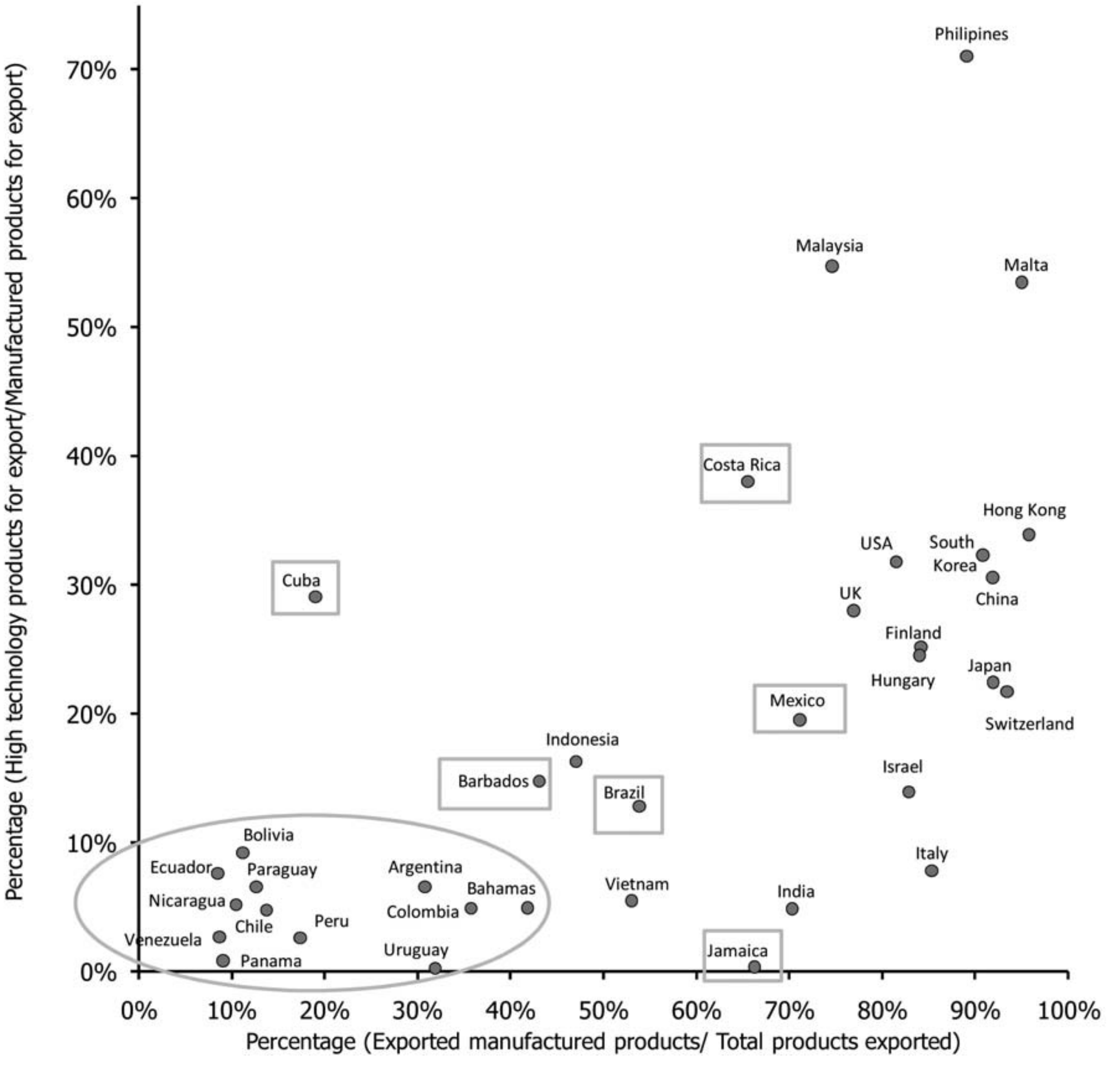

Figure 2: Level of the technological component in exports by country. The percentage of manufactured products of the total of exported products is represented on the horizontal axis. Products with high technological components as a percentage of the total exported manufactured products are represented on the vertical axis. Source: prepared and calculated by Lemarchand (2010: 83) based on source data published in World Development Indicators (2008).

The Costa Rican value, standing out considerably above the regional average, is mainly due to the establishment of major multinational computer corporations such as IBM, INTEL and HP. The arrival of these corporations, together with the establishment of various firms of local origin, has led to the generation of 100,000 workstations (approximately 4% of the EAP) over the last decade. In a survey made in 2005, it was observed that the companies related to ICT that developed over this period and were engaged in developing software, invested up to 12% of their budget in R&D activities. As can be seen from figure 2, these developments are geared to exports, in particular to the US, Mexico and Latin America. Case studies carried out show that the success of Costa Rica's technological policies is mainly based on the quality of its human resources. Most of these companies' professionals have some sort of university degree, although the proportion of workers with a postgraduate degree continues to be low. Some of the companies, such as INTEL have developed training programmes for primary and secondary school teachers to encourage mathematics and science teaching in schools and colleges, aimed at training students with an entrepreneurial profile.

The position occupied by Mexico in Figure 2 is mainly due to sweatshop-assembly lines, together with the application of special export regulations. In the case of Cuba its position is mainly justified by the production of goods and services of a biotechnological origin. Finally, the industrialization policy applied by Brazil over the last few decades has started to show results – it is slowly detaching itself from the exporting profile of the rest of the LAC countries. In particular a considerable degree of integration between industrial policies and incentives to technological innovation applied by this country may be observed.

Countries with a more specialized productive structure in sectors with a high use of technology both demand and disseminate more knowledge and therefore need to invest in strengthening R&D capacity. Industries such as the aero-spatial industry, electronics, pharmaceutics and biotechnology, among others, increasingly demand greater effort in scientific research, experimental development and technological innovation activities.

Over the past decade, national innovation surveys, aimed at measuring technological innovation processes in industry have taken place with a certain degree of periodicity in countries such as Argentina, Brazil, Chile, Colombia, Mexico and Uruguay. They have used the OECD's Oslo Manual and also the Bogota Manual, developed at the request of RICYT.

Within the conceptual framework of such studies, an innovative company is considered to be one that over the period of the survey has developed a new technological process or significantly improved one. Among the most significant results of the productive innovation processes, inter alia, are increased productivity, the opening up of new markets, the reduction of costs based on the introduction of new products and processes, improved quality of processes and products and the firm's increased dynamics. A comprehensive analysis of the surveys carried out in Latin America shows that 38% of the manufacturing firms can be regarded as innovative. The extremes are Chile with 32% and Uruguay with 43%. However, a detailed analysis of these figures shows that the firms centre their efforts on the purchase of new equipment, while investment in R&D tasks and the development of new endogenous technologies is totally secondary. This is the type of "adaptive or incremental innovation" profile, more than a radical one. Figure 3 shows in a schematic way, the type of innovation culture that predominates in LAC and the type of gap that still exists with developed countries.

The information generated in the above-mentioned surveys shows that in Chile the lack of qualified personnel is emphasized, while in most of the cases, reluctance to innovate arises from a culture of the short-term, based on the time it will take for investments in innovation to show results. On a sectoral level, what is most important is usually access to funding. For this purpose, Brazil, Chile and recently, Uruguay have developed a great variety of STI policy instruments stimulating innovation (Lemarchand, 2008).

Recently UNESCO Regional Bureau for Science in Latin America and the Caribbean launched a Science Policy Information Network (SPIN). The SPIN platform includes: a) A detailed inventory –in Spanish and English- describing the structure of each national system of science, technology and innovation in LAC, with a description of their organizational chart (divided in STI policy level, STI funding

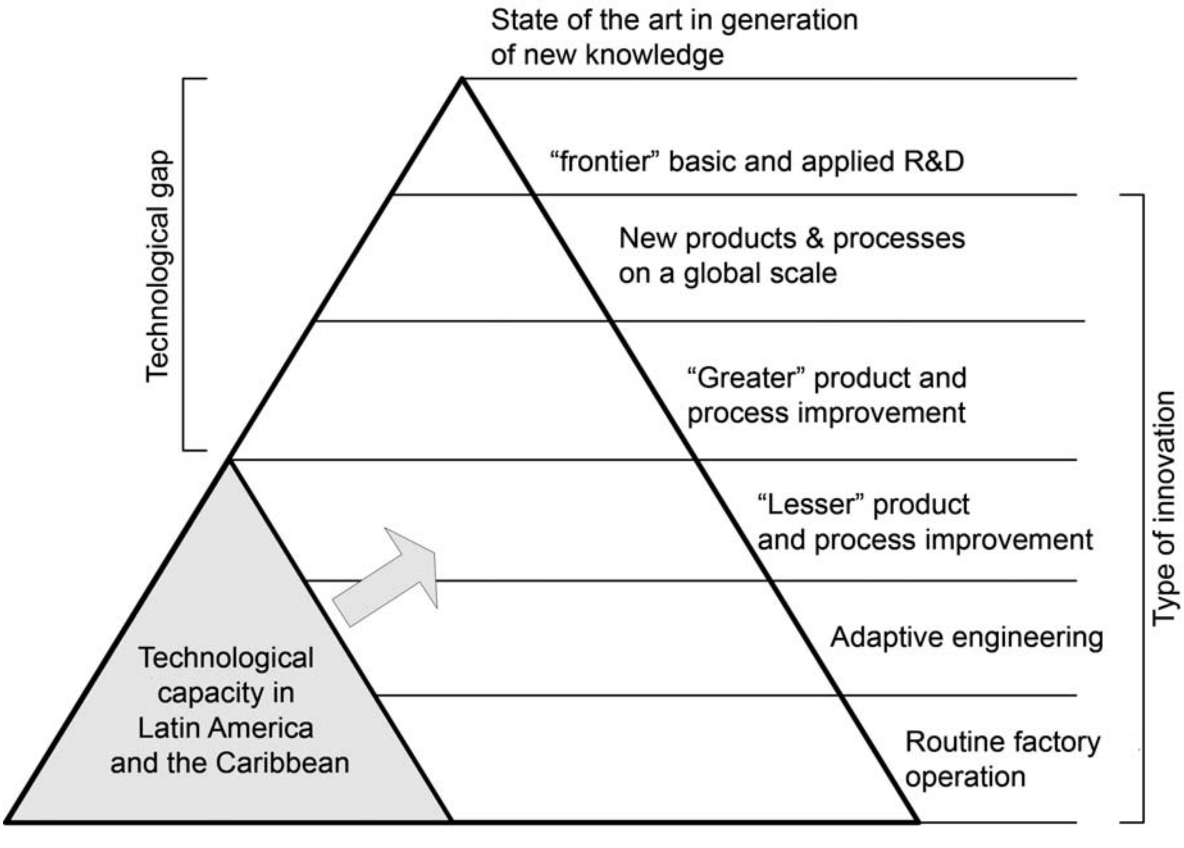

Figure 3: Type of innovation and technological gap characterizing firms in countries in LAC where innovation surveys have been carried out. Source: Based on Lemarchand (2010: 84).

level and STI implementation level), details of their main programmes, priorities, performance, planning and international cooperation strategies; b) A database with the all legal frameworks in science, technology and innovation for each country of the LAC region; c) An inventory with detailed descriptions of more than 900 different technical and financial science policy instruments implemented by the 33 Latin America and the Caribbean countries, classified into nine categories by objectives and strategic goals, in 11 categories by type of facility and in 18 categories by type of beneficiaries. The description of each policy instrument was normalized in a file providing information in 12 different dimensions; d) A database with 170 descriptions of national and international organizations and other non-governmental organizations, which provide technical and financial cooperation in science and technology. These institutions are classified by area and type of cooperation, geographic focus and type of beneficiary. The description of each institution was normalized in a file providing information in 12 different dimensions; e) A powerful geo-referenced analytic software (Stat Planet) –in Spanish and English- which includes more than 450 temporal series –some of them ranging from 1950 to the present time- with different groups of economic, social, governance, gender, environmental, ICT, science, technology, and innovation indicators. The Stat Planet software also enables the analytic estimation of correlations between pairs of indicators, studies of the evolution of different indicators over time, as well as approaching different regions or different countries of the world and allowing decision-makers and specialists to detect different patterns in the behaviour of the data; f) A digital library specializing in science, technology and innovation with over 800 titles produced by UNESCO and g) A tool that makes it possible to export a full country report –with the integration of the whole SPIN information- into a PDF file.

Figure 4 shows the distribution of STI policy instruments among a group of selected countries classified by different categories of goals such as: (a) Strengthening the production and creation of new indigenous scientific knowledge; (b) Strengthening the infrastructure of research laboratories in the public and private sector; (c) Capacity Building, education and training of specialized human capital for the production of new scientific knowledge, technological development, deployment of innovations in the productive sector and management of the knowledge society; (d) Strengthening the social appropriation of scientific knowledge and new technologies; (e) Development of strategic technological areas and new products and services niches with high added value; (f) Promotion and development of innovations in the production of goods and services; (g) Promotion of the creation of new technology-based companies; (h) Strengthening coordination and integration processes of the national system of science, technology and innovation and (i) Strengthening STI information services, technology foresight studies of high-value markets, develop business plans based on technology intensive products and services, building long-term STI scenarios and consulting services.

It is also interesting to note that among the 2000 companies which make the most important investments in R&D worldwide, only three are located in Latin America and the Caribbean (European Commission, 2006). They are all of Brazilian origin: the Brazilian Aeronautics Company (EMBRAER), the Vale

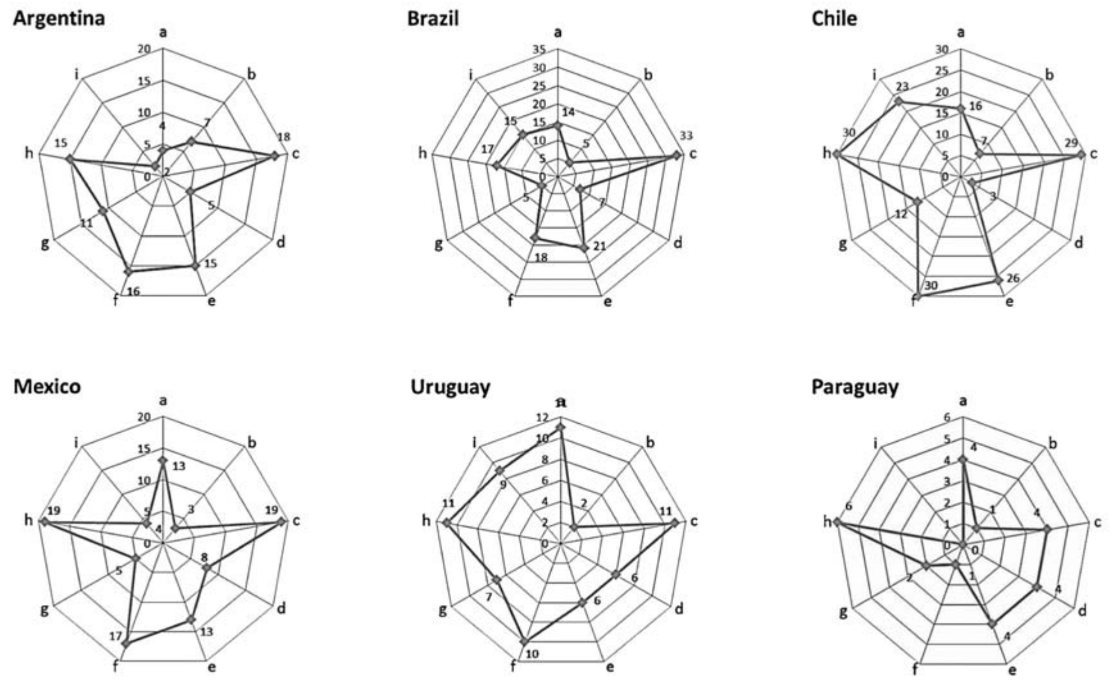

Figure 4: Distribution of national and international policy instruments to promote science, technology and innovation activities applied in a group of selected LAC countries. Source: Prepared by the authors based on information available at SPIN: http://spin.unesco.org.uy/ September, 2010, © UNESCO 2010.

do Rio Doce Company (CVRD), which belongs to the mining sector and Petróleo Brasileiro (PETROBRAS). This fact can be understood in the light of the way Brazil articulated their industrial policy with science and technology policy over the past few decades. For example, the Brazilian Society for the Advancement of Science (SBPC) was founded in 1948 and the National Scientific Research Council (CNPq) in 1951. It is remarkable that the first bill for the creation of a Ministry of Science and Technology in Brazil goes back to the year 1963, when this type of institutions did not exist in practically any other part of the world. Unfortunately, in 1964, the de facto government prevented this bill going through[1].

On the basis of the data from national innovation surveys in LAC, it may be noted that the companies of the region consider it scarcely important to establish cooperation links with R&D university centres. This fact has significant implications regarding innovation patterns observed in LAC. With very low budgets for R&D tasks within the companies, it is not usual for them to cooperate with external research centres. Those companies with an innovative tradition such as INVAP or BIOSIDUS in Argentina, EMBRAER or PETROBRAS in Brazil, PEMEX in Mexico; among others, are much more inclined to cooperate with foreign laboratories than those having a scant innovative tradition. For example, surveys on innovations show that 68% of Argentine companies that cooperate also innovate, in Brazil 94.5%, while in Uruguay, only 55% do so.

Between 2002 and 2006, the Brazilian pharmaceutical industry was granted 33 patents in the US, followed by Argentina and Cuba with 14 patents each. Furthermore, if we consider the number of patents related to electrical appliances during the same period, Mexico only obtained 13 patents, Brazil, 10 and Argentina, 3.

In its medium and long term plans for the science, technology and innovation sector, the region has started distinguishing the importance of developing endogenous qualifications in the new techno-economic paradigms, such as the ICTs, nanotechnology and biotechnology. These represent generic technologies that cross-cuttingly affect a wide range of productive sectors. However, the region has a structural weakness that places it in a secondary position with respect to other regions.

As an example, fixed telephony in the region has remained at a standstill over the past five years at a rate of close on 18% of the population. However, over the same period mobile telephony has risen from 19% to 80%. Also, between 2002 and 2008, the number of people with access to internet in LAC increased from 9% to 27% of the population. This marks a significant gap with the OECD countries where 68% of the population has access to internet.

The impact of the use of internet as a tool to increase the firms' productivity depends on the speed of connection and the human resources' capacity to implement appropriate technical solutions that optimize the circulation of information flow in productive, trading and management processes. In spite of the existing levels of connectivity in the region, there is a considerable gap with the developed countries regarding the productive harnessing of investments made in information and communication technologies (ICTs). This fact may be seen by comparing the impact on the improvement of corporate productivity as a function of investment made to renew ICTs.

[1] In 1963 the Brazilian CNPq presented a bill for the creation of a Ministry of Science and Technology to the Special Minister for the Administrative Reform, Deputy Amaral Peixoto. At that time, there were practically no institutions of the kind in any part of the world. Following the military coup in 1964, the idea of creating a Ministry of S&T was shelved for twenty years, until it was finally set up in 1985. The complete text of the original 1963 project may be found in: J. Lêite Lopes (1972), La ciencia y el dilema de América Latina: dependencia o liberación, Siglo XXI Argentina Editors: Buenos Aires, pages 209-221.

Some studies carried out by ECLAC (2008) show that firms usually apply information networks to manage accounting, financing, communications and human resource management. A smaller proportion, but in expansion, use ICTs for the automation of sales or product management. More innovative small and medium scale enterprises have started applying ICTs in production processes. This points to a trend towards learning and reorganizing internal and external production processes in order to achieve productive automation, optimizing physical and human resources.

Broad-band dissemination in LAC and the lowering of its relative costs represent major challenges. For example, in 2009, within the OECD countries the average lowest tariff for access to broadband had a cost of USD 19, while in countries such as Mexico and Argentina, this cost was USD 30, while in Chile and Uruguay the cost was USD 38. Regarding speed of access, the OECD countries have access to an average downloading of 17 Mbps (megabytes per second), while in the more advanced countries of Latin America and for the above mentioned tariffs; speed of downloading was at around 2 Mbps. It should be borne in mind that in general terms, speed of uploading is usually much slower, making entrepreneurial and government communication, trade and electronic government considerably difficult.

3 The need for a regional STI strategic framework to focus on regional opportunities and threats

To delve more deeply into the contents of the Regional Declaration prepared by LAC Member States during 2009, the next table presents a Strengths, Weaknesses, Opportunities and Threats (SWOT) diagram. This was built on the basis of literal citations from the text of the declaration. This analysis is very useful to define the explicit components of the strategic regional programme for science, technology and innovation.

The challenge facing the region is the establishment of a solid South-South cooperation programme to link and coordinate joint action among the various countries with the aim of providing solutions to the great threats and overcome weaknesses, with the support of strengths and focused on making appropriate use, through a strategic regional programme, of the opportunities identified by the participants during the two Regional Fora on STI Policies and the corresponding regional consultation process. This is a dynamic effort that requires a delicate work of harmonizing priorities among the different Member States. As a priority for its Science Policy and Sustainable Development Programme, the UNESCO Regional Bureau for Science in Latin America and the Caribbean will accompany this process. In fulfilment of its Mission, UNESCO will help to develop the capacities of its Member States, operating as a think tank, centre for the exchange of information, catalyser for international cooperation and policy-setting body.

The setting of agendas for science, technology and innovation policy and investment needs to be informed by an explicitly political consideration of innovation direction, distribution and diversity (STEPS Centre, 2010). After the two Regional Fora on STI policies in LAC it was established that the setting of innovation priorities at national and regional levels need reworking to enable diverse interests and new voices, including those of poorer and excluded people, to be involved in social inclusion debates.

Sagasti (2004) considers that strategies and policies for establishing endogenous science and technology base must fully incorporate into the design of a comprehensive development strategy for the country or –in our case-

Table: Science, technology and innovation SWOT analysis in LAC. The content was prepared based on the text of the Regional Declaration (2009). Source: Lemarchand (2010: 135).

Strengths	Opportunities
• One of the greatest biodiversities in the world. • The region within the global land area that constitutes the largest sink of CO_2. • One of the most dynamic food production regions in the world. • The region in the world with the best gender balance in distribution of S&T researchers, the percentage of women performing R&D activities in LAC was 46% in 2007. • A region where many countries have energy matrices with high potential for the use and development of clean and renewable energy sources;	• The development of a regional strategic framework to co-ordinate and optimize science, technology and innovation policies in LAC, promoting South-South cooperation and social inclusion. • To promote coordination and articulation among multi-lateral agencies responsible for STI activities, with each other and with their Member States, to support common and complementary strategies, avoid duplication, overlapping and institutional gaps. • The design and implementation of a new regional financial instrument for strategic areas in science, technology and innovation and mechanisms and bodies aimed at the linking and harmonization of such regional policies (with private sector participation). • The pooling of high-investment facilities and laboratories, to encourage the dissemination and share of information on STI within LAC countries, to promote the social appropriation of S&T, to work jointly in the development of potentialities and the solution of problems of regional and global scope. • To promote the creation of a Scientific and Technological South-South Regional Cooperation Centre (category 2) under the auspices of UNESCO, to facilitate the coordination and application of the regional strategic programme. • To promote mechanisms for encouraging a closer linkage between modern scientific knowledge and the ancestral knowledge of indigenous cultures in LAC, focusing on interdisciplinary projects related to biodiversity conservation, natural resources and energy management, understanding environmental disasters risks and mitigation of their effects, and other fields such as health, food production and sanitation.
Weaknesses	**Threats**
• One the highest loss rates of biodiversity due to the conversion of natural ecosystems. • Highest rates of increased agricultural frontiers along with secular problems of land tenure and accreditation of rural properties, which hinder conservation efforts and sustainable management of natural ecosystems. • A high level of vulnerability to natural disasters, particularly tropical cyclones in the Caribbean and Central America. • An accelerated degradation of coastal and watershed ecosystems that are increasingly threatened, among other causes, by increasing levels of pollution. • Environmental and economic vulnerability of Small Island Developing States (SIDS) within the Caribbean;	• Strong contrasts of imbalance, despite the decline in poverty and exclusion rates achieved in the last five years. • Increased concentration of population in cities boosts the demand for resources and energy, exacerbating the loss of cultural identity, marginalization and social inequality. • Scant skilled workforce, which limits the ability to address scientific, technological, social and economic development. • A disturbing weakness of STI local capacities to meet LAC needs. • Almost six decades of continuous drain of talents (brain drain) to the developed world.

the region. Furthermore, the cumulative process of building endogenous STI capabilities requires continuous and sustained efforts over a long time. The process must be selective, but without losing sight of unusual opportunities that may emerge while the international dimension must be explicitly considered in the design of strategies.

Our UNESCO Regional Bureau for Science is promoting the previous actions following the recommendations suggested by the Member States within the Regional Declaration. At the present time we are organizing subregional meetings (MERCOSUR+Chile, Andean Region, Central America+Mexico, Caribbean) towards the third Regional Forum on STI Policies in LAC that will be held in Brazil next year.

Some of the proposals we have received in these meetings include: (a) Design a regional "facility" for funding science, technology and innovation activities related with regional priorities; (b) Prepare foresight studies to determine the insertion of regional economies in the global arena and establish how the countries of the region should proceed to convert their economies into knowledge economies; (c) Promote the creation of an STI Regional South-South Cooperation Institute; (d) Expand the Science Policy Information Network (SPIN) at regional and global level; (e) Promote the pooling of installations and laboratories requiring high-investment, (f) Encourage the dissemination of scientific knowledge, the promotion of social appropriation of science and technology, (g) Promote the exchange of knowledge and scientific data, particularly among the countries of LAC and joint work in the solution of problems of regional and global interest.

Finally, we would like to close this article appealing to all those who are responsible for designing science, technology and innovation policies and also to scientists and academics, to focus our efforts to apply the knowledge derived from scientific and technological labour to the benefit of the quality of life of our inhabitants. We must start to consider, as pointed out in the Regional Declaration "that it is an ethical and strategic imperative for science, technology and innovation to integrate social inclusion as a cross-cutting dimension in its activities (STI&I)."

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New Paradigms for Sustainable Innovation in Less Developed Countries

Pablo J. Bereciartua[1]

Abstract. In this knowledge era of civilization, less developed countries (LDCs) will need to review and upgrade their capacities in order to generate more added value goods and services. Hopefully after a learning process out of a frustrating experience of the last decades, new technological possibilities available together with the need for more global prosperity might give rise to a technology revolution in the LDCs. This will have significant impacts for the economic, social and environmental living conditions worldwide and will also mean plenty of opportunities for both more advanced and LDCs countries. A necessary precondition however will be the promotion of the sustainable innovation paradigm on the international agenda. Engineering is at the core of innovation and should play a key role if this is going to happen.

Resumen. En esta era del conocimiento de la civilización, los países menos adelantados (PMA) necesitarán revisar y mejorar sus capacidades para generar más bienes y servicios de valor agregado. Después de la enseñanza adquirida, durante la frustrante experiencia de las últimas décadas, las nuevas posibilidades tecnológicas disponibles, junto con la necesidad de una mayor prosperidad mundial, podrían dar lugar a una revolución tecnológica en los PMA. Esto tendría significativos impactos económicos, sociales y ambientales para las condiciones de vida y significaría una amplia variedad de oportunidades tanto para los países más avanzados como para los PMA. Sin embargo, el requisito previo necesario será la promoción, en la agenda internacional, de un paradigma de innovación para el desarrollo sostenible. La ingeniería es la esencia de la innovación y debe desempeñar un papel clave si esto llega a suceder.

1. The Knowledge Economy for Less Developed Countries

Living in the Knowledge Era

We are living in the Knowledge Era, thus we cannot think of facing our current challenges with the same set of ideas and strategies that were successful in the past. The key issues driving economic growth (Jones, 1997), the values that represent newer and more creative generations (Florida, 2002), and the key role of education and technology for the wellbeing of the societies (De Ferrantis et al. 2003), are among some of the fundamental issues that are shaping our time and our opportunities. At present and possibly even more so in the future, the more competitive societies will be those that manage to reach regional and global markets with higher added value products and services. In other words, they will be the more innovating ones, those that are able to fulfill current and future needs in increasingly efficient manners. Studies focusing in different countries are already showing similar factors in order to explain successful economic

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performance (i.e. WEF Competitive Index). At the core of the more competitive economies is the capacity to dynamically develop innovation, but this is in fact related to other requirements such as infrastructure, good governance, healthy population, literacy, political stability, sound banking and financial structure.

Meanwhile economic growth models that where successful to explain economic performance of the more competitive countries during a large part of the twentieth century took technology capacity as exogenous, in other words as a given factor for the particular country, nowadays it is not possible to represent the more competitive countries by including technological development as an endogenous factor (Jones, 1997). The more competitive societies are those able to constantly learn, change and adapt in order to increase their level of innovation as reflected in the their capacity to commercialize technological added value through goods and services. However, this fact has progressively meant that human capital (i.e. education and skills) and the social capital (i.e. institutions quality and performance) are now at the center of the key factors to be competitive. This has evolved to a level making it possible to identify a new generation of creative people (Florida, 2002) that are driving the more competitive societies even to the point that it is possible to explain the prosperity of regions and cities as a result of how attractive they are in terms of social and environmental settings for those people and organizations.

Less Developed Countries (LDCs) and the predicted future

However not all countries are equally prepared to face the challenges of this new knowledge era. As an example, a comprehensive study focusing on various technologies, including biotechnology, nanotechnology - broadly defined, materials technology, and information technology, which have the potential for significant and dominant global impacts by 2020, has shown that for the most economically and scientifically advanced countries, a strong capacity to acquire and implement the full range of technology applications to address a diversity of problems and issues, meanwhile for the less economically and scientifically advanced countries, there are substantial disparities between their capacity to acquire and implement technology applications (Silberglitt et al. 2006).

The same study concludes that most probably by the year 2020 we will be facing: the technological preeminence of the scientifically advanced countries of North America, Western Europe, and Asia; the emergence of China and India as rising technological powers, with the scientifically proficient countries of Eastern Europe not far behind; a wide variation in technological capability among the scientifically developing countries of Southeast Asia and Latin America (Bereciartua and Miranda Santos, 2006, De Negri J.A., L.M. Turchi, 2007); a large scientific and technological gap between most of the countries of Africa, the Middle East, and Oceania and the rest of the world.

The central issue: the possibility of a technological revolution at the LDCs

As stated above the most probable scenarios do not show significant changes beyond some selected countries. In this framework a central issue to debate about is if there is a possibility of changing the most probable scenario in relation to the LDCs and what should be the agenda in order to reach a technological revolution with high economic, social and environmental impacts, and what might be potential actions to be included at local, regional and global level. We are talking about implementing an agenda to help close a gap in productivity in LDCs.

2. Engineering and Sustainable Innovation

Engineering understood as the art, skill and profession of acquiring and creatively applying scientific, mathematical, economic, social, and practical knowledge to design and build structures, machines, devices, systems, materials and processes that safely realize improvements to the lives of people, therefore to the extent that it is developed and implemented it will play a key role in promoting sustainable innovation in LDCs.

The need for a new approach: do not replicate the developed countries caveats

LDCs do not necessarily have to develop following the same paths that earlier followed more advanced countries. In fact for the most part LDCs are facing different critical economic, social and environmental issues, and furthermore they can learn from other's experiences and avoid going through the same kind of mistakes.

The LDCs should probably focus more of their efforts on adopting and adapting appropriate technologies to foster innovation in response to their specific conditions and also to solving some of their most pressing development issues. Although they do not have to be technology developers, they must have education (primarily, secondarily, universities) and skills to be able to identify appropriate technologies and to make use of them (i.e. in some cases developing countries benefit more from foreign R&D spillovers. This is particularly true for more sophisticated and cutting edge technologies.

However at the same time we are proposing that the LDCs have the chance to use those technologies and the available experiences in different ways and to solve their particular set of problems. In many cases the solution of those problems in newer ways (i.e. transportation and mobility, urban growth, environmental degradation, affordable health technologies, among others) will by itself contribute to create expanding markets (i.e. Prahalad's idea of the base of the pyramid).

A necessary condition for this to happen is to put together an institutional framework with public and private actors that result in a renewed agenda of policy priorities. One that addresses real world issues and that includes higher levels of innovation. This is possible at the core of the barriers for the technological revolution to take place at many LCDs.

Focusing in the pressing issues of the LDCs

The above-mentioned technological revolution can be a major factor in addressing global issues of rural economic development, public and environmental health, and resource use. However, the barriers discussed above must be addressed, and these are most challenging for the countries scientifically lagging behind, which have the greatest needs (Silberglitt et al. 2006). Here below are some examples of areas where there are plenty of possibilities to innovate from LDCs:

a. Alternative energy use. Many LDCs face a growing demand for energy, this represents an opportunity to increase the energy supply by implementing cleaner alternative energy sources such as hydraulic, wind, solar, and biomass power. Because of the lack of industrial development in many LDC's the new projects could benefit from designing innovative energy systems right from scratch including co-generation, smart grids, and recycling materials. These approaches will generate a net saving in CO^2 emissions and could attract financial support from international sources.

b. Current and future urban problems. As it is well documented, one of the main challenges of our times is the rapid growth of urban areas particularly in LDCs. This problem represents a concrete challenge for promoting sustainable innovation ranging from the territorial planning approach (i.e. smart territories) all the way to green technological solutions to key issues such as transportation and mobility (i.e. hybrid vehicles, smart grids), water and sanitation services (i.e. recycling, rainwater harvesting, or using ecosystem capacities – eco-hydrology), housing (i.e. using recycled materials, designing energy efficient housing), garbage management (i.e. generating biomass energy production). Instead of copying approaches from more developed countries, there is significant opportunity for developing new more suitable ones.

c. Increasing food production capacities. Feeding the growing population, mainly in LDCs is one of the most important economic opportunities of our time. LDCs can greatly benefit from the ongoing biotech revolution in this sense. Whereas this is already happening to a certain extent, there is room for a more active participation of the LDCs in developing the new technologies geared to their specific conditions.

d. Developing appropriate health technologies. With the above mentioned growing population and the progressive improvement of living conditions, there are great opportunities for developing health appropriate technologies to assist larger numbers of people in LDCs. There is room for major technological developments in this sense.

The sustainable dimension – adding social and environmental issues

By sustainable innovations we mean innovations that take into account not only the economic dimension (i.e. better technology to address needs and to improve productivity) but also the social and the environmental dimensions. In other words, this is a multi-criteria definition that is looking beyond short term growth and into long term development. A sustainable innovation must deliver a solution that will contribute to improve the social conditions and the environmental standards, in other words it must deliver a process of change in which the use of resources, the direction of investments, the orientation of technological development and institutional change are all in harmony and do not compromise both current and future possibilities to meet human needs and wishes.

3. Towards New Paradigms

Along to the ideas that have been expressed above, following are a set of proposals to renew the paradigms for fostering sustainable innovation in LDC'S:

Upgrading educational capacities at LDCs

The required level of human capital and skills will not be attained within the current state of affairs in most LDCs. In particular there is a need for scaling up the teaching effort in areas such as basic and applied science, engineering and technology at all levels of the educational system (primary and secondary schools, and technological universities).

There is some good news: the new generations are eager to learn and use newer technologies, and education technology is more readily available and the access to information can be reached in easier ways than before. But the bad news is that this type of education is not generally on the agenda of public institutions and governments in LDCs. This needs to be changed and the way to begin the change will imply: educating science and technology teachers, making technology available to all schools (i.e. with programs such as the one laptop per child initiative), relating the new knowledge and technology education, even at the basic levels, to the real world and concrete demands of the specific regions, promoting and recognizing a sustainable and innovative culture through concrete stimulus such as fellowships and financial aid to education. Another key issue is to promote the development of technology-oriented universities in LDCs. For example, in the case of Latin America there is a bias towards the social sciences and humanities over engineering and technology (De Ferrantis et al. 2003) which results in a deficit of educated professionals. This has already been shown to be a bottled neck after these recent years of economic growth in the region.

The need for National innovation systems (NISs) at LDCs

As stated above, there is great disparity in the state of development of NIS in LDCs. Thus NISs need to be promoted and strengthened with sufficient social visibility, recognition and resources; otherwise they cannot be required to play any key social role. It should be stressed that it is not only a matter of resources allocated from the public sector but more to do with the social and political relevance given to them. In fact a main difference between developed countries and LDCs is that NISs are deeply involved with the private sector and draw most of their financial resources from it. The NISs must collaborate with directing public and, to certain extent, private action towards promoting the development and implementation of sustainable innovations and to address some of the local challenges to improving living standards (i.e. with key attention to the link between industry and universities). There is growing literature with specific proposals to improve NISs in developing countries (Fagerberg and Srholec, 2005, De Ferrantis et al. 2003).

The "sustainable innovation millennium goals" for the international agenda

There is a need to create a stronger and more focused international agenda to include these issues. In particular to promote a new set of paradigms geared towards developing sustainable innovation in LDCs. They can be summarized in a new set of a sort of millennium goals around the objective of promoting sustainable innovation development and implementation in LDCs. This will imply a way of mobilizing financial resources towards improving local NISs which in turn will open up higher levels of worldwide prosperity benefiting developed and LDCs. These goals, together with elements to be implemented, such as relevant indexes to measure progress, could be for example developed and proposed at the Rio + 20 meeting to be held next year and discussed by a large number of institutions and governments.

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Engineering and Sustainable Development: Fostering Technology, Innovation and Production[1]

George Bugliarello[2]

Abstract. The relationship between engineering and sustainable development is examined. Some of the major societal obstacles and challenges for sustainable development are presented. A list of imperatives to achieve sustainable development is described.

Resumen. Se examina la relación entre el desarrollo sostenible y la ingeniería. Se presentan algunos de los obstáculos y desafíos societales para el desarrollo sostenible. Se describe una lista de los imperativos para alcanzar el desarrollo sostenible.

1. Introduction

Sustainable development is a complex and difficult goal. To successfully achieve it, engineering plays a pivotal role in fostering technology, innovation and production. It needs, however, to expand beyond its traditional focus on purely engineering artefacts to encompass in the design process factors in the social and biological domains that are integral parts of sustainable development.

To foster innovation, which is the essential ingredient for the creation of those new technologies, the engineering challenge is to maximize the understanding and adoption of the process of transformation of ideas into useful new products.

In production—the result of engineering and innovation, whether in manufacturing, agriculture or services—engineering is challenged to help make it happen on a sufficient scale and speed to respond to the needs of sustainable development.

A key concept to guide the development of technology and innovation, which in turn impacts on the development of production, is a matrix (the "biosoma-environmental matrix) encompassing the relations among technology ("machines"), society and biological organisms (humans and other organisms) as well as among the fundamental constituents of these three components—materials, energy, information and systems. The relationship offers many possibilities for trade-offs and syntheses, such as energy-materials-information or bio-materials-machine information, or bio-social-machine systems. Expansion of the matrix to include the environment and its basic components further enhances the frontiers of engineering design (fig. 1).

2. Today's Major Obstacles

Today, a basic knowledge of technology is diffused globally, through universities and technical schools, industry, and professional organizations. It involves, however, still too small a portion of the population, particularly in poorer developing countries. Often, furthermore, it is anchored to a narrow and rather rigid view of engineering that is not adequate for

[1] These thoughts are the author's and do not represent a position by the National Academy of Engineering.

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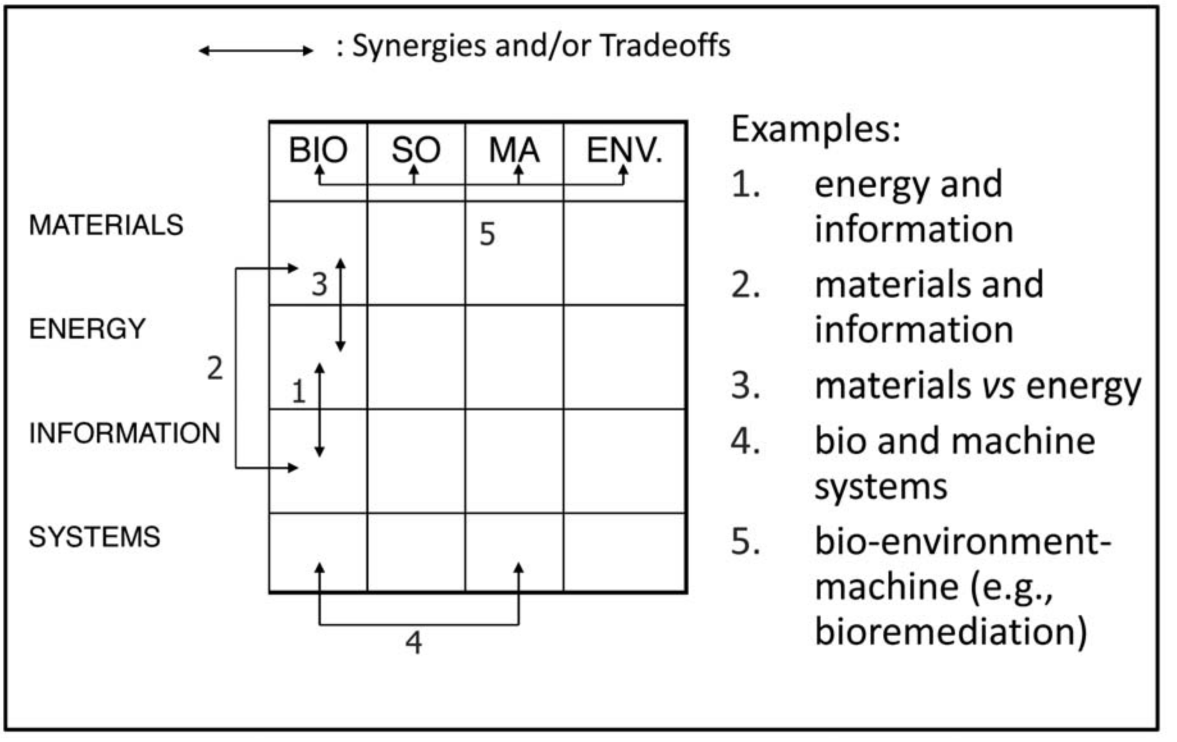

Figure 1. The Biosoma-Environmental Matrix

the needs of sustainable development. Neither is innovation sufficiently well understood in its complexity. To be successful, it needs to be rooted in a well educated and supportive community with an attractive quality of life, as in Bangalore or Silicon Valley; a robust infrastructure of universities and laboratories to generate and transmit knowledge and ideas and to help train innovators; comprehensive data centers; appropriate financial institutions, from banks to venture capital; government support through incentives, enlightened fiscal policies, encouragement of patents, etc; a generally supportive culture open to innovation; forward-looking industrial and business dynamics; a responsible and encouraging legal system. A frequent failure in efforts to promote innovation are attempts to create world class institutions in locations where these requirements cannot be met, as experience in several parts of the world shows they would be unlikely to live up to expectations.

Also, the essential requirements for a production of goods and services responsive to sustainable development needs are often overlooked, from easily accessible markets to the need for experienced and flexible managerial cadres, an abundant source of skilled workers, the existence of pertinent training organizations, networks of suppliers and infrastructural and logistic services, a supporting local community, a good working atmosphere, and an enterprise culture not at odds with the local culture. Not being in tune with that culture was a primary cause of the colossal failure of Henry Ford's Fordlandia—the ambitious development in the 1920s and 30s of a large industrial-agricultural complex in the Amazon. Today, the lack of a supporting environment and of an infrastructure of suppliers, services and logistic networks is seen as facilitating the migration of factories even from low labor cost locations.

If industry, agriculture and the service sector are to create products responsive to the needs of sustainable development in sufficient quantities, and doing it as efficiently, rapidly, affordably and cheaply as possible, technology, innovation and production must operate synergistically, both globally and locally. An essential underpinning to the process is a robust science and technology base that is also flexible enough to draw contributors from other parts of the world. It needs to be supported by enlightened educational policies to create a science and technology literate citizenship and work force, and to facilitate a widespread acceptance of innovation that encourages research and innovation in all socio-economic sectors and at all levels of the educational system.

In general, to be effective, science, engineering, technology, innovation and production policies greatly benefit from being interconnected in an overall national system of innovation, whether formal or informal, which today is usually more an aspiration (and, at that, far from universal) than a reality. The system should have specific centers of innovation. For less affluent nations, the centers could be international, shared with neighboring nations. Frequently, a particular weakness in a national system of innovation is the inability to link productively science to applications and production. This manifests itself, for instance, in the percent of national budget devoted to research and development and in how that R&D budget may be allocated between its two components.

A national system of innovation, at its best, implies setting clear goals, identifying its components, developing effective connections among them, identifying bottlenecks, devising appropriate metrics to assess performance, providing feedback loops and forecasting mechanisms to prepare for external or internal changes and respond to the fundamental requirements of sustainable development. In terms of performance, production of a large number of patents is useless if they are not utilized to advance innovation and production. Similarly, innovation and production do not benefit when the pursuit of science is disjointed from that of engineering, and from technology and production. What is desirable is a creative tension between science for science's sake and science for applications—ivory tower science versus Fraunhofer-like institutions.

3 Major Sustainable Development Challenges

The focus of the widely accepted Bruntland Commission's definition of sustainable development is the question of how can today's needs be met without compromising the ability of future generations to satisfy their needs. It requires in the first place making the point of today's needs, and forecasting what are likely to be those of future generations, ranging from essentials like food, water, and energy, to possible consequences of climate and geopolitical changes, changes of societal paradigms (e.g., networking, decentralization, conservation), and of demography, including the aging of the population of most developed nations and the youth explosion in developing nations, particularly some of the poorer ones.

4. Urban Sustainability

The rapid urbanization of the world population, with currently half of the population living in cities, demands more focus on cities, to address their needs for research, innovation and production, such as:

1. More effective city-agriculture connections, to respond to the growing demand for food as nations become more affluent and consume more today, now that the green revolution of the 1970s has run its course and the prospect of food production shortages is re-emerging. New

approaches are needed, such as the still controversial genetically modified foods.

2. Improved logistics for services (considering, e.g., that globally some one fourth of food goes to waste in transit and storage);
3. Innovations for appropriate environmentally acceptable urban manufacturing and services, to create jobs for the traditional working-age population, but also for today's emerging new young and aging populations;
4. Inter-urban collaboration to develop economies of scale and to create a larger market responsive to urban needs (e.g., for cars more suitable for congested cities);
5. Forecasting of needs, economic opportunities, threats, emergence of new technologies and new societal directions;
6. Reducing consumption through conservation, recycling and city mining.

5. Imperatives

All these challenges demand an involvement of engineering in new directions way beyond the traditional ones. Engineering needs a new paradigm and the embedding of engineering education in a new vision of today's role of the university in society and in promoting sustainable development.

In a necessary and urgent response to the immense new challenges of sustainable development engineering must actively espouse and encourage the fulfillment of a broad set of requirements: an infrastructure of national innovation systems; supporting government science, education and fiscal policies; an energetic pursuit of patents and their use; centers of production specializing in what a nation may have a clear advantage, but still maintaining a minimum of home production for security, keeping tabs on developments elsewhere; fostering co-location of enterprises and research laboratories for invention, innovation and production; an educational system designed to respond to the demands of development by ranging from today's equivalent of the French École Polytechnique to schools for technicians; avoiding wasting precious resources in creating universities to chase the chimera of "one of the top ten" in the world, while neglecting more specialized middle ranking institutions that can make a major contribution to economic and environmental sustainable development and quality of life.

In brief, the pursuit of sustainable development is an enormous enterprise that imposes a severe discipline on nations and demands unprecedented creativity and commitment from engineers.

In Memoriam: George Bugliarello (1927–2011)

Our colleague, Prof. George Bugliarello, an innovative engineer, outstanding researcher and educator, died on 18 February at age 83, in New York. His range of interests and expertise transcended many disciplines, including civil engineering, biomedical engineering, urban development, science policy, water resources, and environmental science. His vision of the role of science, innovation, and education, coupled with a passion for turning his vision into reality, is reflected in today's urban communities, forged through academic and industry interactions in ways that spur economic growth and societal well-being, while respecting the quality of human life and the environment.

Prof. Bugliarello was born in Trieste, Italy, in 1927 and after graduating from the University of Padua in 1951 went to the United States and earned master's and Ph.D. doctoral degrees in civil engineering at the University of Minnesota (1954) and the Massachusetts Institute of Technology (1959) respectively. His career path included a faculty position at Carnegie Mellon University and dean of engineering at the University of Illinois at Chicago (1969–1973), where he explored the seamless melding of biology, society, and machines, and coined the term "biosoma."

He served for 21 years (1973-1993) as president of the Polytechnic Institute of New York University. In 1989 he was one of the MetroTech, the first modern university industry research and technology park in the United States. Prof. Bugliarello's diverse research interests ranged from stochastic simulations of hydrodynamics to sustainable megacities in emerging countries.

While we were organizing the Workshop on "Science, Engineering, Industry" to be held in Buenos Aires, on October 16, 2010, we asked Prof. Bugliarello if it was possible for him to prepare a white paper and, furthermore, to come to Buenos Aires to participate in the Workshop. Fortunately for us: he accepted the invitation and he immediately prepared a significant paper for the Workshop, as well as others on "Megacities" and "Urban Sustainability", that were presented during the "World Congress and Exhibition: Engineering 2010". He came to Buenos Aires with Virginia, his dear wife, and stayed four days, participating actively in several activities. We had the pleasure of listening to his presentations, of sharing some moments with him, and of deeply appreciating his friendliness, outstanding general knowledge and extraordinary modesty. Prof. Bugliarello behaved as a simple man and not as the relevant world personality he indeed was. His example really impressed all of us.

Strategic Foresight as a tool for Enhancing Competitiveness of Brazilian Industrial Sectors

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Abstract. Brazil is expected to have a growing global presence in international markets and an increased influence on major international trade negotiations and agreements. The fact that the Brazilian macro-economic indicators are steadily good, together with more than 15 years of political stability, has created the indispensible conditions for the promotion of long term policies and programs to boost social-economic growth. This paper summarizes the main aspects of a strategic foresight methodology developed by the Center for Strategic Studies and Management of Science, Technology & Innovation (CGEE) to envision opportunities for, and avoid threats to, industrial sectors in the next fifteen years. The main results derived from of these studies provided guidelines to implement technological and non-technological agendas with the aim of maintaining or increasing industrial competitiveness at the sectors level. Sectors studied include: aeronautical, cosmetics, medical equipment, furniture, naval, leather and shoes, textiles, plastics, construction, automotive, and industrial automation, selected by the Brazilian Agency for Industrial Development – ABDI, according to objectives defined in the Brazilian industrial policy

Resumen. Se espera que Brasil tenga una creciente presencia global en los mercados internacionales y una mayor influencia en las principales negociaciones comerciales y acuerdos internacionales. El hecho de que los indicadores macroeconómicos de Brasil se mantuvieran de una manera constante en forma positiva, junto con más de 15 años de estabilidad política, ha creado las condiciones indispensables para la promoción de políticas a largo plazo y programas para impulsar el crecimiento económico-social. Este artículo resume los principales aspectos de una metodología de prospectiva estratégica, desarrollada por el Centro de Estudios Estratégicos y de Gestión de Ciencia, Tecnología e Innovación (CGEE), para detectar oportunidades y evitar las amenazas en los sectores industriales durante los próximos quince años. Los principales resultados derivados de estos estudios proporcionan directrices para aplicar los programas tecnológicos y no tecnológicos con el objetivo de mantener o aumentar la competitividad industrial a nivel de sectores. Los sectores estudiados son: aeronáutica, cosméticos, equipos médicos, muebles, navales, cuero y zapatos, textiles, plásticos, construcción, automotriz y automatización industrial. Los mismos fueron seleccionados por la Agencia Brasileña de Desarrollo Industrial (ABDI), de acuerdo a los objetivos definidos en las políticas industriales brasileñas.

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1. Introduction

Brazil (frequently referred as a member of the BRICS together with Russia, India, China and South Africa) is expected to have a growing global presence and influence on major international trade negotiations and agreements. In this context, no doubt that Brazil is a major global supplier of raw materials and agricultural goods (Goldman Sacks, 2003), and in the near future it has the potential to reap new opportunities in manufacturing and services while improving its industries' competitive position. The fact that Brazilian macro-economic indicators are steadily good together with more than 15 years of political stability have both created the necessary conditions for the promotion of long term policies and programs to boost social-economic growth, even after the global 2008 economic crisis. This has created the substrate for long term planning, incorporating components beyond short term economic pressures over production chains, allowing for integrated policies dealing with science and technology, human resources development and sustainability issues in which the preoccupation with environment impacts have greater relevance.

This paper summarizes the main aspects of a strategic foresight methodology developed by the Center for Strategic Studies and Management of Science, Technology & Innovation – CGEE (its acronym in Portuguese) to envision opportunities for, and avoid threats to, industrial sectors in the next fifteen years.

The mentioned methodology was created during the process of developing future studies for the Brazilian Agency for Industrial Development (ABDI), a non-profit organization with the mission to promote Brazilian technological and industrial development. The main results of these studies provided guidelines to implement technological and non-technological agendas with the aim of maintaining or increasing industrial competitiveness at the sectors level. Sectors studied include: aeronautical, cosmetics, medical equipments, furniture, naval, leather and shoes, textiles, plastics, construction, automotive, and industrial automation, selected by ABDI according to criteria established by the Brazilian industrial policy.

The basis of the sectorial strategic foresight method is the Roadmap Technique (Galvin, 2004), (Price, et al, 2004), (Laat, 2004), which was adapted by CGEE to accommodate the unique requirements of each one of the selected industrial sectors. The aeronautical sector, for exam ple, places a strong emphasis on technology, engineering and innovation; therefore, their foresight study involved an analysis of the significant developments that have been made in aeronautical science and technology. In contrast, the shoe sector's study focused on new technologies and processes that were emerging to acquire the best quality leather shoes, while being aware of environmental sustainability.

This paper starts with a brief description of concepts present in the industrial context of Brazil. Subsequently, the customization of the roadmap technique and its application for the industrial sectors are introduced. Finally, the paper presents the results, and examines the new challenges of introducing an implementation plan, based on the future study, which can increase the industrial sectors' competitiveness. The content of this paper focuses exclusively on the foresight methodology and the environment for its application. The detailed final outcomes of these studies are not shared, due to the sensitive nature of the information.

2. Program to enhance the competitiveness of Industrial Sectors

In contrast to the most dynamic emergent countries, Brazil hasn't followed the evolution of modern industrial sectors. Its average annual growth rate has been well below China and India and, in some industrial sectors, the industry is consolidating and being acquired by multinational corporations. Cumbersome regulations, a high-tax environment, administrative hassles, infrastructure bottlenecks, and skill gaps, collectively add unnecessary costs to doing business, and have driven investments out of the country. In response to this condition, the Brazilian Government announced a new Industrial Policy — Política de Desenvolvimento Produtivo or just PDP — which aims to recover accelerated economic growth and reduce overall financing and tax burdens currently withering several industrial sectors. The overall goal of PDP is to reorganize strategic sectors, enhance their competitiveness in the global market and increase foreign sales of value-added products.

The PDP was launched early in 2008 by the Brazilian government having ABDI as one of the main implementing agencies. Some guidelines were considered in choosing each industrial sector for the development of foresight studies. First, the sector had to have elements that would justify efforts to enhance its competitive position over the next fifteen years. For example, it would have to have a developed production system, a supply chain with some competitive advantage, and updated research and development initiatives that could support incremental and/or radical innovations. Leader associations and industrial communities also had to manifest their desire to embrace the study and to commit themselves in supporting the recommendations. Finally, each industrial sector selected had to be capable of creating positive synergy among government, science and technology institutions, universities, and industry. The main goal was to agree on implementing and maintaining the suggested strategic plans and subsequent technological agendas.

For each study, an Advisory Committee was formed to oversee the development of the strategy and make sure it could be implemented. ADBI carefully chose key stakeholders from each industrial sector to be part of the project. Representatives from the Ministry of Development, Industry and Foreign Trade (MDIC) and from the Brazilian Ministry of Science and Technology (MCT) and its agencies were also involved in each study.

The following main concepts were used in the whole process, to promote the collective understanding by stakeholders on the issues being debated and subsequent associated recommendations:

Strategic Foresight approaches and tools: customized solutions to incorporate the varied needs of each industry sector;

Innovation and sustainable development: "Innovation" more than just bringing new products to market but making sure they are sustainable;

Organizational x Sectorial learning: considers the focus of each sector, their management and shortcomings, and the capacity to implement strategic planning at a broader level;

Strategic Intelligence for Industrial sectors: reasoning, cognition, learning, memory and communication.

3. CGEE's approach to prospective sectoral studies

Over the course of one and a half years, during which CGEE developed these 10 studies, the strategic foresight approach was adjusted and improved to fully incorporate the variety of needs of each industrial sector. Language and visualization were taken into full attention, to present and communicate partial and final results.

The foresight approach used is based on the development of strategic and technological roadmaps, adapted to accommodate unique requirements for each sector. It encompasses four phases as follows: (a) Foresight Planning; (b) Understanding the Present (c) Futuring Perspectives; and (d) Prospecting Future Opportunities. The first, Foresight Planning, includes: (1) defining a work plan and foresight approach; and (2) negotiating with stakeholders the main focus of the study, in the understanding that same of the sectors are to ample to be taken in its entirety. Understanding the Present includes: (1) data-hunting and gathering; and (2) segmentation and prioritization. Futuring Perspectives includes: (1) scanning and detecting trends; and (2) developing vision and action goals. Finally, the fourth phase, Prospecting Future Opportunities, includes: (1) defining strategies and roadmaps; and (2) making recommendations.

An overview of CGEE's four-phase sectorial foresight method is shown in Figure 1. The tools and outputs of each phase are shown directly under their respective activities.

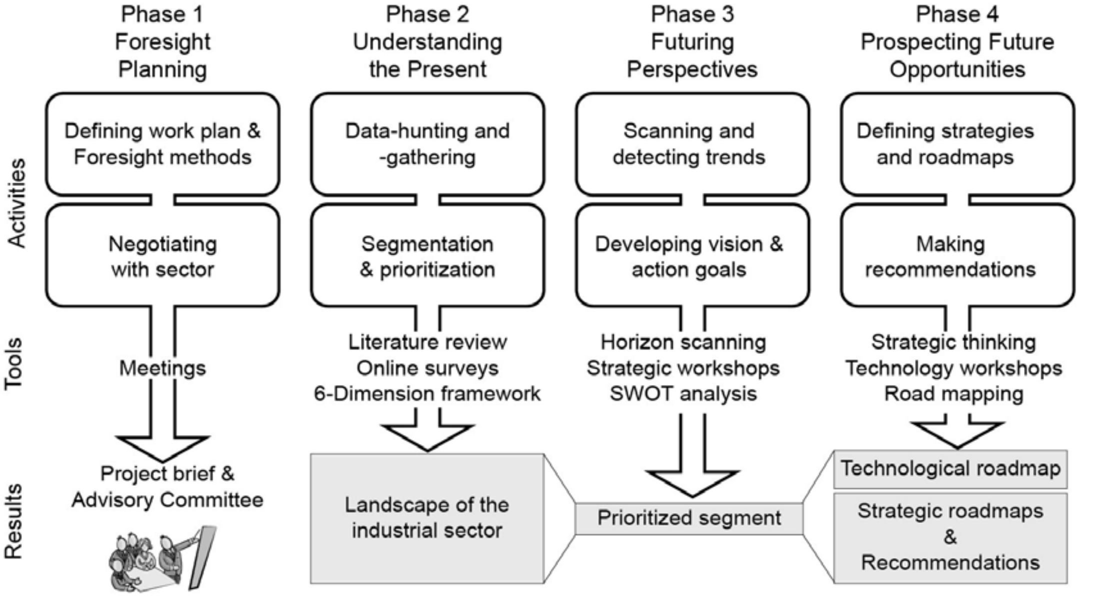

Figure 1: Overview of CGEE's four-phase sectorial foresight method.

Foresight Planning

In the Foresight Planning Phase, the work plan and the appropriate foresight tools are defined. One of the characteristics of CGEE's sectorial foresight method is the involvement and commitment of key decision makers in the foresight development and evaluation. The Brazilian Agency for Industrial Development — ABDI —had a major role in negotiating with the sector in this initial phase. As a political entity that navigates through all levels of the government, ABDI's major goal was to persuade, and gain commitments from, the Advisory Committee representatives who could help organize the sector while improving its global competitiveness. The Advisory Committee was in charge of advising and validating the outcomes of each phase of the study and had representatives from major industrial associations, leading companies, government institutions, universities and not-for-profit organizations, in addition to CGEE's and ABDI's representatives

Understanding the Present

The second phase of CGEE's strategic foresight methodology is about describing current characteristics and market dynamics of the industrial sector in as much detail as possible. Understanding the present is a key element to creating a common vision of the future, one which portrays a place where the industrial sector wants to be in years ahead, particularly in issues of technology and productivity development.

Data-hunting and -gathering are the two major activities in this phase, to describe the landscape of each industrial sector by looking at issues around technological advancements and socio-economic developments. The focus of the study at this phase must be already well defined or the information collected could be overwhelming and lead to inconsistent, faulty recommendations. A structured gathering plan is therefore the basis of this stage. The frame of reference shown in Figure 2 illustrates the plan of action used in the future studies.

Two important views are described above: 1) the industry sector's view, which includes the sources that describe the industrial sector; and 2) the general view, which positions the sector in the global economy through the lenses of specific dimensions. The data-hunting and gathering starts with the identification of complete, relevant, and reliable data sources. Even though this appears to be an easy part of the prospective study, there are several challenges in choosing data sources in Brazil, including outdated statistics and a lack of reliable secondary sources. If data gathering is not well structured, and if it does not cover a broad range of sources, it can compromise the foresight results and give faulty information for decision-makers.

As the first technical stage of the foresight exercise, information-hunting and gathering has to be complete in its scope and detail. It should provide a 360 degree view of data sources that can establish a good foundation for the decision-making process. For example, when considering global competition, it is important to examine new players, main competitors around the world, leading companies, Brazilian companies, and Brazil's environment for business, such as Brazil's productive chain structure. A good amount of detail will guarantee an adequate confidence level for the foresight exercise.

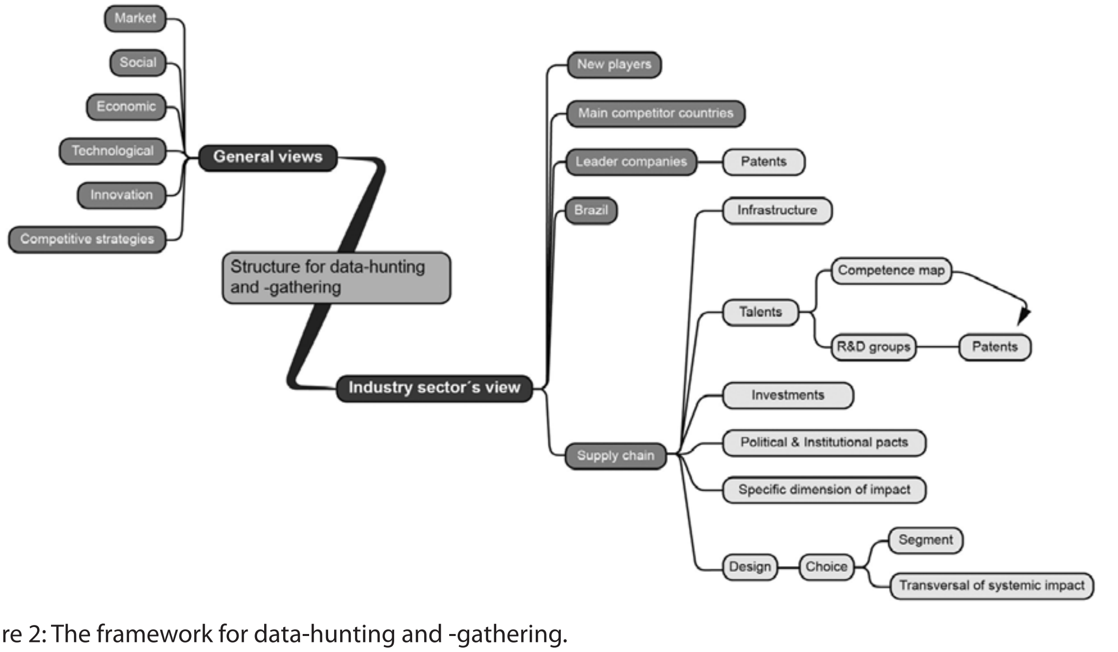

Figure 2: The framework for data-hunting and -gathering.

The interpretation of the information collected is organized based on key dimensions, which should have a strategic connection with the foresight exercises. For industrial sectors, the following dimensions were used: Market, Technological, Investment, Human Resources, Infra-structure, and Political and Institutional Environment. The amount of data allocated to each dimension is sufficient when it provides enough evidence about the industry's sector and its market segments. The last step in this phase is the prioritization of market segments to gain focus for the next phase. Focusing on one or two product lines or technologies helps to optimize research resources and align the sector's stakeholders towards one single goal.

Futuring Perspectives

The purpose of the Futuring Perspectives phase is to gain foresight intelligence for the decision-making process. This phase is similar to doing a puzzle, where pieces of information are carefully selected and then put back together to see how they fit. By choosing the right pieces of information, untangling conflicts, and exploring solutions, a vision of the future and an action plan can be created.

A vision of the future is the first element that needs to be defined by each sector. The vision statement is used to determine how to achieve the sector's chosen goal. It describes a desirable place in which manufacturing is better positioned and, at the same time, challenges existing assumptions about the future, thereby motivating stakeholders to plan and act accordingly (Hines and Bishop, 2007). Elaborating a vision of the future statement with a large group of representatives from an industrial sector is, however, extremely complex and risky.

As the first strategic decision, the visions created in CGEE's future studies were based on certain types of information, including: key findings from the landscape description; latest trends; strengths, weaknesses, opportunities and threats of each sector. The vision statement was made of keywords arranged into a few paragraphs; its composition involved a lot of discussion. For the purpose of illustrating the end result of this exercise, a vision of the future for the cosmetic sector is presented below:

> "To be a world class industry enhancing the quality of life and prosperity of the community through sustainable development, and contributing for the economic growth of Brazil."

The risk involved in creating a long-term vision is that it may point the industrial sector in a direction that may be completely different from how events really unfold. As the world is unpredictable and single-point forecasting is doomed, the future will almost certainly not occur as it is described in a vision statement. With the vision, however, executives from each sector are better served in preparing for a place where they want to be. If the major goal is to be more competitive in fifteen years, then they will need to take it seriously in the coming years and continue monitoring the environment for leading changes that will likely suggest adjustments to their vision and goals.

As described earlier, the competitiveness of industrial sectors is driven by innovation and sustainable development. Consequently, the foresight puzzle could be assembled in many ways. The approach used in ABDI's sectorial prospective studies was to consult experts about market and technology drivers. Experts from industry, academy, and government were grouped in panel sessions to assess market conditions and to formulate action goals targeted towards realizing the industrial sector's vision of the future.

The action goals created were short sentences made up of major tasks that have the potential to organize the industrial sector's environment and produce positive synergies. The sentences originated from SWOT (Strength, Weakness, Opportunities and Threats) analyses and were organized based on the market dimension so that the discussion could focus on how to increase the competitiveness of the sector. The analysis provided indicators for the overall strategy which were the main pieces of the development of the strategic roadmaps for each sector. Table 1 shows examples of broad action goal from some of the sectors.

Table 1. Examples of Action Goals

Action Goals	Sector
"Incorporate strategic technologies (i.e. nanotechnology and biotechnology) into the production chain."	Leather and Shoe
"Expand marketshare of commercial aircrafts and parts in the national and world markets."	Aeronautics
"Gain marketshare in the high tear segment in the United States and european countries."	Furniture

Among all studies, there were recurring goals addressing current challenges. These include, for example, the need to significantly improve the performance of Brazilian educational systems and to directly invest in logistical infrastructure.

The final product of this step is a set of action goals capable of improving the industrial sector's position. The exercise of formulating action goals reveals that the market dimension can be used to link together goals from other dimensions and to promote synergies among them. The last step is to create a communication piece in the form of a roadmap, in order to align high-level strategies, development efforts, market needs, and technology development plans.

Prospecting Future Opportunities

The last phase of CGEE's sectorial foresight method is the development of strategic and technological roadmaps based on the opportunities identified in earlier phases (Camarinha-Matos, 2004), (Rezgui, and Zarli, 2002). Roadmaps are generally used in the context of enterprises, within well-defined boundaries of the enterprise's environment of influence. In the case of creating a roadmap for several industrial sectors, the concept has to be adapted to include fewer control variables. In other words, in order to take advantage of the synergetic connections among macro objectives towards a vision of some industrial sectors, it has been necessary to review and be in control of few variables. This adaptation introduces the risk of losing influences among macro objectives that structure the synergy of the strategy. In order to mitigate this risk, the next phase is an elaboration of a detailed plan to be executed, introducing as many variables as necessary so as to produce a business plan for specific industrial sectors.

The basic elements of the strategic roadmap were the action goals from the market dimension defined in the previous phase. These action goals had to be interpreted in terms of their impact on the competitive system of each sector, and redefined as directives or macro strategies towards the vision of the future. The starting point for this exercise was to define a set of criteria for selecting and evaluating opportunity areas that would guide the development of strategic roadmaps. Extracting objective criteria from subjective judgments included filtering questions, such as:

- Are there fundamental and critical aspects that could either introduce or maintain the industrial sector in the competitive environment?
- Does the strategy stimulate a competitive environment to organize the industrial sector for global competition?

- Could specific technologies renew opportunities for the industrial sector, in order to maintain or improve its competitiveness?

The directives provide the structure for several possible routes into the future. Each route is formed in the following manner:

- Define the main strategy for increasing global competitiveness;
- Organize the strategy into directives which have individual and systemic impact on the industrial sector's competitiveness;
- Structure each proposition into a route, organized by macro actions from strategic objectives considering all dimensions of the foresight exercise. This organization must be complete, clear, and objective for the purpose of creating synergies and fostering a strong ability for the industrial sector to attain the vision of the future.

4. The Challenges of Conducting the adapted Foresight Approach

The foresight exercises provide insights and opportunity areas to enhance the competitiveness of the industrial sectors considered. The roadmap development for each industrial sector was a major challenge. The nature and maturity of each sector required a flexible approach towards the foresight methodology and differed on two major levels:

- At the organizational level: Some industrial sectors have fragmented production chains, while others sectors are organized with major stakeholders and well defined roles that follow the processing of commodities from the extraction of raw materials through the production of finished goods. In the first case, the strategy focused more on action goals to solve short term problems and less on future opportunities. With a fragile production chain, the strategic roadmaps mainly suggested ways to organize the industrial sector as a first step towards increasing competitiveness. In the case of the organized sectors with mature production chains, the strategic roadmaps were designed to include and leverage global competition, focusing more on action goals for middle and long term gains.
- At the technological level: The focus of the vision will impact the recommendations for new technologies and how they may be used to improve the competitiveness of each industrial sector. For a set of industrial sectors, the vision of the future was broad enough to include strategies in technology and innovation that ranged from investments in specific research areas to the promotion of certification and testing. For other sectors, where the visions included a specific market segment or a product line, the strategies were more focused and supported by a technology roadmap in addition to the strategic roadmap.

Another challenge to conducting ABDI's sectorial future studies is associated with managing the various key stakeholders of the project. In some cases, stakeholders took action before the results of the strategic plan were officially released. As the stakeholders helped to elaborate action goals, they were also planning strategies related to their own interests. This behavior can damage the strategy to enhance the industrial sector's competitiveness as programs are implemented without leveraging the synergies. Future studies should consider this fact to avoid disruptions of strategies and actions.

5. Final results and conclusion

These foresight studies for multiple sectors of the Brazilian industry provided several results regarding processes and products. The first result relates to the ability to change perceptions and motivate stakeholders to proactively implement recommendations. Most of the industrial sectors chosen for the foresight exercises initially lack competitiveness, but their leaders are open to the need to enhance their position with respect to global competition. For this reason, industrial stakeholders initially showed disbelief in any government support and were unable to evaluate the potential of the study. This behavior changed during the elaboration of the roadmaps and, as they got involved, they started to promote the political environment to implement the foresight recommendations. This was considered to be an excellent result of the foresight exercise, because the main stakeholders have periodically declared the relevance and importance of each foresight study.

In terms of final deliverables, the strategic roadmaps and recommendations were applied as the basis for the new Industrial Policy (PDP). This result surpassed the initial expectations, and hopefully will support stakeholders with the best decision-making process under a clear, objective, and complete executive plan to enhance the competitiveness of several industrial sectors. Associated publications are available at www.abdi.com.br .

As for methodology adaptation, successful implementation of the foresight approach depends on the reasoning used to structure it and the ability to represent global aspects. In ABDI's sectorial future studies experience, the best results were driven primarily by the constraints of the present, and less by the recommendations of the specific methods applied. It seems paradoxical, because the long-term goals are competitiveness and innovation; why, then, would the current constraints drive the methodology? One simple reason is that the desired future is created based on the present conditions and necessities; and depends on current plans and actions. The desire to be more competitive is not sufficient to guarantee a successful future. In most industrial sectors of Brazil, there are many basic necessities that need to be fulfilled before the sector can implement programs and actions to achieve a desired future. Planning, in cases like this, is a dynamic process, and had to be done by finding a balance between the present necessities and future desires, and generating intermediate demands.

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Engineering Education in a Complex World

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Abstract. The present requirements of engineering education are analyzed. The need for systemic educational capability is enhanced. Together with the clear adjustment of contents in line with the evolution of science and technology, it is concluded that engineering education should be complemented by other specific and generic skills. It is observed that the education of engineers needs new interpersonal and systemic capabilities to cope with and solve complex problems, with listening skills, reflection, dialogue, integration and conceptual modeling of hard and soft variables, so as to contribute, from their profession, to the accomplishment of sustainable development.

Resumen. Se analizan los actuales requerimientos sobre la educación en ingeniería. Se resalta la creciente necesidad de competencias educativas sistémicas. Junto con un claro ajuste de contenidos siguiendo la evolución de la ciencia y la tecnología, se concluye que la educación en ingeniería debe ser complementada por otras competencias más específicas y genéricas. Se observa que la educación del ingeniero necesita nuevas competencias interpersonales y sistémicas para hacer frente y resolver problemas complejos, con capacidades de escuchar, reflexionar, dialogar, integrar y conceptualizar variables duras y blandas, con el fin de contribuir, desde su profesión, al logro de un desarrollo sostenible.

1. The Present World

From the contextual point of view, we are living one of the deepest transformations that humanity has ever experienced along its history. The speed and impact of changes has caused a crisis in human beings' capacity to adapt.

The personal de-estructuring we observe in modern society is partly explained by the quick mutations of contexts that demand more rapid "personal adjustments" than the ones our minds are prepared for; and partly by the lack of educational experiences to live in changing, turbulent and unpredictable environments. We have been educated for predictability.

Today organizational life –of corporations and institutions– is appealing for adaptive rhythms that are not compatible with natural life.

This transformation from the competitive to the global world and from the global to the virtual took place in only two decades. This is a true temporal "shock".

While it took more than a millennium to move from the agricultural to the industrial era, only one century was necessary to advance from the industrial to the competitive global period and only a decade to the virtual era.

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2. From the Global to the Virtual Era

With the development of Internet, the penetration of e-business, the design of advanced telecommunication networks, satellite and broad-band telecommunications, the world shifted from dependency to interdependency and, in a short time, to instantaneity.

This transformation came together with an important change: the predominance of knowledge as a variable of competitiveness. Today nobody discusses the full and wide determination to increase the domain of access to information: this is a social necessary but not a sufficient condition. Today, more than ever, we understand that the challenge is how to use this information to generate new knowledge.

We are in the era of the intangible, where the intellectual capital is the source of value of any society, community or company. There is an enhancement of a source of value which is the Human Capital and therefore the excellence of engineers' education, both technically and socially, is the condition that ensures their efficiency and contribution to a community.

In the competitive, global and virtual world we live in, engineers are required to choose technologies, develop designs and technical specifications, do calculations, understand clients, providing them with the required services, lead assistants and provide a reasonable profitability to make an investment possible.

According to our opinion and based on experience, this is only attainable if the engineering profession h as been guided through the path of integration and not of partiality, of reflection and not of conceptual inflexibility.

Specialized education increasingly needs to be complemented by social, economic and environmental knowledge which greatly exceeds the ordinary education of an engineer.

3. The New Education Required

It is always difficult to speak about the future and doing so with the purpose of generating some ideas on the evolution of a profession such as engineering for a ten to fifteen-year horizon, entails a degree of risk.

We, who graduated in the late sixties, have been faced with phenomenal processes of technological changes as these more than forty years have passed. Electronics was incipient, computing did not exist, and the impact of telecommunications was unimaginable. And all this happened and increased over the past ten or fifteen years, the same period we want to prospect.

The evolution of professional engineering is obviously linked to technological change, though it is also related to research and development, because the essence of our profession lies in the application of technology.

Many of the contents to be taught are basic notions of the profession, such as physics, chemistry and math, but others should be "tuned in" with technological innovation demands. Otherwise the adaptation period of every professional conspires against the competitiveness that every society or firm is demanding.

Learning periods are increasingly shorter, as shown by the reduction of the length of graduate courses worldwide and, consequently, contents and learning methodologies require deep changes to allow for constant adaptation.

A first question to imagine where engineering education will go is to try to identify the dominant technology tendencies for the future that should determine the choice of contents.

One of these tendencies is "micro" technologies with the convergence of the "bio-info-nano-neuro", in cores of knowledge, increasingly transversal to all engineering branches.

The advances in bioengineering show a clear example of what this means.

Another trend is that of "macro" technologies with the growing need for engineering to understand and promote solutions to cope with problems arising from demographic growth, urban planning and environment. There is a "social engineering" which should be part of interdisciplinary groups to solve the great problems of infrastructure, insecurity, unemployment and environment: the most serious problems that we must tackle to ensure the sustainability of our planet.

All this knowledge cannot be left aside in a curriculum revision and update if we want to train engineers for modern times.

But there is another line of thought, besides the technology demand, that guides us: how will these engineers of the future act?

This entails the difficulty of interpreting which type of personal behaviors will be required in the practice of the profession in view of the impact of those technological and social changes.

The adaptation problem has a clearer solution when the profile of the professional to be trained can be previously defined in terms of basic capacities and capabilities.

Basic capacities comprise the specific knowledge necessary for professional practice; these arise from basic and applied sciences, particularly including computing technology as the functional language of the virtual era.

But it is in the concept of teaching capabilities where changes are necessary. Capabilities can be divided at least into two types: specific of the profession and generic, shared by all professions.

Within specific capabilities, it is important that future engineers develop skills in project management, design of products and processes, economics, management of human resources. In view of an economy of innovation, people graduated from a university should have knowledge and experience in these fields to ease their transition to professional practice.

Among generic capabilities, there are three types that are of vital importance for an engineer's professional efficiency:

Instrumental: such as cognitive skills, i.e. understanding and thinking as well as linguistic skills (know how to write and speak in several languages). The global world is already excluding those who have been trained at initial and middle education levels and have not developed these skills.

Interpersonal: expressed in the capacity to share conversations, express feelings, work in teams, showing a social and ethical commitment. These capabilities will be critical in any future scenario as professionals will only work in multidisciplinary projects that will demand the integration of people of different origins and with a very different education.

Systemic: with the key behaviors to cope with "micro" and "macro" complex issues. Dependent on this, the possibility of interpreting totalities, interactions, recurrences and dynamics of the variables involved in any situation.

Success in the development of these capacities and capabilities in agreement with new social and technological demands will bring about efficiency in these new engineers and, consequently, changes cannot be delayed and should be taken on responsibly. They imply a deep transformation which is not observed in most academic institutions of the regions.

I will analyze systemic capabilities in depth due to their importance in dealing with complexity and the frequent lack of knowledge about their theoretical and practical evolution.

4. Systemic Capabilities

Between the 1950s and 1960s, a new way of understanding physical and social phenomena arose and developed. After the work of Ludwig Von Bertalanffy and the wide dissemination of papers written by computer scientists Norbert Wiener and Stafford Beer, there was an increasing interest in linking systemic thinking with engineering and management. From the 1970s to the 1990s, there was a decisive advance in the development of models and software to simulate and process the information arising from contributions by systemic thinking.

Today, knowledge is available to solve "systemic complexity". There are very important theories at our disposal such as the chaos theory and dissipative structure theory by Prigogine. Math can solve non-linear dynamic equations and the great advance of computing science give technical support to heavy data processing, making what some years ago was tedious or impossible to calculate relatively accessible.

However, many years have passed and engineering education in graduate courses has not made use of the important contributions of the Systems Theory, such as conceptual modeling and dynamic systems modeling, with the extraordinary contributions made after the work of Jay Forrester (MIT, USA). These allow engineers to put into practice the technological knowledge they have in solving natural, social and economic problems.

Some of the difficulties arising from the poor dissemination of this knowledge originated from the fact that experts in this way of thinking consider themselves as very exclusive and do not want to leave their safe grounds of abstract conceptualization. In many papers and conferences, Fritjof Capra and Margaret Wheatley agree on a similar diagnosis in more developed countries.

In this field of thinking, Markus Schwaninger, from the University of St. Gallen (Switzerland), explains that the difficulties in knowledge dissemination are caused by the requirement of integrating partial perspectives of many disciplines, which implies the need of understand each other. This is a not a common virtue in the academic world. And this is why, in spite of growing interests and demands, difficulties are largely concentrated in education and in the willingness to exchange ideas, as the basis for understanding and solving complex problems.

This statement shows that if we want to teach our future engineers to cope with the complexity of "macro" problems related to urban planning, environment or social conflicts, we cannot leave aside the importance of interpersonal skills such as knowing how to exchange ideas, how to diagnose based on varied opinions, how to enhance understanding and listening skills as well as written and oral language.

5. The Learning Process

In 1949, the neuroscientist D. Hebb described the process by means of which an axon of cell A excites cell B and, when repeatedly or persistently takes part in firing it, some growth process or metabolic change takes place in both cells. After these works, some neurophysiologists have ratified the importance that presynaptic and postsynaptic neurons have in generating the associative mechanism on which learning is based.

G. Bateson also stated that there may be many random changes inside the brain which result in processes of reinforcement or extinction that then generate possible learning.

According to this author, learning can be described in a hierarchical and evolutional way.

- First-order Learning: the reception of a signal generates an identifiable pattern that favors an action (Impulse… response)
- Second-order Learning: the pattern is modified by experience or experimentation. (Impulse… delay-change… response)
- Third-order Learning: the process of pattern modification and results is re-defined and, as a result, the way of pattern generation is modified. (Impulse… delay-redefinition-change… response)
- Fourth-order Learning: it is quite hypothetical but it implies a general methodology for the regeneration or invention of different patterns according to a situation. (Impulse… delay-regeneration-invention… response)

First-order Learning originates in the existence of a pattern where a set of rules determines the system's behavior. It develops a "learning algorithm", implicit in a neural network which has a certain structure. This network organizes itself and builds patterns of system interaction with the environment. These patterns remain as long as conditions demand their use and their effectiveness is validated in the response. It is often said that this is a reactive learning. If results do not match my "objectives", I correct the action.

Second-order Learning implies a reordering of the aforementioned pattern, caused by a new signal or an alteration of the existing one. The modification of the pattern requires an unlearning of what has been learnt or a relearning; this is often considered as a generative learning. If results do not match my "objectives", I wonder: what is happening? Can I do something different?

Third-order Learning requires the existence of a capacity to understand and modify the established pattern, through a better interpretation of the context, and the way how the system has developed patterns up to that moment is questioned. This is a systemic learning. If results do not match the "objectives", is it necessary to revise my mental model? Do I have to correct any internal structure?

It is not known how the Fourth-order Learning is developed in human beings but its existence is based on "metaconcepts" which have a so far-reaching validity that can be applied to numerous and different situations. Systemic and cybernetic concepts are metaconcepts and provide guidelines to approach interdisciplinary problems. This is a transcendent learning. If results do not match the "objectives", are concepts or theories appropriate?

Based on Bateson's classification and the relevance learning has in the evolution of complex systems, a quick conclusion of its implementation in educational environments may make us state that most of applied learning is of first-order and that the second- and third-order learning are only possible where there are "spaces of freedom" to question and discuss about what our habitual practices or mental models are.

First-order learning has a tendency towards automatic behavior and normative and predictable answers. Second-order learning implies a challenge to routine, a test to the capacity to listen, reflect and make established patterns flexible.

When this does not happen as a habit developed at university, we may wonder: how would these engineers adapt to changing or unpredictable situations?

We should therefore increase second- and third-order learning possibilities in graduate and post-graduate courses if we want to further adaptability and, the more we search for long-term survival, the more our ways of learning should evolve towards higher-order levels.

This poses a problem discussed in the last fifteen years when Senge (1990) introduced the concept of "organizational learning" which, in a short time, became one of the most relevant and widely-spread topics.

According to Senge and his followers, organizations, and not only individuals, learn.

After understanding how people learn, the path to follow is to extend the concepts to a group of individuals who can jointly generate "knowledge", thus becoming a learning community

As such, the learning subject shifts from the person to the institution.

6. Concluding Remarks

In the complex world we live in and will be living in the future, a thorough review of engineering education needs to be made.

Together with a clear adjustment of contents in line with the evolution of science and technology, it is worth mentioning the importance of engaging in an education that, besides developing engineering basic capacities, should be complemented by specific and generic competences.

In that line of contribution, instrumental, interpersonal and systemic capabilities stand out as the basis to train engineers to cope with and solve complex problems, with listening skills, reflection, dialogue, integration and conceptual modeling of hard and soft variables, so as to contribute, from their profession, to the accomplishment of a sustainable development.

This will require changes in universities and, particularly, in the learning methodology with the purpose of encouraging the increasing implementation of the generative and systemic learning types.

Institutional transformation will have to consider the presence of "organizational learning" which should be the new environment for the generation of "engineers for complexity".

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Education: Engineers for a Better Future[1]

Daniel Morano[2]

Abstract. The objective of this presentation is to develop proposals and suggestions to update the education and performance of engineers and to promote their effective participation in innovation and development processes.

Resumen. El objetivo de esta presentación es la elaboración de propuestas y sugerencias para actualizar la formación del ingeniero y el desempeño y promover su participación efectiva en los procesos de innovación y desarrollo.

1. Description of the present situation

Regional and International Scenarios.

The past decades have been witness to a great number of changes, both in the context where business activities are developed and in the sources of growth of the countries.

In this new scenario in which, according to some authors, a transition from managed economy to entrepreneurial economy is taking place, both knowledge and innovation generation, publicity and marketing, play a key role in the growth and economic development of a country or region.

Several studies, carried out in different countries, show that firms, which have recently entered into local and regional markets, particularly those which seem to be the most dynamic, are an important source of employment growth, of introduction of innovations, of strengthening of the productive fabric, of reorganization of regional spaces, and of challenging society's creative energies.

In this sense, the creation of new firms by university graduates or students is particularly crucial in emerging countries such as those of Latin America because the industrial structure is made up of firms of traditional sectors characterized by a moderate technological content, which do not play an important role as "incubator organizations" for new dynamic entrepreneurs.

However, in Argentina, there are niches of technological excellence that need to be expanded. In the last few years, the macroeconomic predictability achieved was a turning point in innovation investments but there are still critical aspects that need to be considered.

Although we are aware of other factors, in view of the scope of this paper, the focus will be centered on the educational needs of the human capital necessary to carry out innovation actions and new enterprises, with particular emphasis on engineering careers.

Training more and better Engineers

The decade that is about to finish has been the decade in which Argentine engineering went along the path of quality control. From 2001, the national standards for accrediting

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engineering careers were approved, thus unifying engineering careers in twenty-one specialties, a proposal which was put forth by the Federal Council of Engineering Deans of Argentina (acronym in Spanish, CONFEDI).

The definition of standards originated in the need to consolidate and enhance the value of engineering and, to this effect, the professional profile expected was outlined, based on the following terms:

> The engineer must be a university professional with a solid general culture, at the service, in the first place, of fulfilling the needs of his country, and with a systemic overall perspective of the world to allow him to apply knowledge anywhere in the world where he is required to, acting in all the cases with social solidarity, protecting the natural environment and observing in his work the basic ethical principles.

Engineering careers of all the universities of the country were accredited after complying with the corresponding accreditation procedures, which brought about diagnoses on the situation of university engineering education, describing particular strengths and weaknesses of the academic units which were evaluated in the several regions of our country.

When the national accreditation process was concluded, the Secretariat of University Policies implemented a project in 2005 for the improvement of the national system of engineering education with a multi-annual scope, taking into account that the State considers it as a key professional field for the economic development of the country.

It was an comprehensive proposal of supporting projects with financial aid to universities, in order to make the necessary modifications and amendments to improve the quality of the engineers' educational system, also taking into account the need of contributing to the productive development of all goods and services in competitive market chains.

The problems that were addressed are summarized in the following topics:

- Modernization of the curricula.
- Education at basic level: improvement of students' performance and of weaknesses in Basic Sciences training.
- Improvement of graduation rate, real duration of careers, and students' dedication to their studies.
- Teacher training and refreshing.
- Increase in teachers' time in order to balance teaching and research activities, development of basic and applied research, and linking of exchange activities.
- Improvement of the necessary infrastructure and equipment for the development of theoretical and practical activities.
- Improvement of co-operation activities with the economic sector, in the industry and services.
- Co-operation and articulation with other universities and research institutions in the several specialties for the shared use of resources and academic efforts in the different regions of the country.

Reforms in the national system of engineering education, besides the specific actions oriented to each academic unit and career in particular, introduced a criterion of belonging and co-ordination of the offer of engineering careers in the geographical context of nearby cities, regions and/or centers, as well as mechanisms to promote initiatives of inter-institutional co-operation for the shared use of human and physical resources. In addition, mechanisms to foster co-operation initiatives were introduced, which enabled circulation and course alternatives on the part of students.

Finally, and within the framework of this improvement process, it was considered necessary to adjust engineering education according to current international trends, in order to achieve professional training that will result in effective support to the sustained recovery of the economic system, production competitiveness and the improvement of our country's export profile.

With the multi-annual improvement projects completed between 2008 and 2009 and with the National Commission for University Evaluation and Accreditation of Argentina (CONEAU) carrying out a new career accreditation process, the country's engineering careers fulfilled 93% of their commitments and recommendations of the first accreditation which had taken place between 2002 and 2004.

The performance of beginners, measured in number of approved subjects, was improved by 47% and number of graduate students by 19% over that same period.

The five-year period of specific investment in engineering careers totaled the sum of one hundred and twenty thousand million dollars (US$ 120 M) out of which, funds corresponding to teachers' salaries, were definitely incorporated to the university budget.

At the same time, a MERCOSUR accreditation system was established in 2004 and its first phase called "Experimental Accreditation Process" (Spanish acronym MEXA) was carried out by twenty-nine professional engineering training courses in five countries: six for Argentina, six for Brazil, seven for Bolivia, five for Paraguay and five for Uruguay.

In 2009, a Permanent Accreditation System called ARCUSUR was put into practice and twenty (20) professional engineering training courses are participating in the first accreditation stage on behalf of Argentina: five Industrial Engineering courses, five Electronic Engineering courses, two Electrical Engineering courses, four Chemical Engineering courses, two Mechanical Engineering courses and two Civil Engineering courses.

Regional activities as well as bilateral recognition of national quality control systems will contribute to the possibility of achieving agreements on degree recognition, based on "substantially equivalent" solid training.

Controlling the Acquisition of Competence by Future Engineers

The process of career quality control, based on previously established standards approved by the Ministry of Education, in agreement with the University Council, has been completed. A six-year periodic accreditation is currently in force and more than 90% of the country's professional engineering courses have already complied with the proposed standards. The following step is then to make sure that future Argentine engineers have the necessary competences, abilities and capacities required by development and innovation.

CONFEDI has described a number of professional competences to be acquired, understanding that:

> Competence is the capacity to <u>effectively articulate</u> a set of schemes (mental structures) and values, to <u>mobilize</u> (make available) knowledge, in a certain context with the purpose of solving professional situations.

This definition points out that competence:

- refers to complex and integrated capacities,
- is related to knowledge (theoretical, conceptual and procedural),
- is linked to know-how (formalized, empirical, relational),
- is within a professional context (understanding this as the situation in which professional engineers practice their profession),

- refers to expected professional performance (understood as the way in which technically competent and socially-committed professional engineers perform their tasks),
- enables the incorporation of ethics and values.

Skills are divided into:

GENERIC COMPETENCE: a local meaning of generic competence is adopted, related to the professional competence common to all engineers.

SPECIFIC COMPETENCE: these includes professional competence common to engineers of a same branch.

It is not necessary to include a long enumeration of detailed competences since these are integrated and complex capacities; so a synthetic approach from complexity is pertinent, which will then be divided into the corresponding component levels for curricular implementation.

List of generic competences

Technological competence:

1. Competence in identifying, formulating and solving engineering problems.
2. Competence in imagining, designing and carrying out engineering projects (systems, components, products or processes).
3. Competence in managing (plan, execute and control) engineering projects (systems, components, products or processes).
4. Competence in effectively using engineering techniques and tools.
5. Competence in contributing to the generation of technological developments and/or technological innovations.

Social, political and attitudinal competence:

1. Competence to work efficiently in a team.
2. Competence in effectively communicating.
3. Competence in behaving with ethics, professional responsibility and social commitment, taking into account the economic, social and environmental impact of activities in the local and global context.
4. Competence in learning in a continuous and independent way.
5. Competence in acting with an entrepreneurial spirit.

It is worth mentioning that, although they have been classified following a numeric order, this does not imply an order of importance or priority among them but is only an easy way of identifying them.

2. Engineering Education for sustainable development

The objective of Argentine engineering schools during the on-going decade is to put into practice actions that will enable graduate students to acquire the aforementioned competences and capacities.

Human Resources Training and Incorporation

Improvement projects enabled the national universities' engineering schools to designate around 2,000 new full-time teachers, with postgraduate degrees, to support research, development and knowledge transfer. These professionals were appointed between 2006 and 2010 inclusive.

Within the framework of the National Program of ITCs Scholarships for students of Electronics, Information and Communication Technologies, during the last year of their scholarship, the beneficiaries join an applied research and/or technological transfer project on the topic. The objective is to form human resources to strengthen a scientific and technological system in the field of ITCs.

These human resources incorporated into professional engineering courses in Argentina, together with the funds provided by the Ministry of Science, Technology and Productive Innovation to the Project for the Promotion of Innovative Production in Argentina, are the bases for the tasks that should be consolidated or carried out.

The great challenge is to achieve the convergence of the public, academic and private sectors in the accomplishment of the proposed objectives.

As an important step, the so-called GTec Projects were put into practice within the framework of the Project for the Promotion of Innovative Production. Within a Training Program for Managers and Technology Linkers, the aims of GTec Projects are: I) to boost capacities for innovation and technological development both in firms and in scientific-technical organizations, business associations and entities of local development; II) to encourage the creation of professional profiles that facilitate and create real links between the academic and the productive sectors; III) to improve the qualification and increase the number of human resources already engaged in the management of knowledge, its enhancement and transfer; IV) to promote the technological and innovation capacities of the firms of the country's many regions and in the various sectors of economic activity.

Between 2009 and 2010, seven regional centers for Management and Technological Linking were established: Norte Grande, Centro Oeste, Centro Este, Metropolitano, Bonaerense (2) and Sur. The proposal is aimed at training professionals at post-graduate level: half of them from universities and research centers and the other half from production and service firms.

In addition, there are also international exchange and cooperation agreements for engineering students and researchers, with other MERCOSUR countries (Project MARCA), with France (ARFITEC and Aeronautics) and Germany (DAAD) among others.

This makes it possible to have the necessary number of qualified human resources to deal with the proposals described.

Competence to contribute to the generation of technological developments and/or technological innovations and to act with an entrepreneurial spirit

The need observed in academic spheres, aimed at improving the quality of engineering training by providing graduate students with a clear entrepreneurial spirit, implies that this not only a national problem but rather an issue that should be dealt with at the level of blocks of countries, so that better conditions can be generated for it to be carried out under optimal conditions, both in terms of its components and of the expected time and, mainly, to favor geographical, academic and economic integration.

The Universities of the region which, over the last years have made their best efforts in favor of an educational and scientific modernization of engineering programs, thus allowing graduate students to achieve training levels compatible with international quality standards, have not yet produced the expected results as regards the creation of well-paid jobs to allow a wider social inclusion, thus reducing poor areas in the region.

Consequently, taking into account that the promotion of an entrepreneurial culture opens up the possibility of transforming new generations from mere recipients of proposals into generators of options, which should not only be useful for the personal and professional development of graduates but also for the development of communities they are part of, since 2009 a project has been in operation with multi-annual scope, known as the "Regional Common Good", with the purpose of introducing the topic of technological entrepreneurs into engineering curricula.

The activity is carried out between Argentina, Brazil, Chile and Uruguay through their own Engineering Associations and Councils of Engineering Faculties Deans, in the context of the Hemispheric Initiative "Engineering for the Americas" (EftA), for whose development it has the participation and support of the joint work of the Higher Education Secretaries and Ministers of all four countries which agreed on this project.

In spite of the consortium-type organization in its origin, it is reasonable and probable that other interested countries can also join the project in the near future and enrich it.

With the certainty that engineering students and graduates are the new sources of technological innovation and generation of employment, for the past few years the four countries have started to implement some projects and initiatives to implement the potential present in universities and research institutes for the establishment of firms. However, these incipient efforts require encouragement, scope and presence of capacities not yet available at the national level due to the lack of sufficient successful experience, knowledge and human capital involved in the issue (deans, professors, students, firms, and government officials).

Although in line with the international trend observed, there is a growing commitment by Latinn American universities to train and develop entrepreneurial capacities among teachers, students and graduates, this is an incipient phenomenon which occurs in isolated cases based on the efforts of specific academic institutions, without enough systemic programs and coordinated work to have a significant impact at national and regional levels.

Research carried out by the Inter-American Development Bank, together with the National University of General Sarmiento of Argentina, shows that on average, 6 out of 10 Latin American entrepreneurs are university graduates[1]. This study also points out that engineering graduates are precisely the most dynamic entrepreneurs, followed by graduates from economics (40% and 30%, respectively). This participation is higher when new intensive-knowledge firms are analyzed; in this case, the percentage of university graduates is 82% compared to 54% in traditional manufacturing sectors, engineering being the dominant profile. These figures clearly show the presence of an important potential source of entrepreneurs among engineering students throughout the countries of the region.

However, this potential is not being capitalized and used at present. This same aforementioned study specifically asks about the main contribution that dynamic entrepreneurs recognize from the several contexts where they were trained (family, university, working experience, etc.). In this respect, it is worth mentioning that the main contribution which professionals acknowledged to universities was the technical knowledge acquired. Recognition of the acquisition of other competences and capacities which are also useful for the development of new dynamic firms was, on the contrary quite marginal.

In view of all this and taking into account their role as main actors in the change of paradigm that is expected to be introduced in the new teaching process it has been considered essential to begin with teachers' training, endeavouring to arouse their own innovation.

1 Dynamic entrepreneurs are those capable of creating a new enterprise that, within a 3-year period, goes on being in business and grows substantially, thus becoming a SME (number of employees more than 15).

The Need for a Change in Engineering Education

Traditionally, education in professional engineering courses has been focused on education for employment rather than for the generation of employment. However, training for work goes beyond professional practice, either independently or as an employee). Training for employment includes the development of a set of useful capacities and competences for the incorporation of students into adult life, not only as employees but also as employers and mainly, as active and responsible citizens. Even though the problem of Entrepreneurship and Technological Innovation is not an exclusive issue of these countries, geographical proximity, their similar development as regards engineering education, the close relationship that exists between Engineering Education Associations in joint work (for example, in regional accreditation programs) and the political and social conditions within the regional context, favor the development of the project and allow the incorporation of future new partners.

The Ibero-American Association of Engineering Education Institutions (ASIBEI) at its last plenary meeting (Belo Horizonte in July 2010) recognized the need for: "the introduction into engineering education programs of such areas as the promoting of entrepreneurial culture, the ongoing reflection of the social responsibility of the engineer and environmental and social impacts in the practice of the profession" in the "Declaration of Belo Horizonte".

The Regional Public Good. Regional Education Program for the Development of Capacities for Technological Innovation and Entrepreneurship at Faculties with Engineering Careers (acronym in Spanish, PRECITyE)

The Program "The Regional Common Good" (in Spanish, BPR which stands for Bien Público Regional) was elaborated by the Engineering Education Associations of Argentina, Brazil, Chile and Uruguay and is supported by their four Ministries of Education. It is aimed at jointly facilitating the development of competences for technological innovation and entrepreneurial culture in the engineering curricula of the four countries. This initiative is in line with the national priorities of the region, aimed at promoting the creation of firms with the purpose of encouraging local and regional growth, the generation of new jobs, the reduction of poverty and the improvement of people's living standards in the context of the south-south co-operation.

The strategy that has been chosen for the implementation of the project is based on raising awareness within the university community, training direct participants (professors and authorities) and implementing mechanisms for joint assistance and co-operation to guarantee the sustainability of the system.

Governments, academic units, firms and other agents that participate in the proposal facilitate the creation of structures and feedbacks in order to implement a virtuous circle of education, generation of entrepreneurial culture, establishment of incubator organizations, and use of proper experiences.

Components

The implementation of BPR has been divided into four components, each of which has a set of activities, as described hereinafter:

- Component 1: Elaboration of Institutional Strategies, Priorities and Co-ordination of the Program.
- Component 2: Elaboration of Working Materials on Innovation and Entrepreneurship for Engineering Teachers and Students.
- Component 3: Education and Training of Engineering Teachers in Innovation and Entrepreneurship.

- Component 4: Education and Training of Engineering Students in Innovation and Entrepreneurship.

Table: Direct and indirect beneficiaries of the National Four-Country Project of Argentina, Brazil, Chile and Uruguay:

	Indirect Beneficiaries	Direct Beneficiaries: Engineering Community		
COUNTRY	Population (1) (millions)	Faculties and Schools	Students	Teachers
ARGENTINA (1)	40.30	70	134.662	18.870
BRAZIL	190.00	399	266.100	32.000
CHILE (2)	16.28	24	70.504	3.525
URUGUAY	3.4	4	7.000	1.200
TOTAL	249.98	497	478.266	55.595

(1) Secretariat of University Policies (acronym in Spanish, SPU).

(2) Council of Rectors of Chilean Universities (acronym in Spanish, CRUCH).

Sustainability

The active participation and support of these four countries' Ministries of Education, together with the strong commitment of the Engineering Education Councils and Associations and other participants involved (Industry Chambers, Incubator organizations) are a way of ensuring the continuity of this common good in the future.

The essential presence and leadership of Engineering Education Councils and Associations in the program provide the necessary framework and link with the recipients and final beneficiaries of this program, the students, since they join engineering faculties and schools which are generally represented by their deans and, consequently, their actions are aimed at discussing and putting into practice guidelines which are applied to engineering education.

Another important element which has been taken into account in the definition and formulation of BPR activities is the implementation of rules, agreements, co-operation networks and, mainly, of a large number of highly-qualified human resources with documented knowledge (cases, materials, teaching models, courses) so as to ensure the continuity of the project, once the initial financing stage of the project has been completed, with a possible expansion and further national and regional analysis. The strengthening of this network will result in working teams which will be responsible for the definition of the project's future activities.

Finally, the Ministries of Education of the four countries involved have some financing programs at the national level (some of which are financed by multilateral funds) for the improvement of higher education which allocate resources so that the 400 academic units represented can adopt and enhance the Regional Common Good produced by this project.

The institutions participating in the development of the project are public entities and comprise Engineering Faculties and Schools; their actions are aimed at the discussion and implementation of curricular guidelines which are used in engineering education. Due to their missions and public nature, they have a close relationship with the Ministries of Education, through the Secretaries or Agencies that regulate Higher Education in the four countries.

3. Conclusions

We understand that there are five goals for engineering education and, therefore for academic institutions and national states, in some cases to be achieved and, in others, to be definitely consolidated in the next decade:

1. To ensure acquisition of the proposed basic and transversal competence.
2. To ensure quality education based on national standards that take into account a national model of engineering education.
3. To increase the number of engineers and professionals of scientific-technological careers.
4. To contribute to local and regional development, by means of research, development and knowledge transfer.
5. To train engineers with a supra-national perspective.

Finally, and quoting the Declaration of the Ibero-American Association of Institutions for Engineering Education (ASIBEI) of July 2010, we can state that: "The Bicentenary of independence of various countries in the region is a good opportunity to promote, through the efforts of all political, academic, social and economic actors, and from the region's shared history and strengths and resources of the region, the strengthening of the training of highly qualified engineers as a key to solve the needs, gaps and weaknesses that setback our societies' access to levels of sustainable development, fostering social equity and welfare, and also promoting the aims of competitiveness and innovation to help economic development and preserve the biodiversity of ecosystems and natural resources of our Region".

Innovation as a Cornerstone of Development

Gonzalo Bernat[1], Fernando Audebert[2] and Ruth Ladenheim[3]

Abstract. At present, the development of nations is closely tied to the strength of its science and technology system and the use of knowledge to generate innovations that respond to the demands and expectations of the social and productive framework.This paper summarizes the basis for policies and actions taken by the Ministry of Science, Technology and Productive Innovation of Argentina. They are based on the understanding of innovation as a cornerstone of development, which must be continually sustained by strengthening their basic structures in science, technology, productive sectors, society and the intermediate structures that contribute to the synergy of the innovations' generating system.

Resumen. En la actualidad, el desarrollo de las naciones se encuentra estrechamente vinculado a la fortaleza de su sistema científico-tecnológico y a la utilización del conocimiento para generar innovaciones que respondan a las demandas y expectativas del entramado social y productivo. En este trabajo se sintetiza el fundamento de las políticas y las acciones emprendidas por el Ministerio de Ciencia, Tecnología e Innovación Productiva de Argentina. Las mismas se basan en la comprensión de la Innovación como pilar del desarrollo, la cual debe ser continuamente sostenida fortaleciendo sus estructuras básicas en la ciencia, la tecnología, los sectores productivos, la sociedad y las estructuras intermedias que contribuyen a la sinergia del sistema generador de innovaciones.

1. Introduction

At present, the development of nations is closely tied to the strength of its science and technology system and the use of knowledge to generate innovations that respond to the demands and expectations of the social and productive framework.

Innovation means introducing new products, processes and technologies that increase competitiveness, diversify the economy and develop activities of higher added value. This enables the boosting of growth and employment, and improves living standards. Innovation is an important stimulus for growth and, economic and social development. In order to increase its capacity to generate innovations, companies in many nations of the Organization for Economic Cooperation and Development (OECD) invest considerably in intangible assets - research and development (R & D), software and databases - such as capital goods.

This economic challenge coincides with the growth of the social and political pressure to address several of humanity's problems; in-

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cluding health, food security, access to drinking water and climate change; many of which are global in nature or require taking worldwide actions. Those problems cannot be solved by one nation and require a more coordinated effort by groups of countries or regions.

The effectiveness of policies to promote innovation depends on taking into account the development chain and knowledge transfer from research to the successful impact of a product or process on the market, or to reaching the solutions of social problems.

Innovation rarely occurs in isolation; it is a multidisciplinary and highly interactive process that increasingly involves the collaboration of a diverse and growing network of organizations, institutions and users. Science has always been the heart of innovation and remains as an essential component, but the chain of development for innovation, also requires an efficient structure as a bridge between knowledge supply and demand solutions. This structure needs human resources (HR) to create and transform knowledge and to manage innovation. Multiple organizations must be strengthened to create an efficient flow between the various complementary activities aimed to developing innovations. The information processing and the generation of diagnostics, monitoring technology, market research and competitive intelligence, foresight analysis and dissemination of knowledge are some of the main tools to be included in the structure of an innovation system.

Developed countries with highly dynamic economies, have innovation systems with strong joint structures and a vast array of human resources that sustains the system.

In contrast, in the case of developing countries, among the challenges they face to transform innovation into a source of economic and social development, they have to strengthen all nodes in the chain of development of innovation and enable an agile joint interactive performance between them. Thus, some of the first challenges they must face are training of human resources, improvement of infrastructure conditions and equipment, strengthening competitive and dynamic industry in the international market, and enhancing the organizations for coordinating sectors of supply and demand of knowledge.

Both the development and economic growth of countries and the solutions to global demands currently depend largely on the efficiency of innovation systems in each country.

2. The Argentine Experience

Recognizing the strategic importance of having an efficient innovation system, the Argentine government is implementing a series of policies to strengthen the system. Considering the value of science in the generation of innovations, the investment in science and technology was increased by 390% between 2003 and 2009.

In this context, the Ministry of Science, Technology and Productive Innovation of Argentina (MinCyT) has decided to focus its efforts on further actions to strengthen structures, improve synergy with the productive sector promoting the development of innovations in strategic areas and sectors for the country, and the production of knowledge of high social impact.

To meet these objectives in the short and medium term, the MinCyT implements a series of programs and tools to help strengthen science and technology activities across the country.

The promotion of human resources training is one of the cornerstones of this policy to place science at the center of the national scene. The support for teaching at undergraduate and postgraduate levels, the improvement of working conditions for researchers, and repatriation strategies for scientists helped to consolidate a foundation of around 57.000

researchers and full-time technical and support staff.

Between 2004 and 2008, the number of researchers and scholars/fellows grew by 34% and 56%, respectively which demonstrates the determination in taking actions addressed to strengthen the system. It is worth noticing that in recent years the number of scientists has increased more than the economically active population.

The increase of funding for activities in science, technology and innovation (STI), includes not only the allocation of resources for research projects but also the implementation of training programs, expansion of infrastructure for research, modernization of equipment, access to large equipments, databases and specialized electronic libraries among other actions that the Ministry is carrying out to achieve the establishment of a strong scientific system.

For instance, Technology Platforms projects aim to support the formation of units with cutting edge technology and highly trained personnel dedicated to provide products and advanced services in science and technology needed for excellent research groups and technology-based companies.

Some of the indicators that reflect the dynamism of the STI sector in Argentina are the increase of 25% in patent applications produced between 2004 and 2007, Argentina's prolific scientific production registered in the Science Citation Index and the increase in the number of agreements for technology development.

Promoting innovation in the productive sector is another key factor in which MinCyT policies are based, aiming to improve the competitiveness of the private sector by encouraging the incorporation of added value to the production.

Funding for innovation projects and technological upgrading in enterprises, especially in SMEs, has been increased through several schemes of refundable and non-refundable grants. Moreover, a favorable environment for creating and developing new technology-based enterprises has been established. This scheme includes grants for R&D projects that can promote the creation of these companies, as well as facilitate access to capital to make it possible. On the other hand, it has also made progress in building lasting bonds between knowledge production sectors and the economy through technology road-mapping activities, transfer and intellectual property protection, training of managers in technology, integration of highly qualified HR in companies, providing counseling on technology and business for SMEs and the development of good practices and legal frameworks for these activities.

The Ministry's decision to create new mechanisms for science and technology applied to solving socio-productive requirements led to policies focusing on priority sectors establishing new grants named "sector funds". These new grants allocate resources to encourage the development of strategic areas and sectors for the country.

Sector Funds, partially funded by the World Bank and the Inter-American Development Bank (BID), are the main tool of this new generation of policies aimed at responding to the needs and expectations of state and society.

Through this new initiative, the Ministry has decided to finance projects up to USD 10 million to public-private consortiums that are committed to the development of general purpose technologies, specifically nanotechnology, information and communication technologies (ICT), and biotechnology.

The decision to promote these areas reflects the need to generate a qualitative jump in the techno-productive Argentine model, which currently is characterized by export products with low and medium technology intensity.

The importance of ICTs lies in the impact of their main component - knowledge - in the creation of value and the possibilities of generating radical changes in other sectors. While the industry has grown in recent years at an annual rate exceeding 20%, it may only be further developed giving solutions that address new challenges that threaten their growth.

The decision to promote biotechnology is based on the potential of this technology acquired when is appropriately integrated with others for the manufacturing of food, medicines and agricultural products, which are areas of strategic importance for the country. Argentina has around 80 companies in the sector, which ranks the country with the largest number of companies per capita in this sector in Latin America.

Finally, nanotechnology has been identified as a priority development area because of its ability to generate products with high added value, with new characteristics that enhance the competitiveness of industries in the traditional sectors, and clearing the access to new market niches.

Meanwhile, the remaining lines of Ministry policies in priority areas, tries to solve identified bottlenecks in science and technology in relation to five priority areas, namely, agro-industry, health, energy, social development and environment.

Projects in the framework of the priority areas are aimed at generating innovations and capabilities that are critical for the development of the corresponding priority sectors. Projects granted are characterized by their potential impact on the sector in which they operate, because they are based on a technological development that has already passed the earliest stage of research and which has identifiable users for their results.

This Sector Funds scheme is aimed exclusively at funding applied research projects, technology developments and/or transfer, and dissemination of technologies that contribute to solving social and productive problems. Projects to be funded must be supported by consultation with advisory bodies formed by representatives of public and private sectors of civil society and academia.

Lastly, it is worth mentioning that further than the progress in the design of new tools and schemes to promote scientific and technological development, the Ministry promotes the production of information on the status of the STI system in the country, as well as prospective analyses that contribute to improved diagnostic activities, planning, promotion and dissemination of science, technology and innovation.

All actions taken by the Ministry are based on the understanding of innovation as a cornerstone of development, which must be continually sustained by strengthening their basic structures in science, technology, productive sectors, society and the intermediate structures that contribute to the synergy of the innovations generating system.

The Engineer Protagonist of a Change in the Production Profile in Argentina

Mario A. J. Mariscotti[1]

Abstract. Engineers trained in both advanced technologies and business administration at the same time are seen as the essential ingredient for gaining competitiveness through the use of knowledge in a country such as Argentina where venture capitalism in high tech initiatives is virtually non existent. It is proposed that the index R&D Expenditures / Sales be used to measure progress towards the goal of reaching, in 10 years, 60% of the value of this index in OECD countries. It is shown that to achieve this goal it is necessary to have 4000 of these engineers at a cost of 220 million US/year.

Resumen. La formación de ingenieros en tecnologías de avanzadas y en administración de empresas en forma simultánea es considerada la herramienta esencial para ganar competitividad mediante el conocimiento en un país como la Argentina donde el capital de riesgo para iniciativas tecnológicas es prácticamente inexistente. En este trabajo se propone que el índice Gastos en I&D / Ventas se use para medir el progreso hacia el objetivo de alcanzar, en 10 años, el 60% del valor de este índice en los países de la OCDE. Se muestra que para lograrlo hacen falta 4000 de estos ingenieros a un costo de 220 millones de U$ por año.

1. Introduction

The purpose of this Workshop is to analyze the role of the engineer as a "bridge" between the academic and the industrial sectors. The importance of knowledge application for the economic and social development of a country is an issue that is no longer a matter of discussion. What is being discussed at present in intermediate-developed countries such as Argentina is how to make this happen, i.e. how to make knowledge contribute to development, and the engineer plays a key role in this regard.

A mechanism to encourage this transfer process is through governmental programs of innovation promotion in the business sector of the type managed by the Argentine Technological Fund (acronym in Spanish, FONTAR) of the National Agency for Scientific and Technological Promotion.

In countries with larger surplus of private capital, the desired convergence between the academic sector, the builder of knowledge, and industry, the driving force of economy, has been possible to a considerable extent due to the existence of risk capital funds, interested in capturing the intellectual potential of graduates from high-level technological schools and making them yield economic profits (well typified by the successful experiences in Silicon Valley and in Cambridge, Massachusetts).

In Argentina, the concern for this problem arose some decades ago with the papers writ-

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ten by Jorge Sábato and Oscar Varsavsky, among others. But the first public document about innovation incentive in the private sector was Law 23877, enacted in 1992 and, then, the creation of FONTAR in 1994. In 1997, these two documents were merged into the Agency and the amounts to finance innovative projects as well as the number of these in the private sector have steadily increased since then.

However, the production profile in terms of improvement of its competitive capacity by means of the use of personal knowledge has not been substantially changed in Argentina.

2. Present Situation:

If we try to put this situation into perspective, one of the most representative indexes is the relation between investment in R&D and corporate turnover. In Argentina, this index is of about 0.3%; it has not changed much in the last decade and it is ten times lower than the value of OECD countries.

This ratio is relevant since it measures directly the "consumption of intelligence" (or personal knowledge) by firms. According to OECD, the pharmaceutical, aerospace and information industries are the ones with the highest values, between 10% to 20% (with some cases in which it reaches 40%!). Microsoft invests 17% of its turnover in R&D. Firms that invest more than 8% are considered "high-tech" by OECD. Industries considered to be of "medium-high" technology invest between 2% and 4%; "medium-low" around 1%, and "low", less than 0.5% (wood, paper, tobacco, textile, shoe industries).

In Argentina, Biosidus, for example, invests 18%, INVAP investment is of about 10% and, in general, the software industry (which in Argentina is growing very strongly) shows clearly high ratios. However, the turnover of these firms is not significant considering the overall amount of the Argentine production sector and, consequently, the global ratio R&D/ turnover is very low (characteristic of low-tech countries according to the aforementioned classification).

It is therefore worth reflecting on what should be done –and what is necessary to do in terms of human resources– so as to move closer to OECD countries in this regard.

3. What should be done?

Suppose, for example, that in a 10-years' time this ratio is expected to raise about six times until reaching the value of 2% (60% of OECD current level). Is this possible? What should be done to accomplish this goal?

By definition, this ratio concerns the private sector. What should be done is to increase production performance based on knowledge. In principle, this means increasing R&D investment in already existing firms or encouraging the establishment of new high-tech companies in which R&D will have a clear leading role. The first alternative is not altogether feasible since, according to the international experience, the R&D component in a firm is primarily related to its business activity. In most of the traditional firms in Argentina, a decision to invest in R&D would be almost equivalent to a decision to change their business activities. So it is necessary to consider the following alternative: the creation of technological firms.

For the purpose of the following exercise, we define "technological" corporation as the one which invests 10% of its turnover in R&D. These firms generally produce goods or services with "added personal knowledge" and are therefore called CPA firms (acronym in Spanish, CPA).

At present, the annual expenditure in R&D of the Argentine industrial sector is of about 200 million dollars a year. The total amount of sales is of around 60,000 million dollars.

It is clear that, in order to reach the 2% R&D/turnover ratio, it is necessary that technological corporations as defined in the previous paragraph add 12,500 million dollars to the total sales. This means an investment in research and development of 1,250 million dollars a year.

A reasonable hypothesis is that 50% of that investment is used for salaries and that 2/3 of those salaries should be assigned to "technology professionals", i.e. engineers with advanced technological knowledge. The total expenditure in salaries for these last-mentioned professionals would be of about 400 million dollars. If each of them earns 100,000 dollars a year, there will be 4,000 highly-skilled people working in CPA firms in 10-years' time. These professionals are the essential "input" of CPA firms.

To have this staff available, it is necessary to create advanced engineering schools (such as the Technological Institute of Massachusetts, the Stanford University, the Northern Institute of Technology Management of Hamburg), that do not exist today in Argentina, and to graduate an average number of eight hundred professional each year (with a planned five-year course of studies).

If we suppose a five-year course of studies and 800 graduated students each year after the fifth year, the number of students will be 4,000. If we further plan 5 annual parallel subjects, the number of professors for classes of no more than 20 students will be 1,000 and, if each of these professors has two teaching assistants, these will amount to 2,000. If the salary of a professor is estimated at 60 million dollars a year and that of the teaching assistant at half of that salary, expenditure in salaries will then amount to 120 million dollars a year. The high-level education that is proposed in order to accomplish the main objective requires good professors but also experimental facilities to allow students achieve first-hand experience in the management of technologies they choose to develop. We estimate that the necessary equipment amounts to 20 million dollars a year and the related infrastructure to 80 millions.

This gross estimation results in a total cost of approximately 220 million dollars a year for a program of engineers' education adjusted to the proposed goal. Although this may seem to be quite ambitious, it is not in terms of costs and of the intended goal: a substantial change of the Argentina production profile.

The decision of carrying out a project of this type cannot be made by one or two individual universities but it should be the result of a government policy. Although much is said about this, yet we have advanced little in the last decades if we take into account figures and the practical decisions which have been carried out. A change in this sense requires a political decision in favor of a program of this type, an important but not difficult decision. A country such as South Korea increased its exports 4,000 times in 30 years since it made the decision of doing something similar. It began by establishing the Korean Advanced Institute of Science and Technology (KAIST), one of the most prestigious institutions of technological education.

It is pertinent to consider whether these professionals, once graduated, will find jobs in local firms in case the present overall technological orientation of the Argentine business sector does not change in the next 10 years. This shows the need of implementing strong incentives, as other countries which have successfully carried out this type of programs, have done to promote R&D in the private sector.

An enhanced alternative would be that, at the same time of being educated as technologists in state-of-the-art areas, these engineers should also be trained as entrepreneurs and they should develop the vocation and skills to set up their own firm after their graduation. Those who learn to do something well like doing it. It is then expected that if the country invests in this "dual" professional, it will achieve what it needs: the creation of many CPA firms.

This type of engineer-technologist-entrepreneur does not exist here or in any other country (there are only some recent isolated examples).They are not necessary in developed countries because there are good technologists on the one hand and, risk capitalists, on the other, which are eager to invest in projects based on leading technologies. In Argentina and other countries of similar development level, this is not the case. There are neither technologists nor risk capitalists in leading technological areas. There are very good business schools but their graduated students are not trained in the "culture" of technology whereas good science schools form scientists but not technologists.

This new type of professionals could be the driving force of the transformation Argentina is in need of. Their education is the mission of universities and it is necessary to make a great effort –and without delay– to accomplish this goal. The estimated cost to finance schools to educate 800 professionals in 10 years is 220 million dollars a year. These funds should be contestable by existing institutions interested in organizing these courses of studies. Approximately half of this amount of money should be allocated to set up laboratories and finance cooperation agreements with international leading technology schools. A draft of the proposed course of studies is annexed hereinafter.

A possible scenario could be to suppose small CPA firms founded, let us say, by two entrepreneur engineers each. The project would therefore imply that after the 10-year period, there would be about 2,000 firms producing products of highly added value, each of them with an annual turnover of around 6 million dollars. It is easy to calculate that estimated revenues from income tax would largely exceed the costs of this program.

ANNEX

Draft of the course of studies of Entrepreneur Engineering

By definition, this course of studies is divided into two areas that will be developed in parallel and simultaneously: the technological area and the business area. The course of studies is composed of a basic cycle and a higher cycle in both areas; the technological area offers several specialties.

- Possible specialties of the technological area are:
- Computer Science, Communication and Information
- Communications
- Semiconductors, Electronics, Optics, Superconductors, Nanotechnology
- Materials Science
- Bioengineering
- Both the Basic and Higher Cycles, would last 5 semesters each (two years and a half)

Draft of the Basic Cycle
(Semesters 1 to 5)

SEMESTER	TECHNOLOGICAL AREA	BUSINESS AREA
1	Physics I, Maths I	Economics I, Administration and Organization of Firms
2	General Chemistry, General Biology	Marketing, Development and Organizational Change
3	Physics II, Maths II	Costs, Accounting
4	Physics III, Maths III(applied)	Strategic Management I, Corporate Finance
5	Automation Engineering, Design and Creative Manufacturing. Process of Product Engineering, System Control Principles and Introduction to Robotics. Experimental Methods, Instrumentation and Typical Engineering Problems. Manufacturing Technologies.	Business Management Cases, Investment Projects

Draft of the Higher Cycle
(Semesters 6 to 10)

Business Area	Production Planning and Administration. Strategic Marketing Cases. Management of Human Resources. Labor, Tax and Intellectual Property Legislation. Costs in Product Design. Unemployment, Quality and Marketing Timing. Clients' Needs and Financial Profits. Product Lifecycle, "Pipeline", Learning Curves, Risk Assessment, Financial Implications, Decision-making Criteria, "Joint Ventures". Entrepreneurial Development, Beginning High-technology Business. Capital Market and Financing. Market Research. Design, Prototypes, Market Share Projection, Market-Oriented Design. Engineering and Management of Development, Design and Manufacture. Management of the Chain of Supplies and Suppliers. Quality Control. Corporate Economics, SME Administration. Strategic Management II. Strategic Alliances. Advanced Marketing.
Computer Science	Digital Systems, Boolean Algebra, Multiplexers, ROMs, Programmable Logic System. Basic Components of a Computer. Algorithms and Programs, Data Structure, Programming, Computational Graphics, Quantum Computer. Computer Architecture and Processor Designs for Specific Applications. Filters. Image Recognition and Animation. Man-machine interface. Networking.
Communications	Electromagnetic Engineering. Microwaves. Fundamentals of Communication Systems. Wireless Communication. Control of Communications and Signal Processing. Theory of the Group of Signal Processing, Broadband Satellite Communications, Data and Voice Communications. Microwave and Optic Communications.
Semiconductors, Electronics, Optics, Superconductors, Nanotechnology	Introduction to Electrical and Electronic Engineering. Non-linear Optics with organic materials. Electronics and Circuits. Circuit Theory. Digital Systems. Signals. Sensors and Actuators. Digital Design. Microprocessors. Solid-state Devices and Semiconductors and Processing. Integrated Circuits. Remote Sensors. Mechatronics. Robotics. Vibrations, Filters and Networks. Design of Analogical Circuits, Design of CMOS circuits. Device Simulation. Micromachining. Computational Architecture Keys, Modeling, System Programming and Design of Chips, Neuronal Networks, VLSI Design Methodology. CAD Tools. Optoelectronics. Solar Cells. Ferroelectric Devices. Thin-Film Transistor. Infrared Detectors. Laser Technology. Storage Devices. Screens. Liquid Crystals. Low-temperature Physics. Superconducting Devices. Squids. Nanotechnology.
Materials Science	Structures, Properties and Processing Ways to Optimize Properties. Metals, Ceramics and Electronic Materials. Compounds and Polymers, Manufacture and Design. Relations between Bonding, Structure and Properties. General Processing and Production Methods. Experimental Methods. Mechanical Behavior of Materials. Kinematic Processes. Modifications and Analyses with Ionic Beams. Advanced Ceramics. Science of Surfaces, Interface and Phase Transformations. Microscopic Techniques. Physics and Chemistry of Materials. Thermodynamics. Manufacture Technologies and Non-Destructive Essays. Corrosion. Degradation of Materials.
Bioengineering	Cellular and Molecular Biology. Engineering of Biotechnological Processes. Fields, Forces and Fluids in Biological Systems. Genetic Biotechnology. Molecular, Cellular and Tissue Biomechanics. Production and Delivery of Recombinant Proteins. Tissue Engineering. Materials for Biomedical Uses. Cell-Biomaterial Interaction. Surfaces. Biosensors and Microarrays. Response to Implants. Material and Biomaterial Nanomechanics. Process Engineering. Thermal and Separation Processes. Particle Technology. Engineering of Chemical Reactions. Biocatalysts and Enzyme Technology. Bioreactors. Processes and Technologies of Membrane Separation. Bioelectrical Engineering. Design of Technical Devices that require knowledge of living systems (pacemakers, sensory aids, artificial tissues...)

Argentina: the development of Science based Technology

Eduardo N. Dvorkin[1]

Abstract. In this paper we discuss the multiple relations between Science and Technology and ways for enhancing the transformation of scientific knowledge in technological applications. The importance of Science for the development of the country is well recognized in Argentina; however, the transition from scientific knowledge to technological development needs more pulling from the public sector.

Resumen. En el presente trabajo discutimos las múltiples relaciones entre Ciencia y Tecnología y las formas de incrementar la transformación de conocimiento científico en aplicaciones tecnológicas. La importancia de la Ciencia para el desarrollo del país es bien reconocida en la Argentina; sin embargo, la transición desde el conocimiento científico al desarrollo tecnológico requiere de mayor tracción desde el sector público.

1. Science and Technology

It is necessary to distinguish between two concepts that we will use in what follows: Science and Technology (Dvorkin 1996, 1997).

Technology refers to the set of skills, knowledge, tools, instruments and organization that allows the production of a product or the provision of a service (Branscomb 1993).

Following Bernal (1986) we will attempt an approximation to the concept of Science:

a. We are familiar with the concept of the scientific method: to study a phenomenon we start by observing it and then we formulate hypotheses on the cause-consequence mechanism that drives the phenomenon (abstraction). The next step is to test the hypotheses via experimentation, which is the reproduction of the phenomenon in a controlled environment (see Fig.1)
b. We can distinguish the scientific instruments, that is to say the measurement and analyses apparatus used for observation and experimentation when a phenomenon is studied via the scientific method.
c. We can identify a language, which is different from the language that it is used in normal life, and that is used by those that employing the scientific method as a tool work on similar topics. This is the scientific language.
d. Those who use the scientific method, the scientific apparatus and the scientific language form the scientific community. The people inside this community interchange experiences, evaluate the production of its own members (peers review), produce its own publications, etc. The members of the scientific community are called scientists.

Hence, following Bernal, we define the activity of the scientists as Science.

In the following table we highlight the most important differences and similarities between Science and Technology:

[1] Engineering School, University of Buenos Aires, and SIM&TEC S.A. Buenos Aires, Argentina, E-mail:

Table I. Science and Technology

	SCIENCE	TECHNOLOGY
PROPERTY OF THE RESULTS	Social	Private (either a person, a company, a coop or a state)
ULTIMATE PURPOSE	Independent	Dependent
DIFUSSION	Irrestricted	Restricted
DEVELOPMENT	Accumulative "If I have seen further it is only by standing on the shoulders of giants" Isaac Newton	Uneven
METHODOLOGY	Scientific method	Indifferent
IMPACT IN TIME	Immediate or deferred	Immediate
LATERAL IMPACT	Ample	Ample

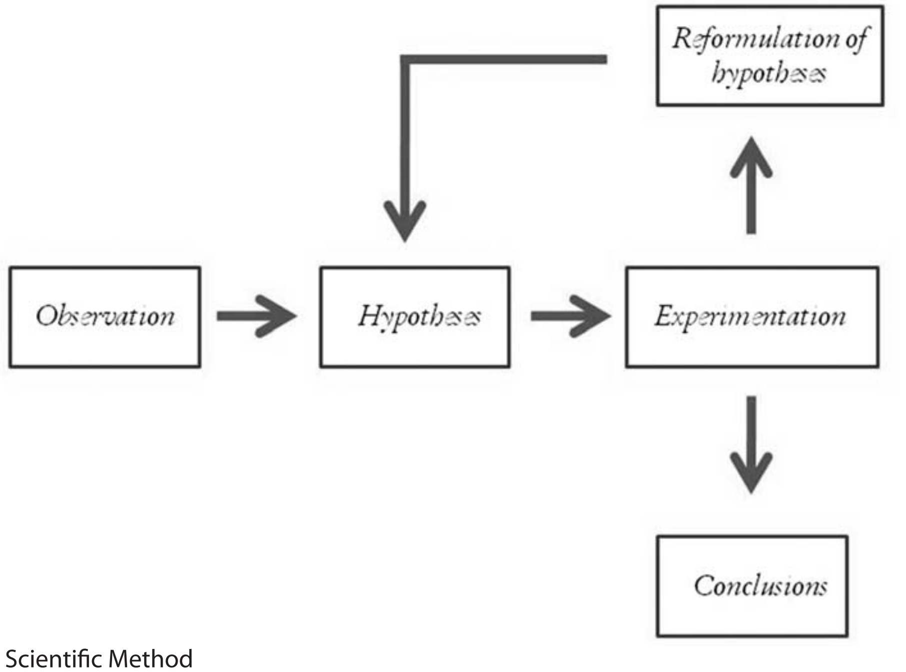

Figure 1. The Scientific Method

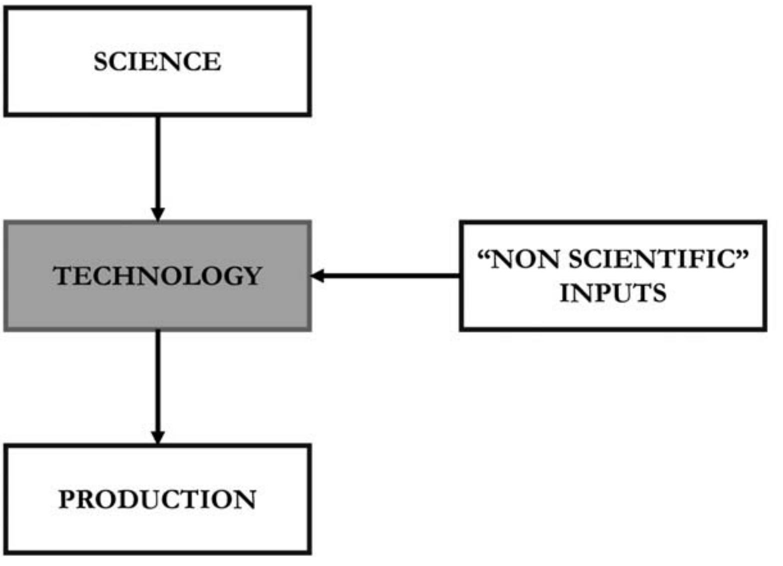

Figure 2. Science, Technology and Production

In Fig. 2 we present a scheme of our vision of the relation between Science, Technology and production.

We should not interpret from the above figure that it is necessary that science precedes technology. Bernal (1986) provides the following counterexamples:

- Bows and scales were used much before Archimedes formulated the lever law. However, the lever law provided the basis for the a-posteriori development of technological developments more elaborated than bows and scales.
- The cathedral builders, in the middle age, did their constructions before the corresponding scientific knowledge was available (Bernal 1986).

Technological developments also impacted on the development of Science; e.g. the construction of precise clocks enabled the development of accurate scientific apparatus and also opened a research field on dynamics. The first mechanical clock can be traced to the year 1286 (Cardwell 1995) and the mechanics for understanding and improving the clock was developed much later by Galileo (1564-1642) and Newton (1643-1727).

A society that is willing to transition from scientific knowledge to technological applications needs to construct the "knowledge development chain" pictured in Fig. 3.

However, neither is the above scheme the only way for a society to develop Technology nor is it the mandatory route for Science.

We can conclude that,

- Technology is not the mandatory objective for developing Science.
- Science is not the necessary prerequisite for developing Technology[1].
- BUT ... when they are matched they can produce high benefits for society.

In this sense, it is important to remark that two important news items in the XX century were Engineering Sciences and Applied Scientific Research.

Vannevar Bush´s vision in the US (Bush 1944):

> "Advances in science when put to practical use mean more jobs, higher wages,

[1] A powerful technological development does not necessarily require a solid scientific establishment and the Korean case is a very illustrative example [Dong-Won and Leslie 1999].

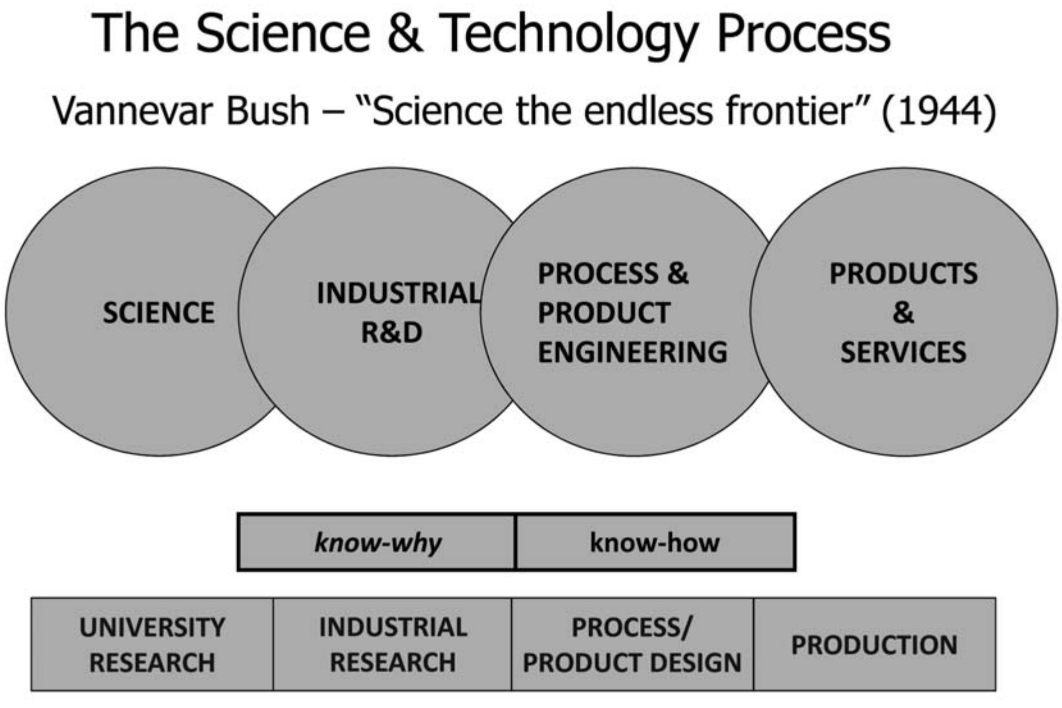

Figure 3. Science and Technology Chain

shorter hours, more abundant crops, more leisure for recreation, for study, for learning how to live without the deadening drudgery which has been the burden of the common man for ages past. Advances in science will also bring higher standards of living, will lead to the prevention or cure diseases, will promote conservation of our limited national resources, and will assure means of defense against aggression. But to achieve these objectives –to secure a high level of employment, to maintain a position of world leadership- the flow of scientific knowledge must be both continuous and substantial."

The Bernardo Houssay vision in Argentina (Houssay 1960):

"Some people believe that Science is a luxurious item and that the most developed countries spend on Science because they are rich. Big mistake; they spend on Science because it is an excellent investment and in that way they get even richer. They do not spend on Science because they are rich and prosperous but they are rich and prosperous because they invest in Science. Nothing gives higher revenues than scientific and technological research."

2. Innovation

Absolute innovation is doing what has not been done before by anybody.

In Science the concept of innovation is absolute and it is also absolute in the very competitive high tech industries.

In other more traditional industries (e.g. the steel industry) we can distinguish local innovation: the process through which a company provides a product or service new to that company or even to its country (Branscomb 1993).

In te '50s the MIT mathematician Norbert Wiener defined four conditions for innovation (Wiener 1994):

1. The generation of a new concept
2. A technological environment that makes possible the development of the new concept.
3. The integration between scientists and producers.
4. The innovation stimulus.

3. Science and/or Technology: motivations

In Fig. 4 (Stokes 1997), research and development activities are classified according to their scientific and/or technological motivations.

In the first quadrant we localize routine engineering activities.

In the second quadrant (Edison's quadrant) we localize very innovative technological activities with low scientific interest.

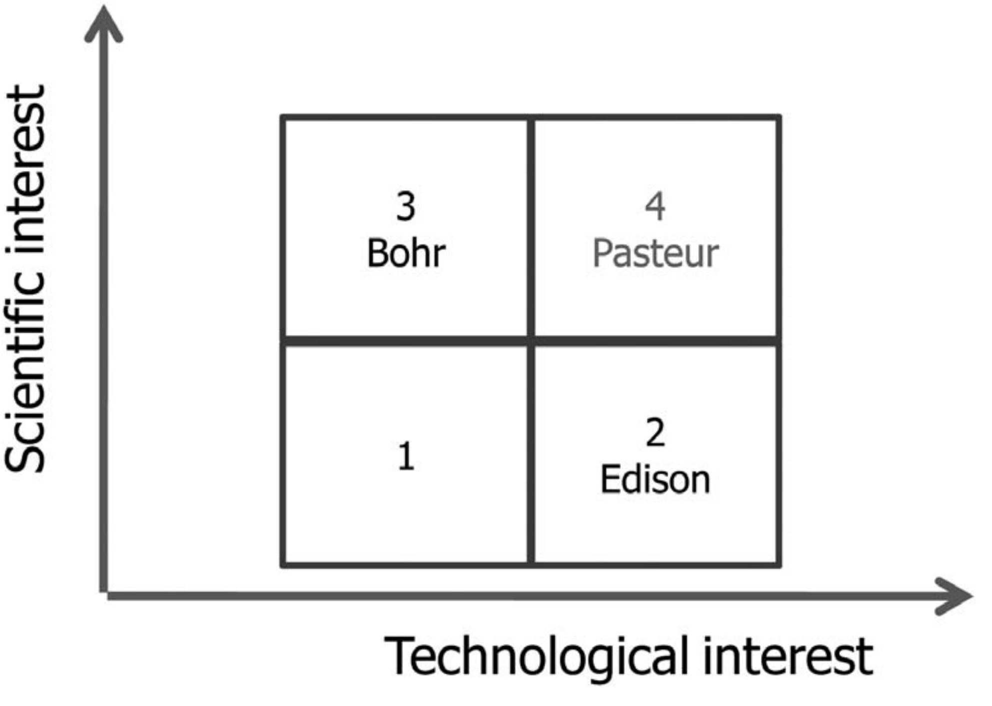

Figure 4. Stoke's four quadrants diagram

In the third quadrant (Bohr's quadrant) we localize activities that have a high scientific interest and do not lead to technological developments.

In the fourth quadrant (Pasteur's quadrant) we localize activities with high scientific interest and high potential for technological innovation.

The desideratum is to evolve the country S&T system to Pasteur's Quadrant.

How to evolve?

Pushing from the side of the scientific offer is good for the scientific system; but, as it is schematized in Fig. 5, we may end up incrementing only the Bohr quadrant without any actual impact on technological development.

It is necessary to pull from the side of industrial demand.

But, who can drive a powerful industrial demand?

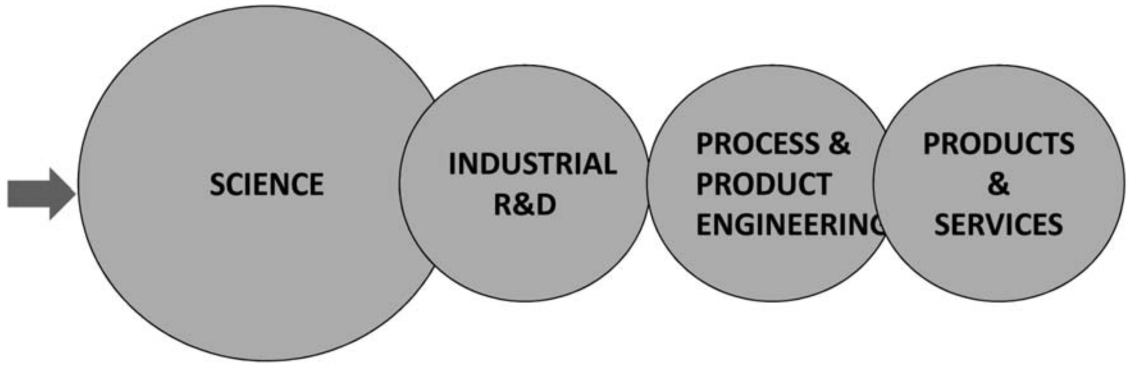

Figure 5. Pushing from the scientific end

In table II we present some international examples:

Table II. R&D Drivers

Country	Main demand drivers for R&D
US	DOE, DOD, NIH, etc.
EU	European Programs
Japan	MITI
Brazil	Petrobras, Embraer, etc.

Only governments can undertake long term and risky research projects.

To evolve to Pasteur's Quadrant, Argentina needs to rebuild its public sector urgently.

In the following picture we show the well-known Sábato Triangle, a scheme of the desirable interaction between the main stakeholders in the technological development process.

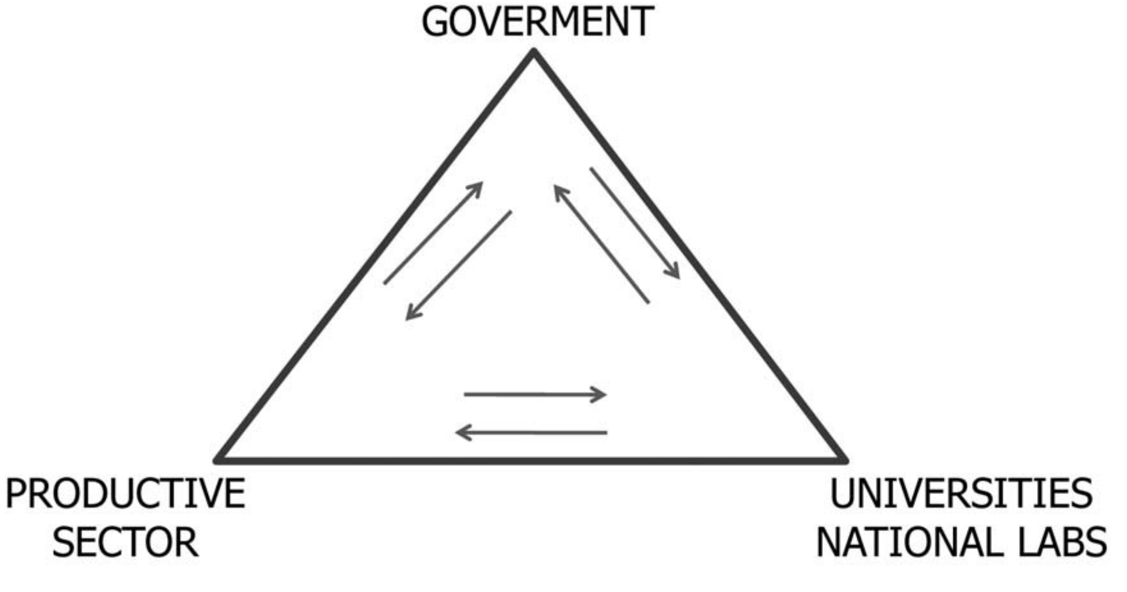

Figure 6. The Sábato triangle

4. Is Argentina investing in S&T?

The answer is yes; and also, as a result, Argentine scientific production is increasing.

However, we are still not spending enough resources in the field as can be seen from the international comparison made in Fig. 8.

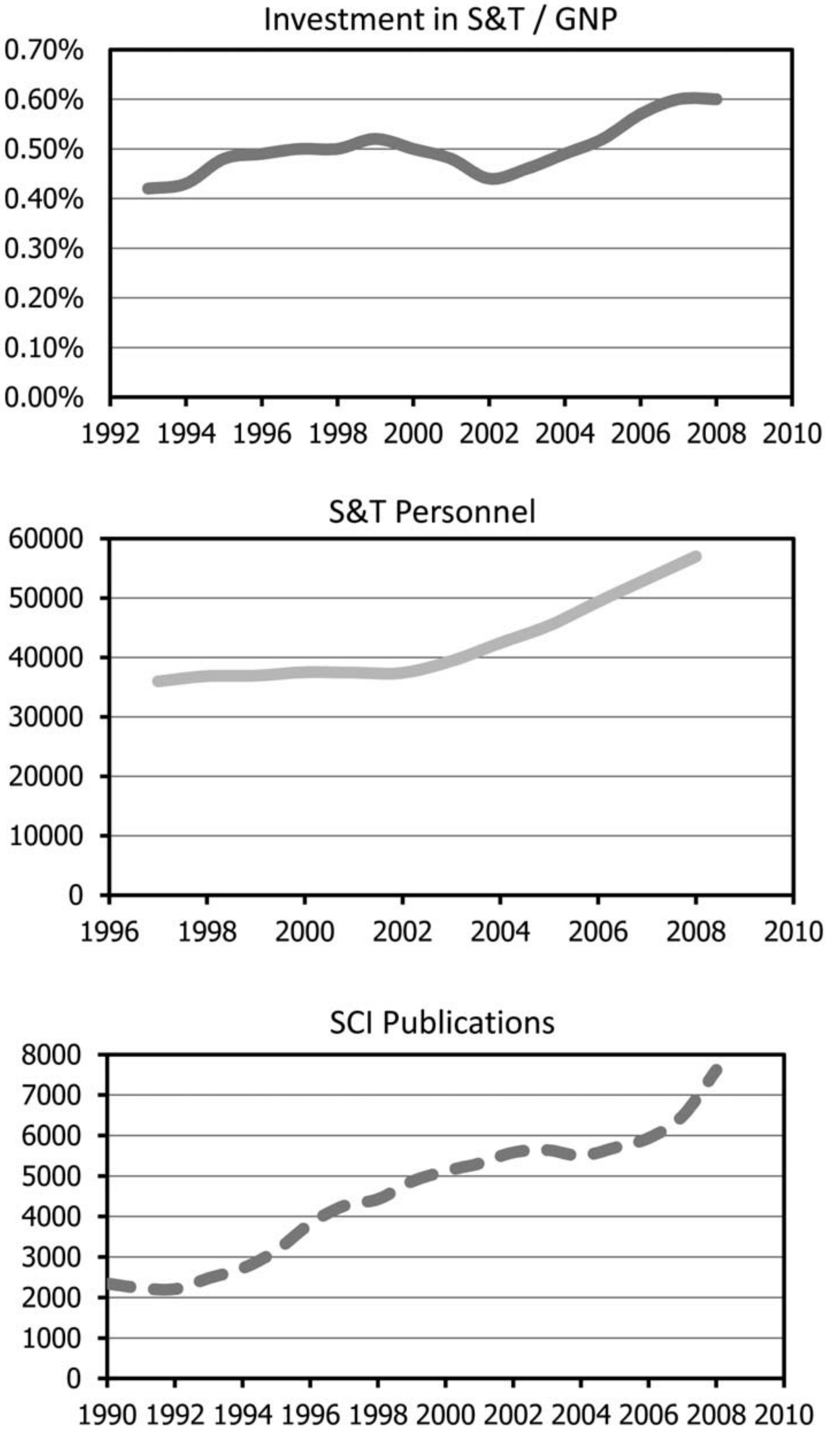

Figure 7. S&T Investment in Argentina

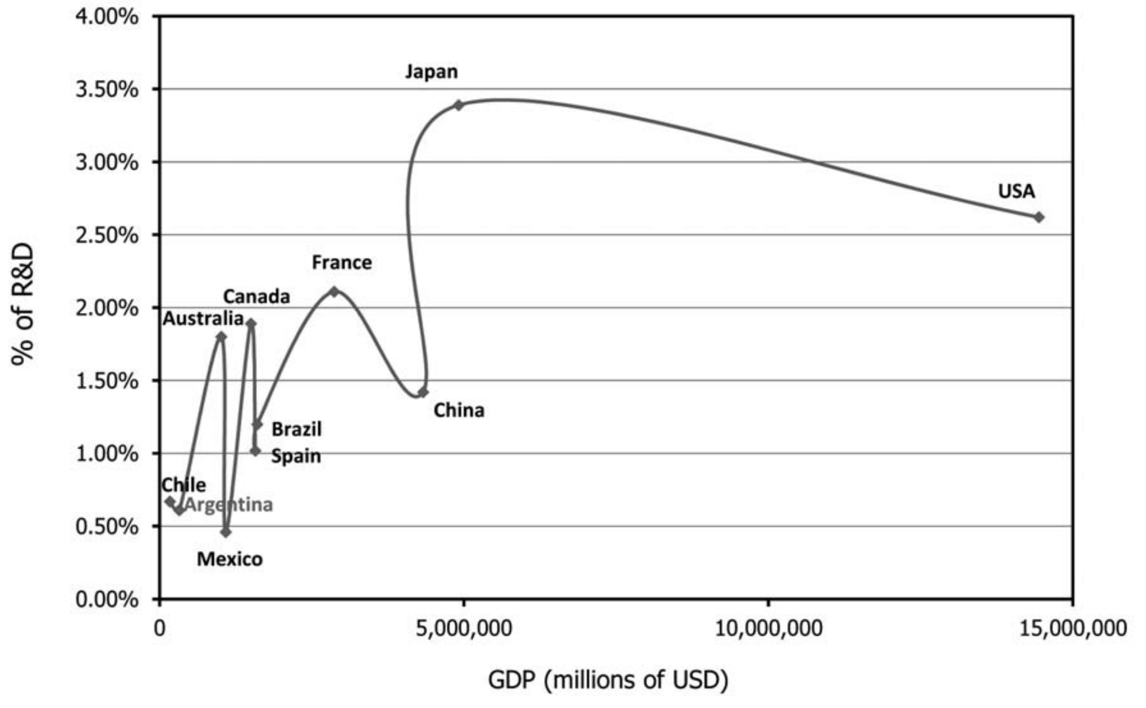

Figure 8. Expenditures in R&D as part of the GNP

It is important to point out that this growth in Argentine Science, has not yet had an equivalent impact on Argentine Technology production.

5. Argentina successful cases of Science and Technology interaction

In this Section we are going to very briefly summarize some successful Argentine cases of S&T interaction.

Company	Owner	Fields
INVAP S.E.	State owned	Nuclear, satellites, radars, industrial equipments, medical systems
CONAE / VENG S.A.	State owned	Satellites and launching vehicles
TENARIS - Siderca	Private company	Seamless steel pipes
IMPSA	Private company	Hydraulic turbines, wind generators
INTA - Bioceres	Public – Private cooperation	Transgenic species
INTA and various agricultural machine manufacturers	Public – Private cooperation	Precision agriculture
INTI	State owned	Development of "enhanced cheese"; development of paintings with bactericide properties
CONICET - SANCOR	Public – Private cooperation	Development of "enhanced milk"
BIOSIDUS	Private company	Development of human proteins in genetically engineered organisms
Laboratorios Beta-IBYME-CONICET	Public – Private cooperation	Development of human recombinant insulin
UBA-CONICET-INTA-BIOSIDUS	Public – Private cooperation	Cows cloning for the production of medicines

6. Conclusions

The importance of Science for the development of the country is well recognized in Argentina. The transition from Scientific Knowledge to Technological Applications needs more pulling from the public sector.

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The Role of Engineers and Seed Capital Funds in the Creation of Technology Based Companies

Tobías Schmukler[1]

Abstract. The work of engineers is a fundamental link within the chain of creation and management of technology based companies (TBC´s). Their education grants them two virtues: On the one hand, their training in hard sciences –composed by a base of mathematics, physics, chemistry, etc. – and on the other hand, a clear orientation in the development of a capacity to solve concrete and real problems. These characteristics set engineers as the ideal professional to take scientific inventions to the requirements of the market. This can be seen both as a nexus between scientists and innovations, or by developing their role as investigators from early stages. In both cases it is important to highlight that those persons who did the initial development must participate in the company, so as to be able to contribute with the evolution of the technology, as is actually demanded by the market. Seed Capital Funds, with their supply of capital, and fundamentally their management, will, in the end, become a complimentary piece so that these technology based companies take a quantitative leap and grow to their fullest potential, hence creating a significant number of jobs, and in particular, of highly qualified labor. In this paper, I propose to list five fundamental aspects in the creation of technology based companies, so as to reach a conclusion in my closing statements.

Resumen. El trabajo de los ingenieros es un eslabón fundamental dentro de la cadena de creación y gestión de empresas de base tecnológica (EBT). Su educación les otorga dos virtudes: por un lado, su formación en ciencias duras -compuesta por una base de matemáticas, física, química, etc. - y por otro lado, una clara orientación en el desarrollo de la capacidad de resolver problemas concretos y reales. Estas características determinan que el ingeniero sea el profesional ideal para ajustar los inventos científicos a las necesidades del mercado. Esto puede verse tanto como un nexo entre los científicos y las innovaciones, o mediante el desarrollo de su papel de investigadores de las primeras etapas. En ambos casos, es importante destacar que aquellas personas que hicieron el desarrollo inicial deben participar en la empresa, a fin de poder contribuir con la evolución de la tecnología, de manera de satisfacer la demanda el mercado. Los "Fondos de Capital Semilla" –con su oferta de capital, y fundamentalmente su gestión- suelen convertirse en la pieza complementaria para que estas empresas de base tecnológica logren dar un salto cuantitativo y crecer al máximo de su potencial, y por lo tanto, la creación de un número significativo de puestos de trabajo, y, en particular, de la mano de obra altamente cualificada. En este trabajo, se presenta una descripción de los cinco aspectos fundamentales en la creación de empresas de base tecnológica, que fundamentan los enunciados presentados en la conclusión de cierre.

[1]. President and CEO of InnovaTekné

1. First obstacle: to set the challenge

I believe it is useful to use concrete examples so as to translate them into effective premises:

- Twenty years ago, a professor from the "Universidad Nacional del Sur" (UNS), Eduardo Nebot, went to live to Australia. In Sydney, he heard a dissertation by a group of engineers that worked designing machines that printed logos on carpeting, and these engineers thought they were the best in the world in at doing that. These engineers, effectively, later on created one of the best centers dedicated to the automation of different kinds of tasks at the global level. Among their best-known works is the technology that is part of the most highly automated port in the world, Sydney, Australia. Working on this example, the Argentine professor was also able to imagine himself as a number one, and with help from the Argentine university, was able to build one of the most successful and innovative technology companies applied to the transport sector.
- Another is my own personal case. I worked at the CNEA (the Argentine Atomic Energy Agency) from 1981 to 1984. At that time, the level of equipment at CNEA was of world-class nature. In 1984 I started working at Hewlett-Packard and I traveled to Sunnyvale in Silicon Valley so as to receive training. There, I realized that my education at UBA (University of Buenos Aires) had not only been very good in sciences –specifically mathematics, physics or electronics, but also –thanks to the time I had spent at the CNEA- I had acquired knowledge that was comparable to that of the engineers working at the research and development department in the PC area at Hewlett-Packard. Strongly convinced that I could do something truly "big", at least from a qualitative point of view, in 1986, I founded a company that some years later, with more than 300 employees and 50% total market segment share, went on to be a leader in its sector.

These two examples clearly exemplify how fundamental it is to be able to discover that those companies or persons that are the "leaders" are by no means unsurpassable or unreachable. Quite the contrary, they are there to be reached and surpassed. The key is to really think "big-time" and tear down your own mental barriers which impose self-limits on yourself and which represent one of the greatest impediments –if not the greatest- when it boils down to creating a company.

2. Second obstacle: practice

It is very ineffective to try to create companies out of a laboratory. The ideal scenario, in this sense, is that engineers be in contact with the markets and market place, so that they can know and understand the concrete needs and ideas about making innovative products or services that are in a sense tailored to that reality.

The ways are varied. As an example of effectiveness we can analyze the Center for Research, Development and Innovation in Engineering and Industrial and Design, known as CIDIDI in Argentina. It is a venture undertaken by the School of Engineering at the University of Buenos Aires, jointly with the Government of the City of Buenos Aires and the Ministry of Science and Technology, which acts as a center for convergence to provide services within the area of steel manufactures' industry chambers so as to find innovative solutions for their manufacturing needs.

Something quite similar occurs in Australia, though with a much more innovative approach. Various mining companies have organized an investment fund –which is also funded by the government- through a scheme called Collaborative Research Centers or CRCs. Through these centers, industry takes its technological needs to the universities that participate in the CRC program, thus producing innovations, and the added benefit of Spins Offs. Let me be clear on this: In this scheme the university does not provide services but rather takes on the role of creating new technological solutions and new companies, that are capable of selling these new technologies. It is important to highlight that these companies are organized based on their capacity to originate technologies, with which they become highly competitive in the international market.

Some examples of this kind of model for incubating companies like these TBCs are Locata for its disruptive positioning technology and Acumine and Cohda for their wireless state of the art vehicle-to-vehicle communications systems.

Taking into account this case as a successful example, it would be very interesting-as well as beneficial- that certain Argentine Industry Chambers be called upon and/or make contact with research centers with their needs and requirements, so that scientists, engineers and all those that are part of the scientific community knowledge base, have access to the real world needs of different markets so as to work hand-in-hand, within a well planned context, to create future TBCs.

As an example, the associations that bring together the farming sector in Argentina could request the technology they need to specialized centers created for that purpose, instead of importing it. This would mean an enormous benefit for Argentina's trade balance and international trade.

3. From an innovation to an innovative company

Deciphering the needs of innovation is not everything. An innovation in itself does not become an innovative company. An innovation just represents a small, static part of a TBC that is complemented with other key resources: tangible ones, like finance and H.R.; and intangible ones –which are profoundly important- such as the culture within the company.

Consequently, to properly conform these TBCs it would be very beneficial to organize multidisciplinary groups at the core of the universities -whether they be public or private-, so that they form there a diverse professional integration that could produce a synergy in the generation and the operation of these companies, which is ONLY possible –this is a significant ONLY- if certain cultural barriers are brought down, ideology being the most significant and difficult to tackle.

So as to produce new TBCs, Argentina´s national universities must not be guided by ideology which usually sustains itself in the past, but by a pragmatic attitude with a projection into the future, focusing on the country's most pressing needs. No doubt, it is my belief that one of them would be creating highly qualified jobs.

There should be a policy in favor of the creation of technology based companies within the core of universities that ought to include both a motivation to entrepreneurial start ups, as well as clear and simple rules regarding the transfer of knowledge, which in turn would warrant the birth of Spin Offs.

But faced with the lack of an accepted and agreed transference policy, universities adopt a particular decision on a case by case basis, by which the future of the company will not depend on its chances in the market or on the skill of its human resources, but sadly, on the circumstantial political composition of the academic council in office at the time that the Spin Off takes place, thus reducing its possibility to succeed.

4. Cultural-educational-structural problems

As I have stated in point (II), without proper proximity to the market, the probability that a researcher undertakes a development and solution that would solve a real need becomes quite vague. And if we factor in that there are very few places where this interaction takes place, it becomes absolutely clear in my mind that undertakings like the one started by CIDIDI, but oriented at the creation of new companies become and are an absolute priority.

On the other hand, and in particular, cultural and ideological barriers add even more complexity -in a completely negative sense- to the relationship between academics and industries. This is further deepened by the low valuation and/or understanding of the benefits that a TBC produces in society (i.e. jobs, taxes, income, etc.) from the perspective of the university's scientific community. Hence, a relationship between a university or research center and a corporation becomes a "bad thing", which leads to a lack of interest and incentive on behalf of companies towards scientific institutions, and in some cases, from the investigators and scientists themselves who believe in cooperation between academics and corporations, but they abstain from doing so for fear of pear rejection or disapproval, and in some cases, even reprimands from their superiors.

Some statistics which show Argentina as one of the most entrepreneurial countries in the world are mistaken when they group high potential technological start-ups with those that are not so, and endeavors for subsistence or low scale ones, with those that have real relevance and that could lead to a beneficial change to living conditions in the country. If you start out with an incorrect diagnosis, that insures you will not find a correct solution to the problem at hand.

If we make this determining condition, the perspective changes and it is possible to state that Argentina lacks a true entrepreneurial attitude in the scientific field. This is related to the fact that there is a very low value assigned to scientific entrepreneurship, which is frequently earmarked as a person that was not able to build an academic career; while academic careers do not offer enough or any incentives to create applied knowledge. Additionally, there are also some negative legal and regulatory issues within the national scientific system.

The Law of Public Ethics, for example, does not contemplate the creation of Spin Offs, which in fact, could actually lead to a scenario of penalizing investigators and university professors if they were to create and work in a TBC, because in their vast majority, these investigators and professors are categorized as public employees. Due to the fact that this law is quite old, it is necessary to contemplate legislation that admits the creation of companies as a consequence of State-generated Spin Offs.

In the meantime, regulatory problems derive from the internal norms and regulations of universities and research centers. In example as follows:

- Part time participation in Spin Offs is not contemplated in scientific or academic careers. Since there is no leave time or the possibility of reducing their full time dedication working schedules, academics and researchers must opt between resigning, without the possibility of recovering their jobs later on, even when their participation would produce not only economic benefits through royalties for their universities but also significant academic and peer recognition. This is in complete contradiction with the customs held true by institutions in other countries where professionals are motivated to take on the challenge of creating companies.

- Not all universities have a proper regulation of their intellectual property policies, which acts as a detriment to the validity of transfer from the academic environment to the company that is created.
- There is no valid liaison in projects with many participants. Many of the projects developed at universities have their intellectual property spread among various universities, as well as among various research agencies. This complicates both the negotiation as well as the approval of each of these transfers.
- There are no relevant experiences in national Spin Offs properly executed, nor approved reference parameters.
- Lastly, but of utmost importance, appears the need to consider changes in the curricula and include "soft" subjects in "hard" university careers. It is a limiting factor for engineers and scientists in general to graduate without being familiarized with, among many other things, basic notions regarding human resources, leadership, motivation and, in other fields, such as knowing what the corporate charter or articles of incorporation of a company are, what they imply and mean, or managerial language, as well as not having any basic knowledge of administration and finance.

5. From an innovative company towards the achievement of maximum potential –the first step to increase hiring and job creation

Once the company has been created, comes the time to take a qualitative leap forward, which is much more likely to occur with the help of a Seed Capital fund which provides much needed management and capital, so as to trigger a TBC going from a few dozen employees to hundreds of them.

Seed Capital funds add corporate capability, which is not reduced to "knowing how to sell" a product or "keeping the books" or doing "tax errands", not even to the more relevant issues such as hiring new employees or negotiating contracts, but instead to a much more significant aspect which is to set an effective and efficient strategy for the young company to survive, grow and prosper.

Corporate capability may be achieved through a process of trial and error by the engineers and scientists themselves, by taking on consulting, or through the incorporation of new partners with experience in business ventures, which is usually felt as a dilemma by these engineers and scientists, due in part to mistrust, but fundamentally to a low appreciation of the value that a business partner may make. This is one of the causes by which Argentina is not completely "comfortable" or accustomed to Venture Capital in general, or Seed Capital in particular.

Conclusion

Scientists and engineers in first place, businessmen in general, and funds that invest and provide management and experience in new companies based on knowledge must participate in the preparation of the policies and of the science strategies in a country.

It would be naïve to expect that TBCs will be founded without the involvement of those who participate in their management and invest in their early stages by providing their vision and experience to the general day-to-day guidelines.

The steps are very specific: the creation of adequate fields where engineers can be in close contact with the real needs of the market is completely crucial; it is fundamental that subjects that contemplate "business realties" and "soft" subjects be included in the education of all scientific and engineering careers; we must tear down all the cultural barriers that separate universities and scientific research centers form contact with companies and Seed Capital funds; and we must promote joint work among Government, Research Organizations, Corporations and the sector responsible for Capital Investments and Professional Management.

All in all considered, I believe that for Argentina to be recognized by the highly developed lifestyle of its people, apart from it already being well known for its brilliant soccer teams, inspiring tango and splendid geography; it is fundamental to achieve awareness about the importance of setting a common course to follow, in which the creation of knowledge-based companies occupies a central and relevant space, given that, without any doubt whatsoever, these are the undertakings that are capable of making a difference in the balance of the indexes that indicate development, and fundamentally, for the creation of highly qualified jobs in Argentina.

Reflections on the Promotion of and Approach to Technological-Productive Capacity

Pablo Abbate[1]

Abstract. Governments, scientific and technological institutions, and the firms of a nation (vertices of “Sabato’s Triangle”) are key elements to foster its growth and to improve people’s living conditions. But it is necessary that these actors work in an articulated and organized way so as to align their individual contributions and to develop positive factors of support and feedback. INVAP SE 34-year experience shows that: (1) Development and growth of national sustainable technology-based firms of highly-advanced engineering are possible, even in non-OECD countries; (2) governments, by means of their investment programs, may offer excellent opportunities to develop local skills that will then bring about export business opportunities; (3) implementation of national solutions and projects offers opportunities to articulate the action of local science, technology and engineering, thus saving large quantities of money and contributing to the improvement of skills; (4) export of technology-based goods helps to reformulate the export profile of a country, contributes to the growth of its international presence and improves the quality of goods and services supplied in the domestic market; (5) technology-based corporations are excellent anchors to promote the development of specific regions; they encourage the establishment of attractive networks of suppliers, and contribute to the settlement and retention of highly-qualified staff and their families, they constitute the natural relationship between the scientific-technological system and the market; (6) the concrete transfer of knowledge to the production system is achieved when scientific institutions are conceived as a service to the society which developed and supported them; (7) the potentiality of a sector is achieved in a productive way when challenges are faced with courage, decision and confidence in personal capacities and when, from governments, there are contributions through policies which remove obstacles and promote the implementation of high added value projects. This paper analyzes the impact on the development of the technical-institutional tripod caused by high-tech projects and initiatives and advanced engineering which can be financed by governments to meet concrete needs. It is concluded that the intelligent use of the State’s purchasing power is a powerful tool to help to boost and focus the production capacity of a country; and that the implementation of large technology-engineering-based projects can be an excellent driving force: to generate cooperation and consensus between interested actors, to solve concrete problems and fulfill needs and to contribute to the betterment of social issues by providing sources of employment and the retention of highly-qualified staff.

Resumen. Los gobiernos, instituciones científicas y tecnológicas, y las empresas de una nación (vértices del “Triángulo de Sábato”) son elementos clave para fomentar su crecimiento y mejorar las condiciones de vida del

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pueblo. Pero es necesario que estos actores trabajen de manera articulada y organizada, con el fin de alinear sus contribuciones individuales y el desarrollo de factores positivos de apoyo al sistema. La experiencia de 34 años de INVAP SE muestra que: (1) El desarrollo y el crecimiento de las empresas nacionales sostenibles basadas en la tecnología de la ingeniería muy avanzada es posible, incluso en países no pertenecientes a la OCDE, (2) los gobiernos, por medio de sus programas de inversión, pueden ofrecen excelentes oportunidades para desarrollar las capacidades locales, que luego traerán oportunidades de negocio sobre la exportación, (3) la implementación de soluciones y proyectos nacionales ofrece oportunidades para articular la acción de ciencia, tecnología e ingeniería local, con el consiguiente ahorro de grandes cantidades de dinero y la contribución a la mejora de habilidades endógenas, (4) la exportación de productos basados en la tecnología, ayuda a reformular el perfil exportador de un país, contribuir al crecimiento de su presencia internacional y mejora la calidad de los bienes y servicios suministrados en el mercado interno, (5) las empresas de base tecnológica son excelentes anclas para promover el desarrollo de regiones específicas, fomentar la creación de redes atractivas de proveedores, y contribuyen al establecimiento y la retención de personal altamente cualificado y sus familias, que constituyen la relación natural entre el sistema científico-tecnológico y el mercado; (6) la transferencia concreta de conocimiento para el sistema de producción se logra cuando las instituciones científicas se conciben como un servicio a la sociedad que la desarrolla y la apoya; (7) la potencialidad de un sector se realiza de una manera productiva cuando los retos se enfrentan con valentía, decisión y confianza en la capacidad personal y cuando, desde los gobiernos, hay aportes a través de políticas que eliminen los obstáculos y promuevan la implementación de proyectos de alto valor agregado. Este trabajo analiza el impacto en el desarrollo del trípode técnico-institucional, fomentado por los proyectos de alta tecnología, iniciativas e ingeniería avanzada que pueden ser financiadas por los gobiernos para satisfacer necesidades concretas. Se concluye que el uso inteligente del poder de compra del Estado es una herramienta poderosa para ayudar a potenciar y concentrar la capacidad de producción de un país, y que la realización de grandes proyectos de tecnología basados en la ingeniería puede ser un motor excelente: generar la cooperación y el consenso entre los actores interesados, para resolver problemas concretos y satisfacer las necesidades y contribuir a la mejora de los problemas sociales al proveer fuentes de empleo y la retención de personal altamente calificado.

1. Introduction

Innovation and the improvement of productivity it entails are driving forces that promote economic development. In the global economy of the beginning of the 21st century, technological development and innovation in engineering are key elements to ensure the competitiveness of countries. The global market, increasingly more competitive and integrated, is gradually reducing the number of local niches in which it is possible to implement solutions that are not in line with the use of advanced technologies.

The challenges that a country faces to answer to this global economy should be dealt with in such a way as to ensure that, in that process, people's living conditions are also improved. This improvement should therefore provide a framework which will contribute to increase of academic levels and the generation of jobs for skilled staff, with the consequent trickle-down effect of advantages in health, eradication of poverty and environmental and social sustainability. It is the innovation capacity, the creation of new services and products, which should have a leading and decisive role in the accomplishment of this goal. On the way, this will lead to include and encourage sectors of the population which have been left out of the production cycle.

As a consequence of innovation processes, the development of technology and the implementation of engineering techniques transform scientific knowledge in products and services that meet the needs of a country and of markets. They also give rise to the creation of employment and import substitution.

Innovation in the field of technology and engineering goes hand in hand with the opportunity offered by the solution of tangible problems from two perspectives:

- On the one hand, there is the strategic investment and innovation carried out by firms with their own capital. In some cases, firms adopt and elaborate ideas or technologies initially developed within public programs (for example, in USA, developments derived from the know-how financed by the NASA or military programs). This scheme is the one applied by international large corporations which generally locate their innovation centers in their countries of origin, although in recent times they have established ad-hoc development centers in countries with lower labor costs and high availability of skilled workforce, such as India and China.

- On the other hand, there are the opportunities that represent for the scientific-technological-business tripod of a country the solution of specific problems and requirements of governments. The development of quite large and advanced projects can act as an excellent driving force to increase innovation levels, attract the attention of industry and grease the mechanism of co-operation between the actors that make up the technical tripod.

This paper describes the case of the Argentine company INVAP, that illustrates how it is possible to implement a model of technology-based firm in Argentina, that promotes the know-how developed to meet the real needs of a country and generates export opportunities and, at the same time, serves as a motor for a network of supplier companies that contribute to the welfare of the population.

2. The case of INVAP

History and Present Time

INVAP is an Argentine company (800 employees and an annual turnover of 70 million US dollars) engaged in the design and construction of complex technological systems and solutions. The company was established 34 years ago as a "spin-off from the laboratories that the Argentine Atomic Energy Commission has at the Atomic Center of Bariloche; the company's purposes are to act as the executor within the Argentine Nuclear Plan and to create high-level jobs in the Province of Rio Negro. Among the most relevant achievements in its initial stages, it is worthwhile mentioning the development of uranium enrichment technology in Argentina (1983) and the construction of the nuclear reactor RA-6 in Bariloche (1984).

INVAP has developed wide experience as the main contractor of high-tech projects, which have been established in Argentina and in other countries of the world. Its main activities are focused on satellites, radar systems and experimental nuclear reactors. INVAP has also carried out some projects in other engineering fields such as: extractive metallurgy, metal processing technologies, optimization of industrial processes, nuclear medicine, wind power, radioisotope production plants, petrochemical processes and lyophilisation plants.

In the nuclear field, its main products are nuclear reactors for the provision of medical radioisotopes and scientific research. In this area, INVAP has become a leader in the market, competing at the same level with large international companies such as Siemens (Germany) and Areva (France). INVAP has built this type of facilities in Argentina, Peru, Algeria, Egypt and Australia, through turnkey supply contracts. For example, the OPAL reactor project in Australia (200 million US dollars, 1999) comprised the engineering and supply of fifty primary systems that required more than 1,500,000 engineering man-hours within a 6-year period. INVAP coordinated the supply of more than 100 firms from several countries and was in charge of the project planning, management and logistics. Its long expertise in the nuclear field has allowed INVAP to become the advisor and contractor of strategic projects of other nuclear companies such as Westinghouse Nuclear and Babcock & Wilcox in USA, and AECL in Canada.

In the field of aerospace industry, INVAP is the only company in Latin America certified by the National Aeronautics and Space Administration (NASA). This Agency and the Argentine Space Agency (CONAE) have entrusted INVAP with the construction of a group of three satellites, the SAC-A, the SAC-B and the SAC-C. These satellites include useful instruments to measure parameters on Earth and in space. INVAP is currently working on the design and construction of three other satellites: Aquarius/SAC-D, which will carry an instrument provided by the NASA (estimated cost is 200 million US dollars). This device will map and measure global sea surface salinity and is part of a program to analyze climate changes on Earth; the second is a geostationary communication satellite for ARSAT; and the third will carry a group of antennas than operate in the microwave spectrum for Earth observation.

Due to its expertise in instruments and satellites, INVAP is developing and manufacturing, in compliance with strict international air regulations, a group of 20 radars for air traffic control at the request of the Argentine government. In this same field, INVAP is currently developing the technology for the construction of radar for military applications and air space control of frontier areas. These two devices are expected to become export products in the future.

Mission and Strategy

INVAP is a designer and constructor of complex technological systems, of the “mission-critical” type. Its mission is to supply systems and solutions designed to meet its customers’ requirements wherever they are located.

INVAP strategy is aimed at penetrating new product lines and developing specific know-how through the supply of solutions and projects in Argentina to meet the country’s needs. Its success is the result of the combination of a policy of competitive prices with a competent management of technology in line with international quality standards and an attitude of co-operation with its clients to provide them with custom-made solutions. The following step is the use of knowledge and expertise acquired through projects carried out in our country to undertake the search of commercial opportunities abroad.

INVAP Business Model

INVAP’s business model is entirely based on revenues from the sales of plants and equipment. The terms of many of the contracts are of 3- to 5-years, which what means an attractive backlog of work. However, the company does not have repetitive or continuous operations or extended service contracts which would provide a continuous flow of income. Due to the features of custom-made development of many of its projects, it rarely has the opportunity of obtaining the benefits of a scale economy in the manufacturing of equipment. Two exceptions in this regard are the series of TERADI units for medical radiotherapy treatments and the series of INKAN radars for air traffic control.

Since its highly-qualified staff is the core of the company, INVAP cannot take the risk of not retaining its group of technologists and professionals once a projected has been completed. The result is a low staff turnover and fixed labor costs except for those services provided by external consultants. To mitigate and compensate the impact of this issue and to be able to face the requirements posed by several on-going projects, the staff is particularly flexible about moving from one project to the following and from one business unit to another; this brings about the additional benefit of cross fertilization.

To expand as much as possible the image and prestige acquired in specific projects to other branches of technology, the company operates under one single corporate name which is "INVAP".

Some Features of INVAP

Here is a list of some features of INVAP, with some comments about them, highlighting the impact they have had on its development and growth.

Scale of Values and Purpose: INVAP has a scale of values and has remained faithful to it since its origins. These values include doing business in an honest and transparent way, and being in favor of agreements through dialogue over litigation; the precedence of quality over cost. Concern about the well-being of its staff is of high priority for INVAP and, consequently, it considers it important that salaries guarantee a decent standard of living, although this implies that workers in the lower segments receive salaries higher than the market average. Moreover, the company is aware of its objective and purpose as a factor to promote technological development in Argentina and to create jobs for qualified people in Patagonia. All these go beyond the mere objective of gaining economic profits which, nonetheless, is a sine qua non condition to ensure its sustainability and growth.

Company: INVAP SE, even though state-owned (SE stands for Sociedad del Estado), it considers itself as a corporation. This feature is clearly shown in the organization of its managerial structure, in its efficiency, planning, and approach in the search of business opportunities and the commercial activities it undertakes. This element plays an important role in the determination of the necessary reliability levels so that a foreign customer feels comfortable to enter into contracts with INVAP for the supply of projects of important contract prices and terms of five or six years.

Self-Financing: Since its creation, INVAP has operated independently, self-financed by the revenues from the contracts made with its clients, either public agencies or private companies. This modus operandi, without subsidies or budget allowances, requires a careful management of its operations and costs, and the concentration of all its efforts on its clients, to understand what they want and to provide them with competitive offers.

International: The company looks for and appreciates the possibility of working in association with foreign firms and agencies as well as participating in international competitive biddings and working for foreign private or governmental customers. Besides the revenues in foreign currency these contracts represent, INVAP values the possibility of "expanding limits", both institutionally and professionally on the part of its employees, and considers that international businesses are an excellent way to develop its technical and managerial staff and to enhance INVAP's corporate name.

Professionalism and Character: Since its creation, the success of the company has been related to the diligence, spirit and competence of its professionals and technicians. An entrepreneurial and "can-be-done" attitude is a characteristic of its staff members who are personally and professionally committed to the task or project in which they work. The idea of technological challenge is an underlying concept that is present in many of the projects that the company undertakes.

Staff Mobility: The nature of the business activities carried out by INVAP gives rise to a lifecycle of the projects and most of its groups of professionals and technicians are organized according to them. This mobility between projects, areas and work-mates has had a positive impact on the dissemination of successful experiences and methodologies, in the motivation and retention of technical staff, and in the promotion of an adaptation capacity and dynamism, essential on an agenda in which innovation has a key role.

Consistency and Alignment: Consistency is an attribute that characterizes the company and its Management. To a certain extent, this is the result of a low turnover of managers (throughout its history, it has only had two General Managers) and of the promotion to responsibility levels of the staff which has worked in many INVAP projects and has had the opportunity of apprehending the essence of the company's culture.

Resilience: As a result of the vicissitudes of the business world and the changing conditions Argentina has suffered since the establishment of the company, INVAP has also been affected by the ups and downs that have sometimes threatened its existence. The experience in facing these crises, together with the improvement in the management of conditions and contexts which have effects on its operations, has led to the development of some countermeasures and contingency plans which help to reduce to a certain extent the possibility and/or seriousness of future crises.

Faithful to its Competence: Along its history, INVAP has been defining its competence in an intuitive way. As a result, today the company is aware that it can be highly competitive in carrying out "mission-critical" projects in which elements such as reliability, availability, security and technological complexity play an important role.

These projects generally begin with considerable design and engineering work that is supported by a careful process of calculation and analysis of the designs, with state-of-the-art equipment for the calculation of mechanical, material and energy transport, and electronic systems, among others. Projects often comprise the processing of low-intensity electronic signals, design of redundant and failure-proof systems, with precision-mechanical applications, sophisticated instruments, operations in hostile environments and with high reliability. In other cases, works include the design and engineering of complex chemical processes, or the engineering of nuclear reactors.

The company also has an almost obsessive dedication to customers and their requirements, which has become a very important competitive advantage when participating in bidding processes and business proposals, over competitors more inclined towards reproducing previous solutions. It is in multidisciplinary works of development and integration of technologies, with a component of custom-made innovation and development, in which the groups of professionals of all INVAP engineering specialties make a difference.

Learning by Doing: As an integrated part of the methodology implemented to solve problems of development and technology applications, a combination of methods, analyses and calculation is used, complemented by the construction of models, prototypes and essays of principles or components. This approach helps to minimize the time of development, to detect at an early stage the difficulties of the designs, and to substantially reduce technical risks as regards project schedules and costs.

3. Example of Promotion and Approach Projects in INVAP

The company has grown through some emblematic projects, which have been the keys to enter into international markets and to have business opportunities with benefits largely surpassing the price of the first promotion projects. These so-called "Promotion and Approach Projects" share some distinctive features.

- All these projects were aimed at finding a solution for a concrete need of an Argentine governmental agency.
- In all these projects, a political decision was made to choose the national alternative over international actors with specific expertise in the topic.
- All of them were put into practice by means of contracts according to customary industry guidelines for technology and engineering projects, in compliance with explicitly-established project schedules and performance and quality requirements.
- In all the cases, the price of the contract was not higher than the one an international supplier would have charged.

The following are three case examples.

Nuclear Reactors. In the case of experimental nuclear reactors, the design and construction of reactor RA-6 in Bariloche (1984) laid the foundations of INVAP's present success in this field. From then on, and thanks to the reference and expertise shown in this reactor RA-6, INVAP has built six experimental reactors, some of which were awarded as a result of international competitive biddings or public tenders. At present, INVAP is a world leading company in this segment; for example, in the last international competitive bidding in Holland, the INVAP bid which amounted to more than 500 million US dollars, won over bids submitted by French and Korean companies.

Satellites. INVAP expertise in the design and construction of satellites and their instruments was developed based on the knowledge on high-reliability electronics, precision mechanics, materials and system analysis, consolidated by nuclear projects. In particular, it was necessary to hire SAC satellites through the Argentine government and to obtain the co-operation of NASA centers. From these first small scientific satellites, INVAP has shifted its interest towards communication satellites for ARSAT and large satellites for scientific purposes such as SAC-D. Based on technological development, the company has studied the international market and it is currently working, at an advanced stage of completion, on the design and assembly of a flight computer for the Brazilian Space Agency.

Radars. On the basis of the instruments designed for satellites grew the idea of constructing radars to meet the needs of Argentina in the field of air traffic control. At present, there are several on-going subjects in this area.

The case of INVAP reproduces and illustrates a way of development which is used in central countries. Governments use their purchasing power to promote technological developments with a degree of risk that private entities do not take on spontaneously. In the case of emerging countries, the equation is somewhat different since it is often possible to buy the product already developed by a foreign supplier; it is therefore necessary that governments consolidate a strategic and political vision in the long run which will take into account the local capacity to generate solutions and products.

4. Proposals

The following are some proposals for actions and policies that could help to multiply the technological-productive capacity. These are based on the idea that National Programs encourage Projects that in turn encourage the High-Added Value Industry.

To implement policies for the promotion of innovation and technological development

Public policies have a very important impact on the innovation capacity of the private and public sectors. These policies should encourage and be a source of motivation for the technical tripod, contributing to the mitigation and management of risks inherent in investments in innovative projects or in the implementation of advanced technologies. It is of vital importance that these policies promote the establishment of a framework and an ecosystem in which engineering innovation and the development of scientific-based technologies can germinate, by providing opportunities in terms of projects and conditions that mitigate some of the risks they face.

Among the measures that should be implemented, worth mentioning are:

a. Adoption of stable governmental policies on technology-engineering.

b. Systematic consideration of national companies to carry out the country's technology-based or engineering projects, provided that these comply with certain requirements, such as: cost should not be higher than that of an alternative project by an international supplier; performance and quality levels should be in compliance with international standards; projects should be audited and controlled by technically-qualified agencies; participation of actors from the national technological system should be maximized.

c. Promotion of the participation of the national technical tripod, together with foreign companies, as an additional requirement to hire the services of foreign companies in the cases in which they are necessary.

d. Coordination and implementation of tax incentives, for large projects of great importance, which are assessed as relevant due to their contribution to the growth and consolidation of national scientific-technological-engineering capacities.

To promote public and private financing in activities of scientific-technological-engineering development

The innovation capacity and the ability to capitalize on innovations depend to a great extent on the vitality of the scientific-technological-engineering system of a country. Investment in research and development, properly coordinated and in line with the business-engineering sector, can give rise to important increases in the productivity of a country and, consequently, in the living standards of the population.

As a result, the initiatives to be put into practice should:

e. Coordinate and give priority to activities of scientific-knowledge development which are in line with strategic technological and/or engineering projects of a country.

f. Allow for a proper balance between investments in scientific-knowledge development, consolidation of technological solutions and implementation of technology-based projects to meet concrete needs of a country,

g. Foster alliances and other co-operation schemes between the government, universities, research institutes and corporations.

h. Encourage corporate investment in critical technological areas to promote the country's growth.

To promote exports of plants, equipment, goods and services with a high scientific-technological-engineering component

The sustainability of the national technical tripod depends not only on the turnover and opportunities arising from the fulfillment of the needs of the companies and the government of a country, but also on the impact that export activities have. This is particularly important in the areas of reference in which the local demand for some products or services does not guarantee by itself, in the case of advanced technologies, the economic sustainability of companies operating in these fields.

As a result, actions and policies which promote and support the search for commercial opportunities abroad should be implemented, such as:

a. Implementation of special loans that ensure commercial competitiveness.
b. Implementation of a fund or mechanism for the provision of guaranties and bonds for international projects.
c. Encouragement of collaboration, business associations with international entities.
d. Development and adequacy of legal, customs, and tax regulations so as to take into account the problems of exports of high-tech industrial plants and equipment.

To create and support the implementation of educational initiatives which provide employees and employers with the necessary tools and knowledge to be able to compete in the global economy

Innovation capacity and competitiveness in the technical field depend to a great extent on the capacities and knowledge of professionals, technicians, and senior staff that make up the technical tripod. Countries should therefore adopt policies in support of technology and engineering that:

a. Enable education and educational improvement of the techniques and skills necessary to face technical and technological challenges.
b. Provide dynamic schemes that enable improvement, the organization of training courses and workshops according to needs.
c. Promote the exchange of successful experience among the various actors, favoring activities of reflection within the framework of workshops, forums or interest groups.
d. Encourage the development of projects with foreign institutions and organizations, favoring access to new technologies and knowledge.

5. Final Remarks

In his scientific-technological policy model, Jorge Sábato wrote about the three vertices or legs that contribute to this model and about the need for the state (as policy-maker and executor), scientific-technological infrastructure (as the sector of technology demand) and the productive sector (as user of technology) to be closely related in a permanent way in order to have a true scientific-technological system.

It seems that, to some extent, the message of Sábato has been altered in the course of time and that the vertices have given privilege to solving their challenges in quite an independent way, without using to their full potential the contribution that would result from the use of collaboration schemes with the other vertices. It is worth pointing out that this is no more than remembering that, in fact, Sábato's message is not focused on the vertices of his famous triangle but on their virtuous interaction, on the construction of growth spirals and on mutual support, with the ultimate goal of contributing to the development of a nation and to the welfare of its population.

A first diagnosis seems to show that interaction mechanisms between the actors should be improved and updated otherwise they will remain inadequate or ineffective. The world context has also changed and globalization has led to transformations that have altered nature and the behavior of the aforementioned actors and, therefore, the relationship between them. On the other hand, technology itself has suffered transformation processes and, for example, electronics, systems engineering and new materials have had an impact on the technological core of projects while the explosive development of communication and the new methods of information management have enabled a wide range of possibilities for collaboration and distance work between the actors worldwide. All this suggests that this may be a good moment to rethink and adjust the paradigms of technology-based project development, and thus not miss the contribution they may make to the construction and growth of society.

Corporate Training and Education in Engineering: The Tenaris Experience

Horacio Bergero[1], Juan Carlos González[1], Daniel Krishock[1], and Raúl Topolevsky[1]

Abstract. Attracting, developing and retaining talented technical graduates are major challenges for the steel and other industries. This article describes the initiatives undertaken by Tenaris to train and educate its technical employees within the framework of its Corporate University founded in 2005. The curricular model adopted and the course delivery methods including trends in virtual classroom used by Tenaris University are mentioned. The actions that Tenaris University is undertaking with universities across the globe to develop longstanding and fruitful relationships are also described.

Resumen. Atraer, desarrollar y retener el talento de los graduados técnicos constituye uno de los grandes retos para las industrias del acero y otras. Este artículo describe las iniciativas emprendidas por Tenaris para entrenar y educar a sus empleados técnicos en el marco de su Universidad Corporativa fundada en 2005. Se describe el modelo curricular adoptado, y los métodos de impartición del curso, incluidas las tendencias en el aula virtual utilizadas por la Universidad Tenaris. Se mencionan las acciones de cooperación que la Universidad Tenaris está llevando a cabo con universidades de todo el mundo para desarrollar relaciones duraderas y fructíferas.

1. Introduction: Recruiting, selection and training

One of the mayor challenges the steel and other mature industries face today is attracting, recruiting and retaining a new generation of industry leaders and experts. The perception of steel as an “old” industry has led many engineering students and universities or departments alike to abandon steel for what they view as more exciting and lucrative industries, such as biotechnology or robotics. Like many perceptions, this one is really a misperception. Extremely demanding service conditions in terms of mechanical properties and corrosion resistance are opening new avenues of opportunity in a wide range of industries where steel is used: for instance, in the oil and gas, construction and automotive industries, to name just a few. To meet that demand and stay competitive, steel companies are deploying an increasingly sophisticated array of technologies backed by cutting-edge research.

To get that message out, modern steel companies need to be actively engaged with universities and reach out to students while they are still evaluating their career options. Once students are recruited, companies must then provide them with the training and development that will allow them to see sooner rather

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than later the opportunities the industry affords. Training also needs to be designed to meet the needs and preferences of a cohort of students marked by hyper use of digital technologies and social media.

As a young company built on decades of experience in the steel industry, Tenaris is addressing the challenge of bringing students back to steel and retaining them through a variety of initiatives, including:

- Undergraduate and graduate scholarships to promote the study of engineering in general and its application to the steel industry in particular.
- An innovative Global Trainee program that provides recent university graduates who enter the company with two years of intensive training and development as a first step toward preparing them to take on critical managerial and professional functions in the future.
- Proactive recruitment at more than 40 universities worldwide that seeks to build recognition of Tenaris as a growing, multinational company that offers significant opportunities for professional growth.
- The establishment of the company's corporate university, TenarisUniversity, to manage training for white and blue collar employees.
- The use of new methodologies in training which are in accord with the learning preferences of young people comfortable with web based learning and informal learning.

2. Tenaris

Tenaris is a leading manufacturer of seamless steel pipes for the world's oil and gas industry. The company also produces seamless steel pipes for a wide range of industrial and automotive applications and is the leading supplier of welded steel pipes for oil and gas pipelines in South America.

Tenaris is the product of an industrial endeavor that can trace its roots back more than five decades to the founding of the steel pipe manufacturing company Siderca, in Argentina, in 1954. In the ensuing years, Siderca greatly expanded its own capacity and, in the 1990s, embarked on a series of acquisitions of steel pipe companies in other countries.

In 2002, Siderca and its affiliated companies were merged into a single corporation, Tenaris, to enable them to operate in unison at a global level. In the last several years, the company has made significant progress in unifying both its external image (to customers, investors, suppliers, etc.) and its internal operations (production, sales, financial administration, research, etc.).

Today Tenaris has 24,000 employees, pipe manufacturing facilities in nine countries (Argentina, Brazil, Canada, Colombia, Italy, Japan, Mexico, Romania, and the United States) and customer service centers in more than 20 countries. In recent years, Tenaris has moved beyond manufacturing to providing customers with a service that combines manufacturing, procurement, distribution and on-time delivery around the world. Tenaris had sales of US$8.15 billion in 2009.

In addition to its pipe manufacturing operations, Tenaris owns an 11 percent stake in Ternium, a company that was formed in 2005 to consolidate the Techint Group's holdings in flat and long steel manufacturers Siderar (Argentina) and Hylsa (Mexico). Like Tenaris, Ternium lists on the New York Stock Exchange and both companies are part of the Techint Group.

3. Tenaris University

Corporate Universities vs Degree Awarding Universities.

Companies recognize that employees and their knowledge base are a defining factor to achieve competitive advantage. Since the 90s, a wave of top companies have invested in the development of corporate universities. Included in these ranks are Motorola, Mastercard, Caterpillar, Toyota, and Cisco.

Corporate universities differ from regular academic institutions in that the training provided is designed for company employees and in some cases, customers or suppliers. They do not provide regular classes or degrees for the general public.

Corporate universities also differ from traditional company training centers. Corporate universities are closely aligned with the company's strategic development rather than simply responding to current training needs. Also, corporate universities have responsibilities beyond classroom led instruction in areas such as knowledge management and informal learning.

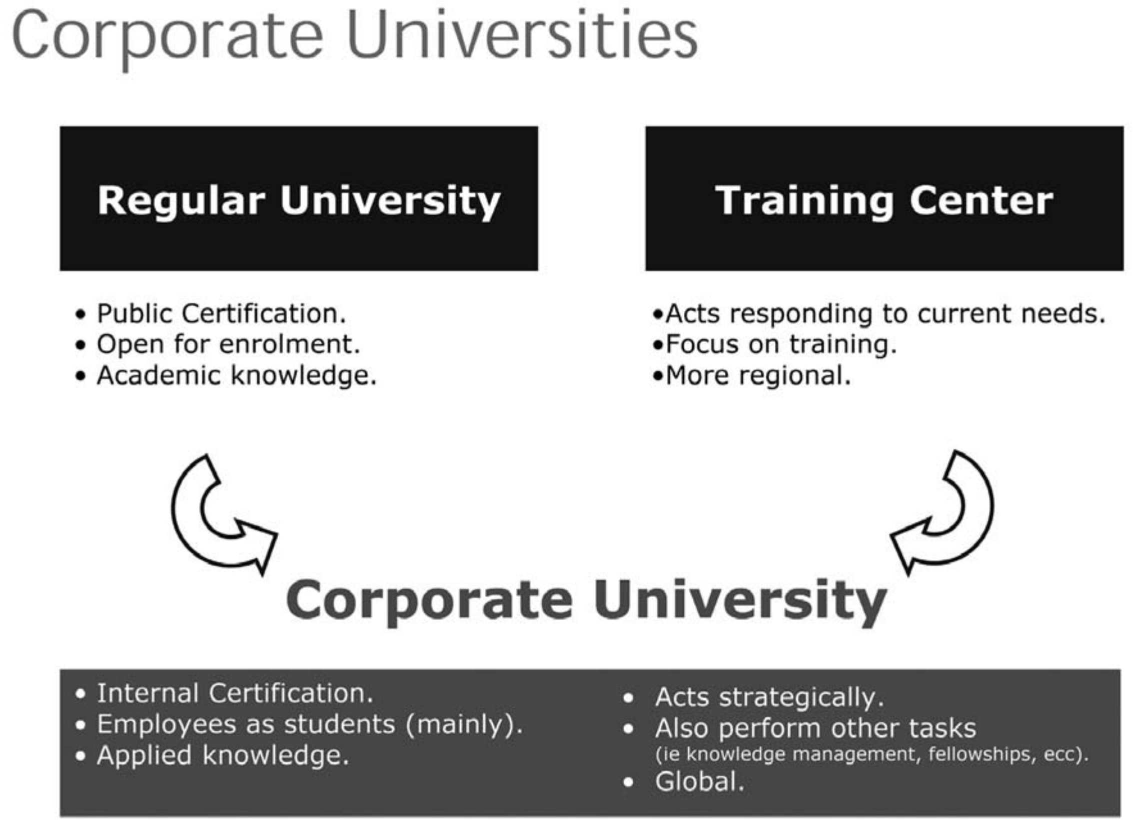

Figure 1

Mission and General Structure

Tenaris University's mission includes training and educating its employees, gathering and codifying the knowledge and best practices accumulated throughout the company's history and disseminating and developing that know-how through ongoing training programs.

TenarisUniversity's academic program spans the entire range of company needs from products and processes to business practices and management skills. Training forms an integral part of Tenaris's management philosophy. The average Tenaris professional staff person spends an average of 70 hours in training annually and an operator approximately 55.

TenarisUniversity's mission is critical given Tenaris's evolution since 2002 from a group of affiliated companies to a single corporation. Acquisitions including companies in the

United States, Romania, Indonesia and China have increased the Tenaris presence to thirty countries. Expansion has made consolidation and integration one of Tenaris's strategic objectives. TenarisUniversity plays a pivotal role in facilitating the integration of business processes as well as creating a common corporate culture. TenarisUniversity is also responsible for administering Tenaris's corporate intranet, company wide knowledge management, and support to universities.

Primary responsibility for the training of employees is vested in six "Schools": Industrial School, Commercial School, School of Finance and Administration, School of Management, School of Information Technology, and Technical School (for plant operators) [2]. Training delivery occurs virtually and/or through instructor led classroom training. Classroom training may occur globally bringing together employees from multiple countries and or with local staff at one of TenarisUniversity's regional centers.

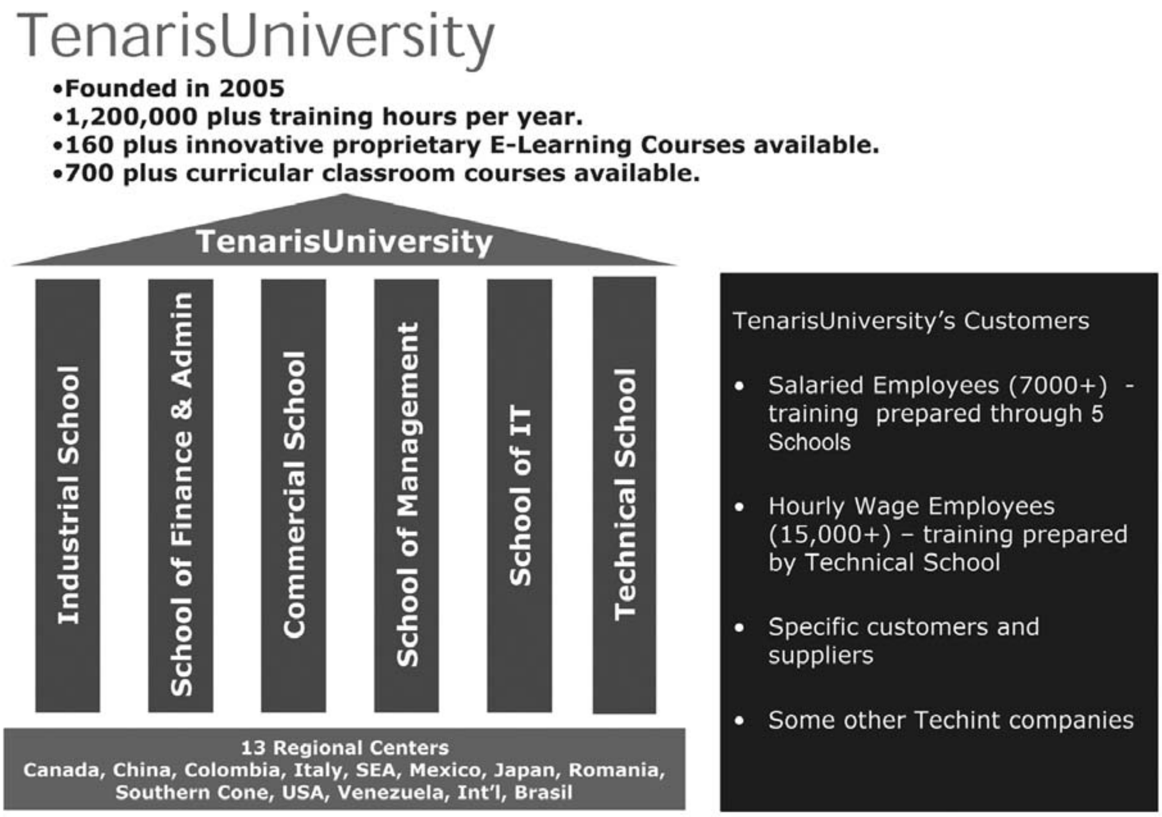

Figure 2

Total training hours for professional staff and operators combined are expected to exceed 1.4 million man hours for the year. TenarisUniversity currently offers more than 1200 courses for professional employees – approximately 450 e-learning courses (190 proprietary) and 750 classroom courses. In addition, there are more than 250 different courses currently delivered for operators.

TenarisUniversity has an annual operating budget of 16 million dollars, more than 100 employees spread between its headquarters in Argentina and 12 regional offices. The learning unit receives strong support from top management, including the CEO who leads numerous training sessions during TenarisUniversity's flagship training programs for managers and new employees from around the world.

Identification of Company Needs

As a fast-growing company that has gone from an alliance of three companies in 2002 to a truly multinational corporation in over 40 countries, Tenaris faces three main challenges in terms of human resources recruitment, training and development.

The first is the challenge that comes with growth itself and the need to integrate a diverse array of people, products, processes and systems into a unified whole, a task that is as daunting culturally as it is operationally. Company management realized that to achieve the benefits the joining together of so many once independent companies could bring, it would be necessary to build a common corporate culture founded on shared values and objectives and backed by common knowledge of essential business processes and procedures.

This was especially evident in the areas of quality and safety among plant operators. Ensuring that the 17,000 hourly wage workers, who speak eight different official Tenaris languages, adhere to identified best practices is a daunting task which has been taken on by the Tenaris Technical School.

The second is the need to replace a graying workforce, especially in key technical and engineering areas that are vital to Tenaris's success. Company demographics underscore the importance of this task. Although less than 40% of Tenaris's white collar workforce is 41 or older, the percentage exceeds 50% in critical technical areas like quality, operations and engineering.

This challenge is further compounded by the fact that Tenaris operates in a sector (steel) that many young engineers in countries where Tenaris operates do not view as a particularly attractive career option and other companies in the same sector face the same aging workforce problem. In other words, talented individuals with the specialized engineering skills Tenaris needs are in short supply and the competition for those individuals is fierce.

The third challenge, which is related to the second, is finding the expertise to train the new generation of engineers Tenaris would need. The tendency for young engineers to pursue careers in what they consider to be more exciting industries has been accompanied by a general decline in the resources universities and other educational institutions devote to subjects and research relevant to the steel industry as well. This tendency has been further accentuated in developed countries by the general decline of the steel industry itself in those countries. At the same time, the capacity of educational institutions in the developing world to provide the level of training (and in English) required by a multinational company is limited.

In light of these challenges, Company leaders determined that keeping Tenaris at the forefront of its industry would require a major transformation in terms of transferring knowledge assets and of recruiting and training a new, diverse generation of employees who could be the organization's leaders of the future. TenarisUniversity was created to be the main conduit of this change.

The decision to form a Corporate University was also consistent with the decades-old philosophy that has guided Tenaris's founding family-owned Group – which remains Tenaris's largest shareholder -- of recruiting recent university graduates and grooming them to assume the leadership positions of tomorrow. Thus, concurrently with the launch of its Corporate University, Tenaris launched a revitalized version of its Global Trainee (Young Professionals) Program, a two-year program for recent university graduates. TenarisUniversity plays a major role in the training and development of Tenaris's Global Trainees, of GTs [3].

Industrial School and its Curricula

The Industrial School was created in early 2006 as the first of TenarisUniversity´s six schools. It held its first classroom courses in September 2006. The audience for Industrial School training is Tenaris's engineers in products, processes and research and development. The vast majority of all new white collar hires are engineers.

The Industrial School has established a highly structured and systematic, academic program through which to train Tenaris's industrial workforce. The first step in establishing the program was to establish a Academic Council made up of senior management to assess training needs for each engineering related position in the company. The Dean of the Industrial School remains in constant contact with these line directors to ensure that training continues to reflect Tenaris priorities.

The next step was the design of a curriculum for each job family in the industrial sector. A curriculum is a long term training plan which an individual completes in order to fulfill training objectives for his or her job and hierarchical position. The curricula are intended to ensure homogeneity of skills and knowledge among personnel in similar job areas and position classifications, regardless of the country in which they work. The Academic Council must approve all curricula and major changes.

The Industrial School has developed fourteen curricula for the various engineering job families. They include Steelmaking, Hot Rolling and Heat Treatment, Engineering, Finishing, Quality, Product Engineering, Industrial Management, Welded Products and Process, Warehouse, Sucker Rods, Equipment, Maintenance, Research and Development and, Health, Safety and Environment.

There are three levels to each curriculum which roughly correspond to the position grades of the company. As employees successfully complete a curriculum level, they receive a credential which certifies their training achievement.

Curricula combine training in both the expertise area as well as communication and

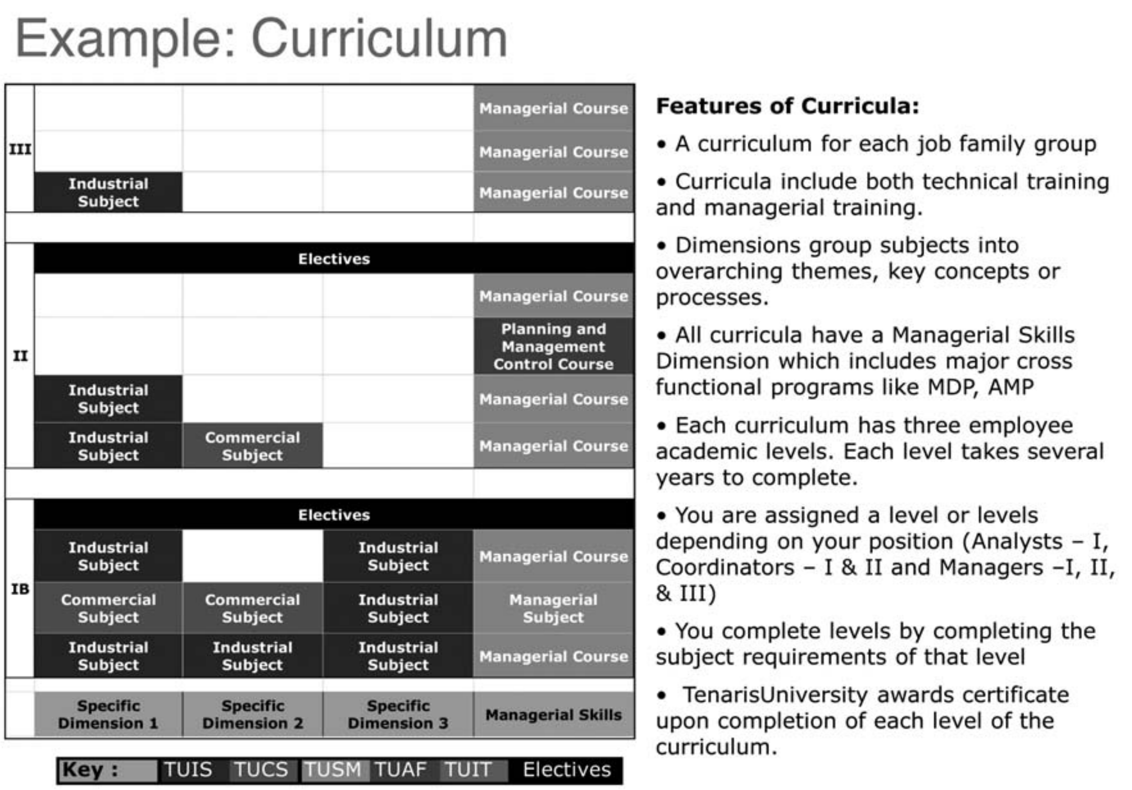

Figure 3

managerial skills needed for taking on greater responsibility and leading work teams. The School of Management leads this managerial training.

Level I of the curriculum provides an introduction to the company as well as fundamental courses specific to a job area but taught at an introductory level. Level II normally taken during an individual's sixth and seventh year in the company, is geared toward employees tasked with greater supervisory responsibility. This curriculum includes both basic and specialized courses and seminars. Although all courses taught by the Industrial School are designed centrally to ensure uniformity of quality and content, many of the courses at Level II are taught regionally to provide greater access for employees in the various regions. Level III, the highest level curriculum in the Industrial School training plans, includes courses and seminars. Participation in these curricula provides Tenaris engineers with training in their specific job area as well as the opportunity to network with their colleagues, also considered an important albeit informal learning activity.

Training is aligned with company needs through the fact that the content of the vast majority of courses is proprietary – both e-learning and classroom – is designed and delivered by Tenaris employees. Professionals from the line are carefully chosen and cultivated to by the Dean of the Industrial School for their expertise as instructors and as content experts.

The contributions of these employees to TenarisUniversity is recognized and rewarded by the Industrial School. Recently a "knowledge sharing" component was added to the company's annual Performance Evaluation process. These Performance Evaluations ultimately determine the annual bonus given to each employee.

Various faculty activities such as providing expert content for an e-learning course, instructing a classroom course or leading a group activity is recognized as knowledge sharing.

One recent development which has helped to ensure high participation in training has been the linking of compensation increases to the completion of Level I of the curriculum. Cluster 1 employees who have completed subjects required by the curriculum are eligible to receive raises in their compensation and position classification.

4. Technical School and Development Plans

Between its inception in 2005 and 2007, TenarisUniversity's main focus for training was its 7,000 plus salaried employees. This continues to be a major priority, but TenarisUniversity began in 2008 the enormous work of driving strategic company change through the standardization of training processes and contents worldwide for its 17,000 operators, traditionally known as the blue collar population.

Training for this group is particularly challenging given the audience's heterogeneity in many aspects. In addition to the linguistic and cultural differences, plant operators have varying levels of preparation in terms of mathematics, computer literacy, reading, abstraction, and analysis.

The training strategy for operators has included the creation of 400 standard courses and accompanying manuals covering all Tenaris basic operative practices. Each course is translated into the eight official Tenaris languages and includes a student course book, an instructor guide, a presentation to be used by the instructor and a test to check employee comprehension. 250 courses have already been completed and piloted and are being delivered in the various Tenaris plants.

In order to define which training courses are needed for each position, the Technical School has drafted Development Plans which are grounded in the concept of competencies. There are 28 Development Plans for each of the major global industrial processes: 13 in Operations, 6 in Maintenance, 6 in Operations Support, and 3 in Logistics. A Development Plan is defined as a road map for growth in training, practice and experience during an individual's work life in Tenaris. Depending on the specific job position, employees must obtain certain competencies. Competencies are both technical – for example "Crane Operation" – and managerial – such as "Team Building and Leadership".

A competency may be achieved through completion of a course, but in the blue collar world where individuals are operating heavy and dangerous machinery, theoretical knowledge is not enough. A worker must also gain practical skill and experience. The Technical School therefore incorporates on the job training and experience as part of its training model. Each competency has different requirements which may be met through classroom instruction or may require on the job training or a certification. .

Although Tenaris has always emphasized the importance of safety, it has recently launched a new program which strictly enforces the requirements of the Development Plan for new hires. This policy is intended to drastically reduce incidents of non-compliance with safety regulations.

The basic tenant is that individuals who are newly hired or who rotate to a new position are not allowed to work independently without completing specified requirements of the Development Plan. Supervisors are responsible for attesting in writing to the employee's achieved competency. The operator must complete the courses as well as on the job training which includes first shadowing an experienced operator, then supervised operation of machinery. The duration of the job training varies according to the complexity and risk of the position. Knowledge and experience acquired is always verified through a checklist exam.

5 Ternaris University and External Curricular Universities

TenarisUniversity also plays a major role in Tenaris's efforts to reach out to universities and students. One way it does this is by coordinating Tenaris's support for steeluniversity.org, an on-line portal developed by Worldsteel Association. Steeluniversity.org provides a comprehensive package of free access interactive e-learning resources on steel technologies.

TenarisUniversity, through the Industrial School, translates steeluniversity.org's training modules to Spanish, organizes activities for students and university professors built around the site's interactive simulations in steelmaking and participates in the creation of Steel University contents. The Industrial School also uses some of Steeluniversity's learning tools in its own training programs.

TenarisUniversity works together with the Roberto Rocca Education Program that manages a major scholarship and fellowship program on behalf of Tenaris and two other companies that form part of the Techint group. Through this program more than 700 Scholarships per year are funded for undergraduate engineering students at universities in countries where the sponsoring companies have a major presence. Each year the program also funds approximately 15 fellowships for students to pursue a Ph.D. in selected fields of engineering at leading universities in North America and Europe.

TenarisUniversity also provides opportunities for Tenaris Engineers to participate in advanced studies in external universities. Many engineers take part in short to medium term lab assignments in recognized research laboratories. Also, in some areas such as Research and Development, employees enroll in post graduate Master's or PhD programs.

6. New trends in training:

One of the most important and innovative aspects of corporate universities in the last ten to 15 years has been the rise of methodologies beyond the traditional instructor led classroom training. These methodologies are designed to meet the demands of a new generation of employees raised on a wealth of digital resources and instant communication.

In addition to e-learnings which TenarisUniversity has made one of the corner stones of its learning strategy (approximately 20% of all training hours are conducted through e-learnings), various new technologies are being used to train the members of the digital generation.

Webinars, or conferences held in real time in a web based virtual classroom, have opened new training horizons. All employees, regardless of their location, can participate in virtual classes simply through their internet connection. Through this methodology, students can see the instructor through a webcam, view the power point presentation, and pose questions to the instructor online. The professor can use his or her presentation as if it were a chalkboard, making notations directly on the screen which are instantly transmitted to the students. Additionally, tools such as videos and polls can be used in order to make a better training environment.

The benefits of the webinar technology are numerous. Webinars ensure that all employees receive the same high quality training without necessitating travel and even if they are working in a region where the low number of staff do not allow frequent classroom courses. In the economical crisis of 2009, webinars also have allowed Tenaris to reduce logistic and travel costs by transforming traditional instructor led classroom events into webinars.

Total flexibility in terms of allowing the instructor to give a talk from his or her computer in whatever location is most convenient has also allowed Tenaris to attract worldwide experts to give talks to Tenaris employees on the latest industrial technologies and trends. They have also helped build bridges between outstanding academic institutions and individuals.

TenarisUniversity is also exploring many avenues for informal knowledge sharing through learning communities. The purpose of a learning community at Tenaris is to allow employees to discuss problems and solutions as well as share best practices – as in a blog or forum – while at the same time providing a minimal supervisory structure which avoids propagation of any confusing or erroneous information. Recently TenarisUniversity launched a new site for technical sales representatives in which individuals can post and respond to questions as well as review previous posts in the knowledge base.

Other new tools which TenarisUniversity has incorporated include smart boards (LCD screens which serve as digital chalk boards) and Mediasite recordings (recordings of classroom courses or presentations which can be quickly posted in high resolution on the company internet).

7. Evaluations

TenarisUniversity's management realizes that evaluation is critical to measuring the impact of training as well as demonstrating the value of that impact to the rest of Tenaris.

In terms of data collection, TenarisUniversity carefully monitors numerous aspects of training. Items tracked include the hours spent in training per person, per region and per func-

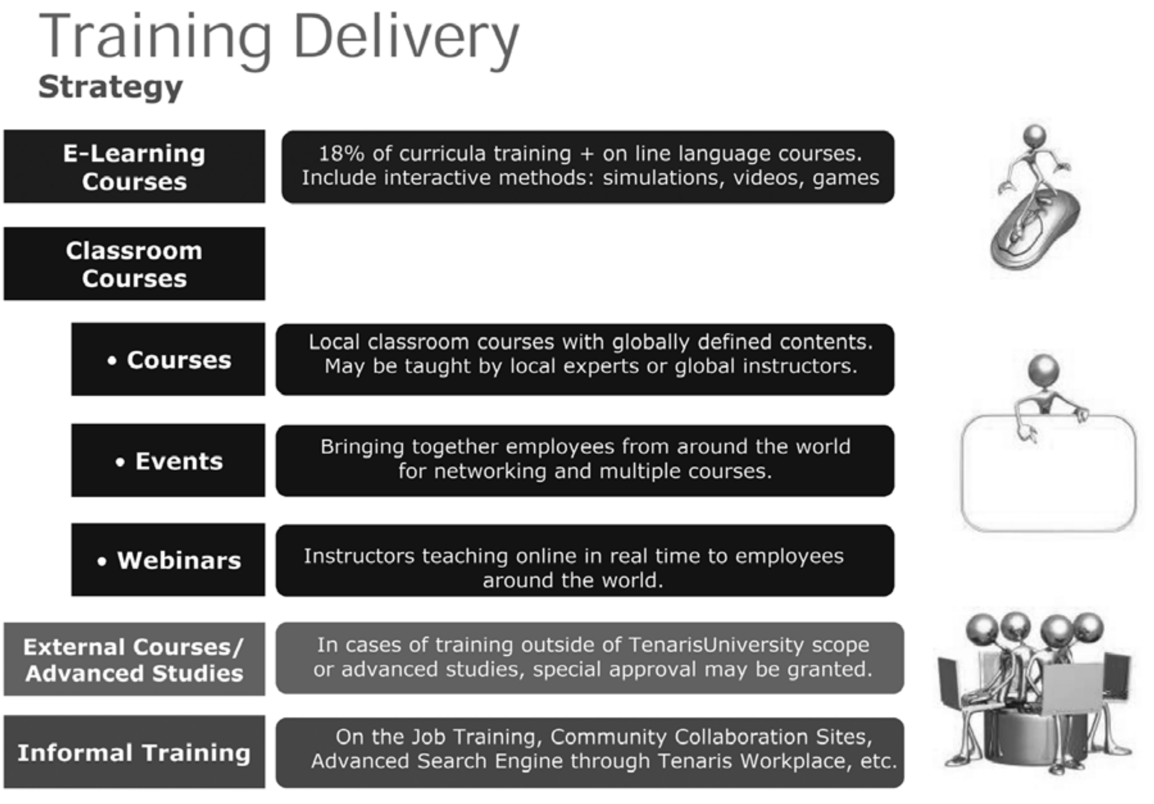

Figure 4

tional area, the types of programs available, and the money spent on training. Employees English language level is systematically tested and recorded through the TOEIC English test for non-native speakers.

In terms of evaluation, TenarisUniversity has a three part system. At the first level TenarisUniversity measures student satisfaction with training through a survey at the end of each course. Questions cover areas such as course content, duration, materials, instructors, networking opportunities, and logistics. Through TenarisUniversity's balanced scored card Control Panel, the 30 best and worst ranked courses are identified each month and are analyzed more closely. Results of these evaluations are used to identify exemplary courses and instructors as well as those which need to be improved.

Courses also have a Level II evaluation which measures the knowledge and skills students have acquired after having completed a course. These are given in the form of multiple choice tests which can be taken online or in paper format. Staff must register a 70% score and operators an 80% score before the pass the course. Results of the exam are also used to check that the course content is meeting the defined course objectives.

Finally, TenarisUniversity also added Level III evaluations to measure the extent to which students are able to apply to their jobs the skills and information they gain from a course. Given the complexity of evaluating this aspect, various tools are being used.

The first, and most traditional, is a short survey to employee supervisors which requests that the supervisor rate the degree and type of the employee's improvement based on his or her participation in a training course. The evaluation is carried out via a standard questionnaire the employee's supervisor fills out on the Learning Management System. The supervisor is asked to fill this out approximately 3 months to 6 months after his or her employee's completion of the course.

In addition, in some cases a focus group is conducted which composed of supervisors of the trained employees in various countries. For example, in a recent focus group of a mechanical maintenance course the following results of the training were observed: In the electrical resistance welding line, the time to change the equipment was improved from 1,8% to 0,8%. Also, the quantity of bearings replaced were reduced from 4 to 0 per budget achieving a U$S 50,000 of cost reduction.

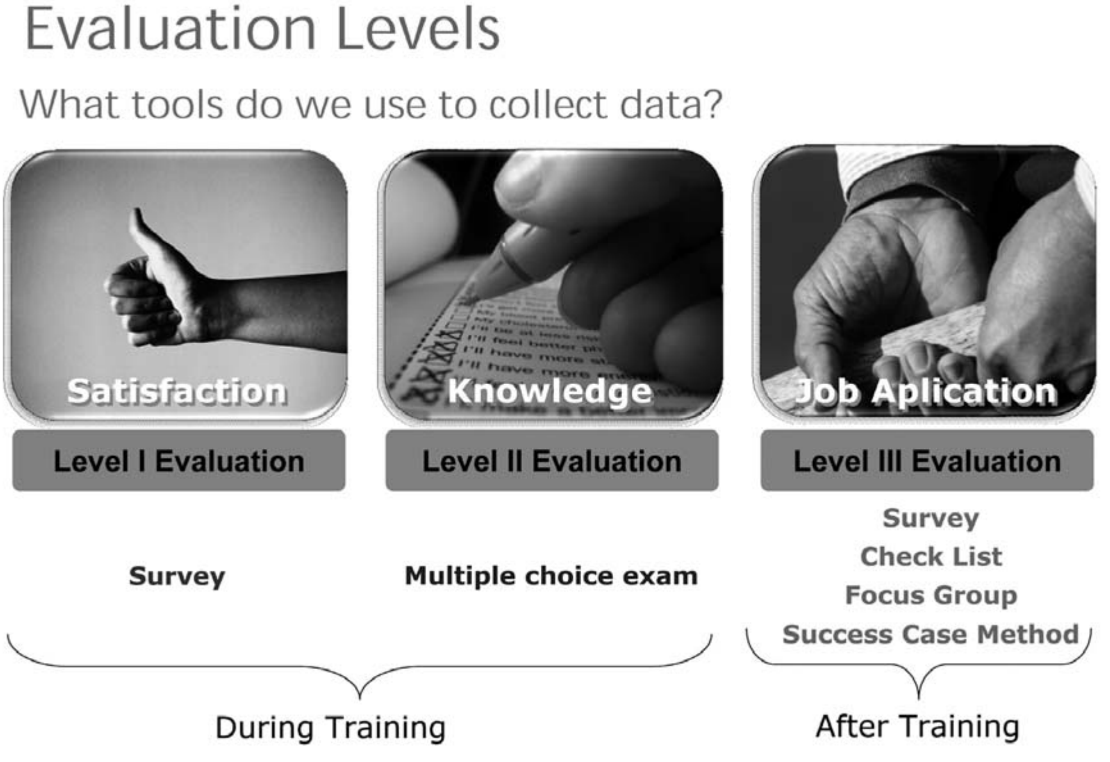

Figure 5

8. Results

Since TenarisUniversity was only founded in 2005, the impact on participants' behavior, particularly in the long-term, is difficult to gauge. Nevertheless there are promising results based on the previously mentioned evaluations Level I, Level II and Level III. In addition, surveys of employees who have participated in training are very positive. The periodical Human Resources satisfaction survey shows that employees are satisfied with the services provided by TenarisUniversity.

In addition, by establishing TenarisUniversity and making a major investment in its development, Tenaris has sent a clear message to employees of the value it places on training and developing its personnel. The active involvement of senior management in oversight, development and delivery of training contributes mightily to reinforcing that message.

The establishment of a reservoir of training materials and courses was a great boon to the company in the recent economic turndown. As the demand for tubular solutions declined worldwide, Tenaris was able to make productive use of employee time by increasing the number of hours spent in training. When customer purchases picked up again, employees returned to the production line with improved skills.

9. Conclusions

To meet the challenge of attracting, recruiting and retaining qualified individuals and to fill the generation gap Tenaris is focusing its efforts on building technical capacity in students and employees alike, in the belief that this will build appreciation for the steel industry and its opportunities. At the same time, the company is strengthening its already considerable interaction with universities to reach out to students and train employees. It is believed that the combination of scholarships, internships, the Global Trainee program, innovative training methods and other initiatives will provide Tenaris with the next generation of leaders and experts needed to excel.

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Aknowledgements.

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SIS Technology: the Scientific Basis for this Innovation and Present Development in the World

Rafael Guarga Ferro[1]

Abstract. This paper analyzes some aspects of the so-called "SIS Technology" (TSIS). The acronym SIS stands for "Selective Inverted Sinks". TSIS was created in the mid-90s in Uruguay and SIS has been patented in several countries (among others, Argentina, Chile, USA, several EU countries and Uruguay). The TSIS is aimed at controlling damage caused to various crops by radiation frost. It is a radical innovation in this specific field and the result of a search for a solution to frost damage, compatible with the environment and with the economy of large-scale crops. Today TSIS is being used in fifteen countries of both hemispheres and has been awarded international prizes due to its contribution to sustainable agricultural development.

Resumen. Este artículo analiza algunos aspectos de la llamada "Tecnología FIS" (TFIS). La sigla FIS significa "Fregadero Invertido Selectivo". La TFIS se creó a mediados de los años 90 en Uruguay y la TFIS ha sido patentada en varios países (entre otros, Argentina, Chile, EE.UU., países de la UE y Uruguay). La TFIS está encaminada a controlar los daños causados por las heladas de radiación en varios cultivos. Se trata de una innovación radical en este campo específico, y es el resultado de una búsqueda de una solución a las heladas, compatible con el medio ambiente y con la economía de los cultivos a gran escala. Hoy en día las TSIS se están utilizando en quince países de ambos hemisferios y ha sido galardonada con premios internacionales por su contribución al desarrollo agrícola sostenible.

1. Origin of TSIS

TSIS originated in Uruguay at the beginning of the nineties. This innovative technology arose as a result of the concern caused by heavy frosts which occurred at the end of the eighties in relation to the local citrus industry, aimed at the export of fresh fruits to Europe. In those days, Uruguay was free of citrus canker and this fact enabled Uruguay citrus fruits to enter in the European citrus production counter-season. Such an advantageous situation gave rise to substantial investments in citriculture in Uruguay which resulted in the settlement of large agricultural facilities which produced citrus fruits for export.

The heavy frosts of the late eighties had significant effects on the sector and required a search for solutions to the frost problem, which began with a critical analysis of the existing technologies.

Background Information on Frost Control Technologies

Available technologies twenty years ago were divided into the most traditional ones, based on heat supply to the crops to compensate for

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heat loss due to frost action and modern ones (in the mid-20th century) which added some knowledge related to the structure of the atmosphere under frost conditions.

The most traditional technologies, based on heat supplied by fuel burning heaters distributed within the crop site, could not be used in Uruguay in the 90s because of their high operating costs (fuel cost) or their high investment costs (anti-frost irrigation system) and the environmental unfeasibility on a large scale.

The most modern technologies in the nineties included large mills installed within the crop area (we will call them "wind machines" WM) or the use of helicopters hovering over the site at night. These technologies differ from the above mentioned traditional ones in the fact that they are not aimed at a direct compensation of heat loss during the frost period; this technology is based on the use of the peculiar organization of the atmosphere itself under radiation frost conditions (stratification of the atmosphere). However and although favored by the stratified organization of the atmosphere, both technologies are not cost-effective due to the high investment and operating costs per hectare, and the noise of WM or helicopters makes them incompatible with populated centers near agricultural facilities.

The Search for Innovation

The above considerations on the available frost control technologies in the world made citrus producers wonder if, with the scientific knowledge developed over more than half a century since the introduction of the last technologies in use (large mills and helicopters) it was possible to innovate and create a new radiation frost control technology with a lower cost per hectare, compatible with sustainable agricultural development.

The answer to this question was affirmative and the new technology created was TSIS.

In the following section, I will briefly refer to the scientific basis that led to that technology.

2. Scientific Basis of TSIS

Radiation frosts form on calm (without breeze) and clear (without clouds and fog) nights, at 1.5m height, with air temperatures that typically fall below 0°C during the night but are above 0°C during daytime. It is a mesoscale phenomenon (200 Km or less) and, in the affected region, air temperature falls from sunset until sunrise. The surface loses heat by radiation back to the atmosphere (the atmosphere is semitransparent to infrared radiation) at a generally constant rate of 100watts/m^2 and this cools down atmosphere layers near the surface; layers lose more heat as they are closer to the surface level. As air density is inversely proportional to absolute temperature, the lowest layers will be the densest ones. When the terrain is flat and horizontal, there is a situation of "stable" and unchanged atmosphere where temperature and density distributions in height and at the end of the night are as shown in Figure 1.

Figure 2 shows a crop and the temperature-height distribution. It is enough to look at the picture to see that frost will affect all sensitive tissues of the crop at the same height above the surface alike and the farther they are from soil level, the less damage they will suffer. Figure 2 also gives an immediate understanding of frost control action by means of the use of a WM (Figure 3) or a helicopter hovering over the crops (Figure 4). These two control alternatives move warmer air from high layers (10-20m above surface level) above the crop, increasing its temperature and thus reducing or eliminating frost damage.

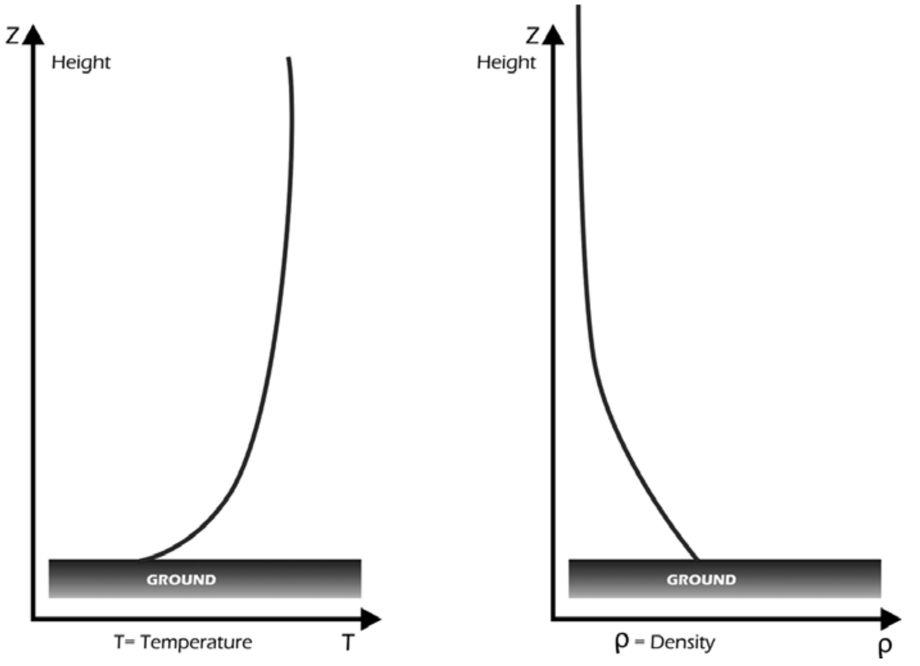

Figure 1: Temperature and density distributions in height, under radiation frost conditions

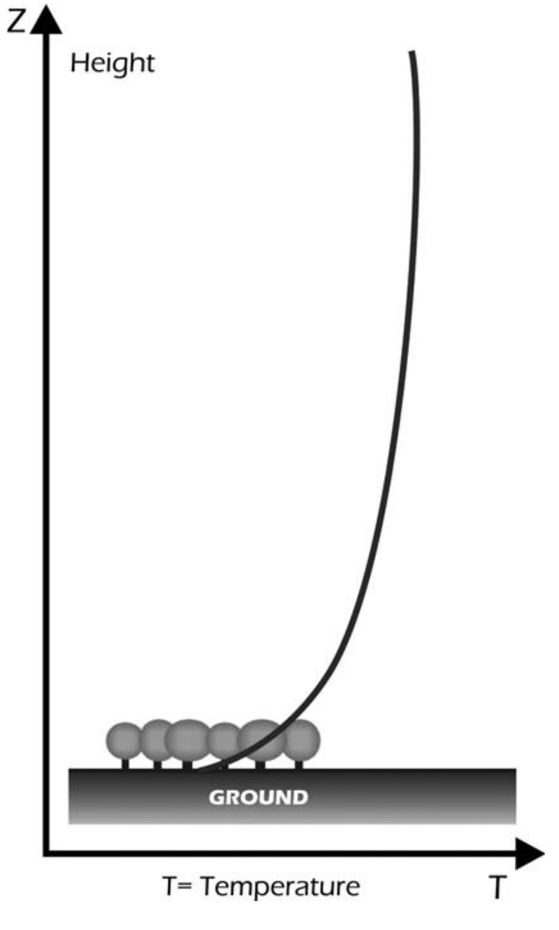

Figure 2: Relation between temperature-height distribution and crops, under radiation frost conditions

However, in undulated terrains, very frequent in Uruguay and in most arable lands worldwide, the situation is quite different from the one described in Figures 1 and 2.

Figure 5 shows that particles closer to the surface level (few meters) will no longer remain still and will move downwards, generating complex flow structures called "down-slope winds". Figure 5 illustrates a simplified scheme of down-slope wind, with related temperature and speed profiles. As can be observed, the speed profile is very different to that of water flowing through a course.

All this means that, during a clear and calm night, on a complex topography terrain, these so-called down-slope winds will develop on all hillsides, moving the cold air downwards. The topography selectively drains cold air coming from high areas and hill-slopes, flowing this air towards lowest areas.

This briefly described mechanics explains the fact, ratified by the experience of agricultural producers, that frost damage (when it occurs) is worse in the low areas of cultivated lots than in topographically higher ones.

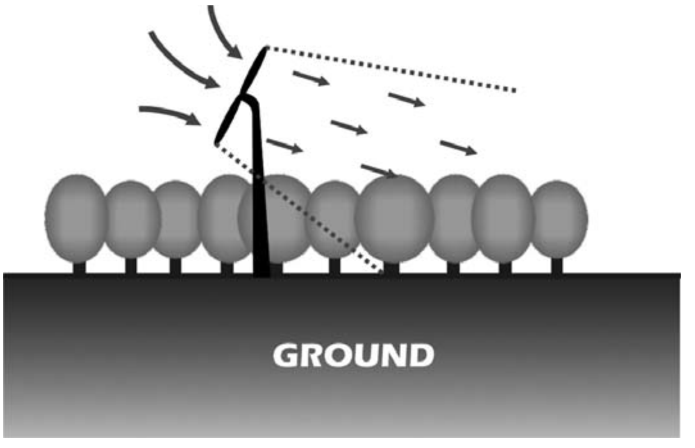

Figure 3: Action of a Wind Machine (WM) above crops, under radiation frost conditions

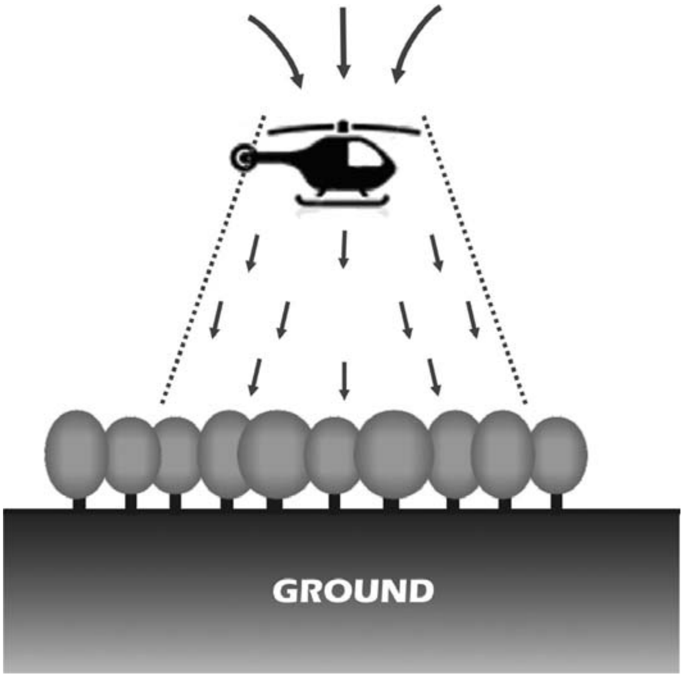

Figure 4: Action of a helicopter above crops, under radiation frost conditions

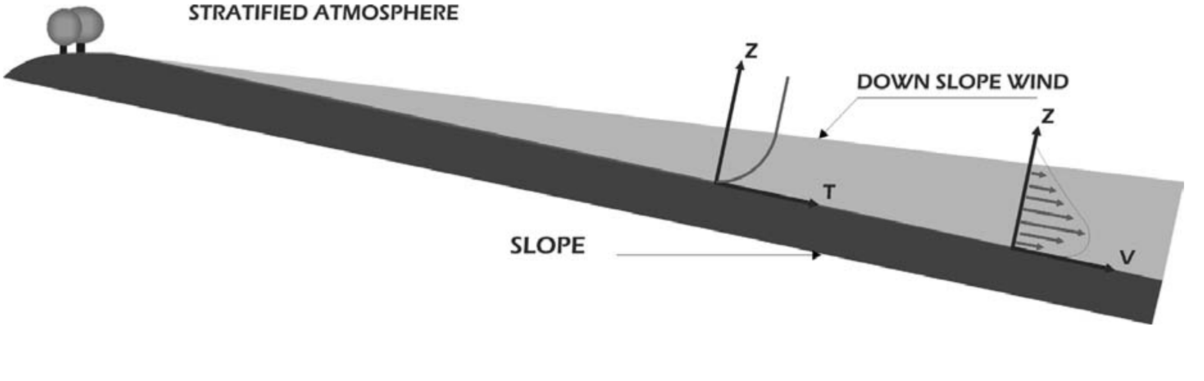

Figure 5: Downslope wind, under radiation frost conditions

Previous observations led us to envisage the possibility of carrying out in low areas a selective drainage of cold air coming from nearby hill-slopes. This drainage in low areas should be quite similar to that of high areas due to topography. The action of that drainage, properly dimensioned, should transform low areas into high areas from the point of view of their behavior as regards frost.

Selective Drainage of Low Areas through the Application of Mechanical Power

Selective drainage processes of the densest portions (due to temperature or salinity concentration) of a fluid began to be scientifically studied sixty years ago in France, by Craya (1949) and Gariel (1949). In fluid mechanics, the interest in these processes arose with the problems of water extraction in stratified reservoirs due to salinity, of "salt wedge" phenomena in estuary dynamics, and of lava flows at different temperatures in volcanology.

Specialized literature on dams, estuaries and geologic formations gave rise to the idea of how to develop a device for selective extraction of cold air in the stratified atmosphere scenario.

With this device, it seemed possible to transform, from the thermal point of view, low areas into areas with a similar thermal behavior to that of high areas if the cold air extracted could be removed from the protected area.

If these two aspects of the problem could be satisfactorily solved, agricultural producers would have the possibility of eliminating frost damage in the low areas of their plots, in the (very frequent) cases that damage does not occur in high areas.

The "Heavy-Fluid" Jet into the Stratified Atmosphere

When the problem of the selective extraction of the lethal cold air to the crops was technically solved, the other aspect to be considered –in order to achieve an innovation of practical interest– was what to do with the huge masses of air at life-threatening temperatures for crops, selectively extracted after an overnight frost in a real valley.

At that stage of the invention process, the alternatives we identified were the following: to warm the portion of lethal air and then release it to the environment, to channel the lethal air flow through a duct and expel it away from the protected area and, finally, inject the lethal flow upwards by means of enough kinetic energy so as to prevent it from re-entering the low atmosphere.

The reasons of each of these options will not be discussed in this paper but say that the available scientific information led us to choose the third option, i.e. the lethal flow injected vertically upwards into the low layers of the stratified atmosphere. So the cold and dense air flow extracted at crop level gradually mixes with layers where the temperature (in the stratified atmosphere) increases with altitude. The vertical jet goes on increasing its temperature and reducing its mean speed till it reaches its maximum height; all the flow remains in a high layer (tens of meters above the fifth) and spreads horizontally in that infinite "reservoir" until sunrise.

Related literature refers to diverse problems with the technique which have led to the study of vertical jets in an atmosphere with a controlled density. Our case is that of a "heavy-fluid jet" (of mean density greater than that of the atmosphere in which it discharges) injected into a "stratified atmosphere". An updated discussion on this topic can be found in Bloomfield et al. (1998).

The Selective Inverted Sink and TSIS

Once the problem was theoretically solved by means of a device capable of moving air flows as the ones of a down-slope wind on a hill-slope representative of the actual topography, it was necessary for the device to eject the captured air flow upwards, with enough speed for it to reach a certain height above the terrain and not damage the crop.

However, there was still a problem, unsolved by the technical literature of the nineties, which was essential to solve for the operation of the device described above. It was finding out whether, at the moment of carrying out the selective extraction with the intensity necessary for the device to be of practical use, stratification could be destroyed around the device nozzle, thus inhibiting ulterior selective extraction.

This topic was not dealt with in the literature of that time, so we had to design a physical model of the selective extraction process. In this physical model, the fluid used was water, which stratified by temperature according to escalation requirements. Figure 6 illustrates a photograph of this physical model.

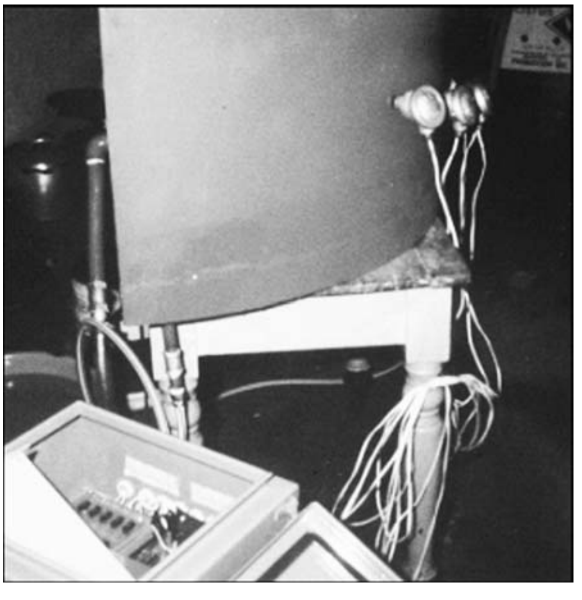

Figure 6: Physical model used to study the conditions of selective extraction

The result obtained with the model confirmed that air extraction rates would not destroy stratification in such fluid and, as a result, the device known today as "Selective Inverted Sink" (SIS, acronym in Spanish, English and Italian, at least) was born.

Figure 7 shows an operation scheme of a SIS device, working in a stratified atmosphere.

3. Present development of TSIS in the world

The process that turned the invention into an innovation lasted a couple of years. The device was proved to scale in several versions as regards it mechanical performance and, in 1995, a first test controlled from the agricultural point of view was carried out in a 54ha site. This test was internationally reported in the article referred to in Guarga et al (2000).

In 1995, the Uruguayan patent was awarded the "Genesis" Prize to the best invention patent in the period (see www.frostprotection.com).

The US patent was granted in 1997 and the first system in California was installed in 1998. The Argentine patent was granted in 1997 and the first machine in that country was installed also in 1998.

In 1998, TSIS won the Rolex Prize for Innovation, in Geneva, Switzerland; in 2003, SIS won the prize for the best innovation in agricultural machinery, at the International Fair of Agricultural Machinery, held in Zaragoza, Spain and, in 2005, the TechAwards to innovation (on "Environment"), granted by the United Nations University, UNDP, Santa Clara University (California) and leading companies of Silicon Valley (see www.frostprotection.com).

Today TSIS is being applied in 15 countries in 5 continents and its contribution to sustainable development (basis for Rolex and TechAward prizes) is acknowledged in very strict regions (Franson 2009). There are sev-

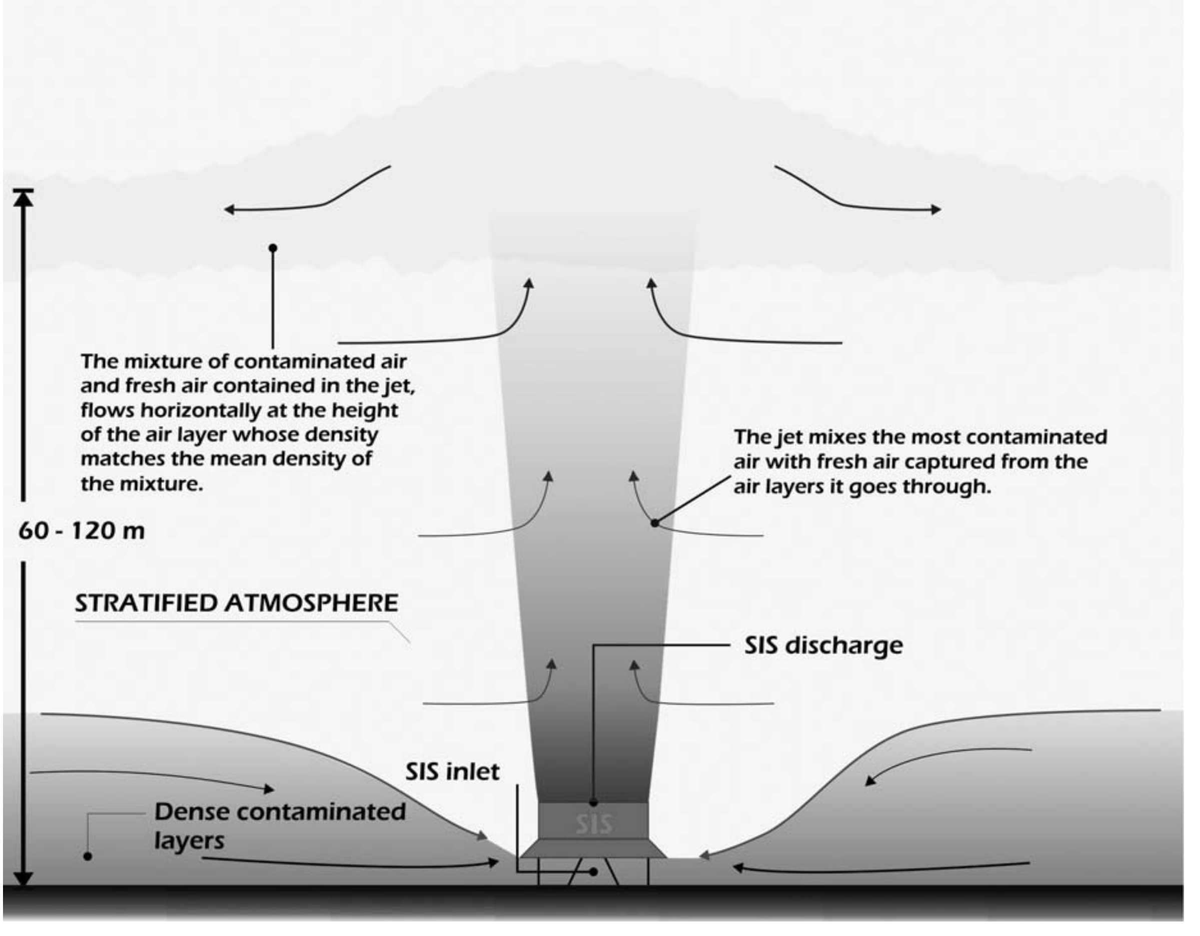

Figure 7: SIS operation scheme under a stratified atmosphere

eral publications on TSIS, for technical congresses[1].

4. Future Possibilities for TSIS

What has been described so far refers to the application of TSIS in the field of agriculture. However, the peculiar conditions of the atmosphere in clear and calm nights, mentioned above, are the physical support of (at least) two environmental phenomena that substantially affect the quality of life of millions of people worldwide: odor propagation and dust propagation.

In both cases, this means the action of down-slope winds in the nearby areas where odor or dust are emitted.

In clear and calm nights, these down-slope winds transport odors emitted by wastewater treatment plants, tanneries, poultry and pig farms, etc., kilometers away from emission sites, thus affecting large urban areas in the world.

Dust emissions are mainly caused by large open-pit mines, of great economic and social relevance, as in the case of Chile with copper, and of Uruguay in the near future with iron.

[1] Among them: a) Wilson, S. "Frost protection: evaluation of new system. Project Number CY07015", Sydney: HAL, 2009; b) Arias, M., Mendina, M., Arbiza, H. "Two Experiences of Frost Damage Control in Vineyard with Selectively Extraction of Coldest Air: Alto Valle, Argentina and Napa Valley, California USA", in: Libro de resúmenes (Acta Horticulturae). VIII International Symposium of Temperate Zone Fruits in the Tropics and Subtropics (Florianopolis, Brazil - 21-25 Oct. 2007); c) Augsburger, H. K., "Frost Control in Temperate Climates through Dissipation of Cold Air", in: Aspects of Applied Biology 61 (2000). IAMFE/AABB UK 2000. The International Conference and Exhibition on Mechanization of Field Experiments.

As regards odor control, TSIS has already been successfully used in the wastewater treatment plant of Punta del Este (Maldonado Department, Uruguay) belonging to OSE (State Sanitation Works).

5. Conclusions

A new technology has been introduced, created in Uruguay to meet a specific local demand in relation to the control of the damage on citrus crops caused by radiation frosts. This technology (TSIS) has shown to have important environmental and economic advantages over other available technologies in the world in this specific field and today it is present in countries in the five continents. It also offers very interesting possibilities for development in new areas such as (at least) odor and dust control under conditions of stratified atmosphere.

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ISTIC-UNESCO-WFEO Workshop on "Science, Engineering and Industry: Innovation for Sustainable Development"

Conclusions and Recommendations

1. Towards an Economy based on the Knowledge Society. The prosperity of countries and societies is increasingly linked to the capacity to innovate which, in its broadest sense, implies applying knowledge and new technologies to meet the growing needs and demands of sustainable development. In this process of innovation, particularly in developing countries, engineering and engineers have a key role to play between new knowledge and its transformation and implementation in applied technologies.
2. Better Linkage in the NIS. It is necessary to strengthen and promote new instances of articulation between public and private actors as well as the search for a more dynamic relationship between the several governmental areas, within each other, and with universities, professional organizations and firms, to boost investment in local technology-based projects, and to direct the purchasing power of the state to promote challenging and representative projects which develop endogenous technological capacities.
3. Engineering and Sustainable Development. The use of engineering should be strengthened to minimize or mitigate the consequences of natural disasters (floods, droughts, tropical hurricanes, earthquakes, and volcanoes) which are a priority in Latin America and the Caribbean. Social inclusion and the accomplishment of the United Nations Millennium Development Goals (MDGs) should become cross-cutting issues in every engineering work, design of new technologies and productive innovations resulting from researches for sustainable development.
4. Engineers' Education. Capacity-building for engineering, technology and young innovative entrepreneurs, focused on the production of goods and services with "added personal knowledge", oriented towards state-of-the-art areas should be promoted (particularly) in developing countries.
5. The Incorporation and Institutional Development of this Theme. This theme should be institutionally assumed by WFEO by transforming its Committee on Technology into one on Science, Engineering and Innovation and including this topic in the future world conventions, Switzerland (2011) and Japan (2015). It is also recommended that it should be included in the forthcoming UN Rio+20 conference in Río de Janeiro (2012). ISTIC-UNESCO-WFEO Workshop Science, Engineering and Industry, supported by the UNESCO Regional Office for Science in Latin America and the Caribbean, will issue partial progress reports on the advances achieved and difficulties encountered in the implementation of these recommendations, including suggestions to contribute to their solution, with the assistance of the Argentine Union of Engineering Associations (UADI), the Argentine Engineering Centre (CAI), the National Academy of Engineering, university faculties and other organizations.

Buenos Aires. October 16, 2010.

World Congress and Exhibition (World Engineers' Week)
ENGINEERING 2010 – ARGENTINA:
"Technology, Innovation and Production for Sustainable Development"

Final Summary Report

1. General Recommendations of the Congress

The Congress discussed the technical framework required for engineering to enable it to strengthen its capacity to solve problems and weaknesses and to lead a just, powerful and integral development with growing competence.

It was unanimously agreed that, to achieve this, the support and advances of scientific researches and, particularly, of inventiveness, creativity, technological research and development (R&D) proper to engineering, are necessary.

It was also proposed to strengthen the action of engineers in the productive sector of goods and services, facilitating the incorporation of scientific and technological advances to promote productive innovation and clean production in firms.

In this regard, cautious action was recommended so that the process of change encouraged by new technologies effectively solves humanity's problems and does not boost the technological gap between developing and developed countries.

To enable that action to promote the progress desired, it was recommended that the technical and economic actions of engineering should be integrated within a framework of co-operation and complementarily with social sciences, whose respect and encouragement of the values of solidarity are crucial to achieve development, sustainable human development, which requires action in a complex and multidisciplinary context.

The Congress reaffirmed the conviction that worldwide, engineering, with its innovations and impulse to productivity and protection of the environment, promotes the essential conditions to build the environment in which civilized communities live and develop.

The Congress also insisted on the fact that the action of engineering should be inspired by a committed cooperation to meet the Millennium Development Goals, unanimously decided upon by the United Nations.

To progress in this direction, governments and non-governmental organizations should promote an appropriate dialogue between the different sectors. This dialogue and the resulting policies to be implemented should allow for the consolidation of national development plans and encourage the active participation of engineers, both of men and women, in a social context.

To that purpose, it was agreed that engineering must favor, from the instrumental point of view, the selection, adoption or creation, and use of "sustainable technologies", i.e. technologies that help to support and achieve that equitable and progressive sustainable human development.

Engineers and businesspeople should commit themselves to the search and selection of undertakings within programs related to agriculture, infrastructure and buildings, and productive processes of goods and services, which take into account, preventively and protectively, the complete "lifecycle" of each initiative (inputs, processes, products and wastes).

In each stage of constructive and productive processes, engineering should evaluate the legitimacy of ends, the economic aspects of the means used and the effects on the physical and social environment.

The Congress stressed, as a way of reaffirming and supporting these ideas, the importance of a committed attitude of engineers in spreading information and technical alternatives that are illustrative examples for decision-makers and for society in general, and that facilitate clarity of discussion and decision-making.

Also pointed out was the significance for development of the performance of the judicial and legislative powers and of the concrete impact of executive actions of governments whose mission, complemented by a proper administrative and advisory management, monitoring and control, is crucial to ensure the effectiveness of regulatory, economic and financial, credit, tax and educational systems and of support programs for technical research and management.

Acknowledging the important influence and effectiveness of basic competences, the Congress recommended including in the different levels of education plans, knowledge and respect for the contribution of science, engineering and business to the general welfare. This will result in the awakening of early vocations at primary and secondary schools that will lead students to consider and freely choose technical courses of studies to enable every country to achieve, regardless of gender, the critical mass of active agents in sciences and engineering.

It is only on the basis of a growing group of engineers and scientists, men and women with a good level of knowledge and a strong commitment to their scientific-technical, social and ethical responsibility and to their country, and aware of the fact that personal achievements are socially legitimate when they mean an effective contribution to the common good, that the expected true, suitable and supportive advance towards sustainable human development can be strengthened.

Finally, the Congress approved the "Buenos Aires Declaration.

THE BUENOS AIRES DECLARATION

We, the professionals at the World Congress "Engineering 2010-Argentina: Technology, Innovation and Production for Sustainable Development", organized by the World Federation of Engineering Organizations (WFEO) together with the Argentine Union of Engineering Associations (UADI) and the Argentine Engineering Centre (CAI), proclaim that it is necessary to:

1. Call upon the institutions that bring together engineering professionals to disseminate what has been done by this Congress and assume the responsibility of contributing to advance towards the integral development of our societies, both with their proposals and works.
2. Encourage the action of engineers and that of governmental and private organizations to boost the capacity to innovate and to increase business efficiency and competitiveness, applying knowledge and new technologies to meet the growing needs and demands of an inclusive and sustainable development.
3. Call upon public authorities to give the necessary priority to the development of vocations and to the promotion of engineering courses of studies, with particular emphasis on greater participation by women.
4. Cooperate with UNESCO to implement the "International Engineering Program", proposed by WFEO Convention in Brasilia (WEC 2008) and under consideration by UNESCO in October 2010.
5. Foster the systemic participation of engineering institutions in decision-making processes of governments and organizations related to development, as members of honorary advisory councils.
6. Ask national governments, and multilateral banks and agencies, to politically and financially support the action of engineering institutions and engineers, in the fulfillment of their responsibility as drivers and executors of technological innovation and physical development, to further the effective accomplishment of the world commitment to overcome hunger, extreme poverty, social segregation, gender inequality, environmental damage and climate change threats.

Buenos Aires. October 20, 2010

2. Objectives of the World Congress and Exhibition

In the year 2010, several Latin American countries celebrate the bicentenary of the beginning of their independence processes. In Argentina, this process began with the Revolution of May 25, 1810, in Buenos Aires. In 2006, when the date of this celebration was approaching, the authorities of the Argentine Union of Engineering Associations (UADI) and of the Argentine Engineering Centre (CAI) proposed the organization of a world engineering congress and an exhibition as a way of joining in the commemoration and of strengthening the commitment of engineering to the development of nations.

It was considered of international interest to promote an updated analysis of global technological advances and their critical evaluation, organized as an in-between World Engineers' Week within the World Engineers' Conventions which have been held since the beginning of this century by the World Federation (2000 in Hannover, 2004 in Shanghai, 2008 in Brasilia, and 2011 to be hosted in Geneva).

The initiative was also aimed at encouraging the dialogue of engineers with all social sectors, promoting sustainable development as a cross-cutting objective of all engineering disciplines, showing the significance of engineering and productive business worldwide, and enhancing the cooperation between them, as key factors of the physical aspects of sustainable development and as an active contribution to the accomplishment of UN Millennium Development Goals.

The proposal was submitted to the World Federation of Engineering Organizations, and its Executive Council unanimously approved its participation and support (Chicago, October 2006), confirmed by WFEO General Assembly in New Delhi (November 2007). Sponsored and supported by UNESCO, the National Government of Argentina, those of the Province and Buenos Aires and of the Autonomous City of Buenos Aires, UPADI and several national and international institutions, organizational activities as well as the dissemination of related information were intensified to host this "World Congress and Exhibition ENGINEERING 2010 – ARGENTINA: Technology, Innovation and Production for Sustainable Development", stressing in its name the key objectives and the theme to be addressed.

3. Characteristics of the Organization and Operation

During the organizational process and with the approval of WFEO, the key topics to be addressed by the Congress and the parallel Exhibition were selected. It was also decided that the venue of the Congress would be "La Rural Exhibition Center" of Buenos Aires, with the support of EFCA, a firm specialized in the organization of this type of events.

It was agreed that the Exhibition would provide stands where each exhibitor, either governmental or private, would showcase their productive, organizational or methodological innovations.

With the aim of advancing towards sustainable human development, the Congress was to analyze how the successive stages of engineering actions may be better used: 1) creativity and inventiveness of technology; 2) the achievements of innovation, and 3) the production of processes, goods and services. To this effect, and considering the Millennium Goals and the priorities established by the World Summit in Johannesburg 2002: Water, Energy, Health, Agriculture and Food, Biodiversity (WEHAB), it was decided to organize several parallel meetings called "Chapters" of the main Congress, selected due to their interest and current international relevance. The Congress therefore include three types of Chapters:

a. Specific to Engineering
   1. Information Technologies and Communications - ITCs;
   2. Energy and Climate Change - ECC;
   3. Innovation in Primary Production and Agro-Alimentary Industries - IPPAI;
   4. Megacities and their Infrastructure (water, transport, urban settlements) – MI.

b. Engineering Issues
   5. Engineering Education for Sustainable Development - EESD;
   6. Professional Practice of Engineering PPE;

c. Fora

7. Women in Engineering and Business - WEB;

8. Young People in Engineering and Business – YPEB;

The shared approach given by the theme of the Congress (technology, innovation and production for sustainable development) was interpreted by each of the Chapters separately but their conclusions and recommendations converged in an integrated document, representative of the Congress as a whole.

The Congress (with the attendance of more than four thousand registered participants) and the Exhibition (with more than thirty stands) concentrated their work in four days, from Sunday October 17 to Wednesday October 20, including the opening and closing ceremonies. Both the Chapters of the Congress and the opening and closing ceremonies were attended by internationally distinguished invited guests and keynote speakers, together with a large number of registered participants, many of whom presented technical papers.

During the week prior to the Congress and in the days following it, WFEO and UPADI hosted their annual institutional meetings and those of their technical committees in the building of the Argentine Engineering Centre (CAI) and in other facilities specially chosen for that purpose as well as the Pan-American Academy of Engineering and the World Council of Civil Engineers.

Also during the previous week, of October 13 to 16, other meetings were held, sponsored by UADI, CAI and WFEO: a seminar on "Disaster Risk Management" and two events co-organized together with the UNESCO (Regional Office for Science in Latin America and the Caribbean, with headquarters in Montevideo) and ISTIC (International Centre for South-South Cooperation on Science, Technology and Innovation of developing countries, with headquarters in Kuala Lumpur, Malaysia).

These two events consisted of: 1) the opening ceremony, held at the premises of the Faculty of Engineering of the University of Buenos Aires, with the support of the National Universities of La Matanza and Lomas de Zamora, of the First Regional Postgraduate School of Engineering, which organized a three-day course (October 13-15) on "Entrepreneurship in Engineering towards Sustainable Development" for recently-graduated Latin American engineers; and 2) a full-day workshop on "Science, Engineering and Industry" (October 16) held at CAI headquarters, and sponsored by CARI (the Consejo Argentino de Relaciones Internacionales) and the Technological Institute of Buenos Aires, as the culmination of an elaboration process lasting several months, including the writing of white papers on: the role of science, engineering, and governments in the promotion of research and development (R&D) and advances in technology and innovation in industry and services; the role of engineers in creating new technology-based firms; engineers' education and their relations with the productive sector (see conclusion in section 4.9).

The content and proposals of the Congress and the Exhibition as well as the aforementioned technical activities will be included in special publications for public dissemination.

4. Relevant Proposals and Issues Discussed in the Meetings of Chapters and Forums and in the pre-congress Workshop

As a first advance report, this section summarizes the Chapters of the Congress and their objectives.

4.1. Information and Communication Technologies (ITCs)

The chapter addressed the close interrelation that exists between Information and Communication Technologies (ITCs) and society.

To analyze these interrelations and to reach practical conclusions that, in line with the Millennium Goals, can be submitted to the consideration of governments, WFEO members and the various social stakeholders, the Chapter included four topics for discussion:

1. Analysis and evolution of related technologies and their impact on technological development in the field of computer science.

2. Safety in ITCs. The other side of technological and service evolution are the increasing cases of computer crimes. The Chapter aimed at understanding the phenomenon so as to prevent it at the lowest possible cost.

3. Elaboration of governmental policies in this area. Governments were considered to have a great responsibility in the harmonious development of sectors related to ITCs. There were proposals as regards the criteria to promote and update contributions, incentives and regulations.

4. ITCs and society. Some of the multiple interactions between society and the sector's products and services were analyzed to understand the changes and the new needs that arise, recommending in this respect several policies within the context of sustainable development.

4.2 Energy and Climate Change (ECC)

The Chapter pointed out the significance of energy availability as a basic element for economic activities and social development, and the importance of the contribution of engineering to creating proper conditions to promote public and private investment in efficient and sustainable energy technologies. The Chapter ECC analyzed energy grids worldwide and agreed on the need of gradually shifting from the use of highly-polluting and non-renewable fossil fuels, to the development of other types of non polluting and renewable alternative energies.

The Chapter considered that this transition cannot be immediate but is essential and requires the close cooperation of engineering and of the private sector, together with global policies and a committed contribution and financial support on the part of the governments, to carry out research and improve alternative technologies so that they can compete with conventional energies.

The serious problem of environmental pollution and the impact of man-made green-house gas (GHG) emissions, mainly caused by fossil fuels, were a key topic of interest and discussion. The Chapter discussed several measures to reduce and mitigate their effects and to adapt to those impacts that are more difficult to control as well as the necessary cooperation of developed countries to finance projects. It was agreed that engineering should assume the reduction of GHG emissions as a key issue of concern and action and promote the use of low-carbon technologies to achieve a low-carbon economy, thus advancing towards the objectives, although still not satisfactory, of the Kyoto and Copenhagen Protocols with the hope that it can provide more optimistic results in next meeting to be held in Cancun.

The Chapter considered it necessary to promote the trading of carbon credits in an effective and equitable way for the various countries involved. It also supported the use of nuclear power in strict compliance with safety and accident prevention rules.

4.3 Innovation in Primary Production and Agro-Alimentary Industries (IPPAI)

This Chapter emphasized the importance of agro-food production efficiency to overcome undernourishment and hunger in the world, as the main constraining factors: Solving them will be the starting point for sustainable human development, particularly in less developed countries that are highly dependent on agriculture.

It also pointed out the relevance of technological innovations to increase food production, through the responsible use of available natural resources, particularly of soil and water, the protection of which conditions present and future productive horizons that the world population depends on.

Many papers and guest speakers put an accent on the necessary expansion of biotechnological innovations and their potentialities to overcome food and environmental problems with a positive impact on social progress. The Chapter also addressed the problem of agro-chemicals and the control of their use to spread their beneficial effects and limit their negative consequences on health and the environment.

The necessary implementation of the multifunctional analysis in the use of the territory as a unit was agreed on, stressing that environmental and social sustainability should be the essential dimensions in every technology-based rural project.

4.4 Megacities and their Infrastructures (urban settlements, water and sanitation and transport) (GMI)

The Chapter on Megacities was propitious to discuss in detail world trends towards urban concentration and the growth of megacities with the intrusion of precarious settlements in their peripheral areas and even within their own urban fabric.

The Chapter mentioned that the most widely-accepted hypotheses forecast that, with sanitary improvement, increase in life expectancy and reduction of child mortality, population growth will continue for some decades until its stabilization by 2050 with an expected number of around nine thousand million people. Current trends clearly show that most population growth is expected to take place in less developed countries, inversely proportional to the socio-economic level.

So the impact of population growth on the increasing urban concentration, which is expected to reach 60% of the population by 2030, would have its main effects on developing countries due to their less developed spatial planning and lower capacity to organize the growth in cities.

4.4.1 Urban Settlements

Even though increasing urbanization rates imply important benefits, absorbing their effects in developing countries will demand a great effort on the part of engineering and other related professions such as architecture, and a very committed action by governments to control and direct urban growth and improve living conditions in slums, trying to incorporate them into the formal urban fabric.

The final message of this chapter, with a strong presence in the Congress, called engineers and governments, particularly city governments, to carry out the necessary planning and actions to urbanize marginal suburban sectors.

4.4.2 Water

This Chapter considered that the lack of both comprehensive planning of city expansion and soil use caused uncontrolled growth, with the consequent shortage of safe water and sanitation services and the increase of impervious areas and the resulting interference and/or modification of run-offs. It was observed that in many countries, the development of drinking water infrastructure is not proportional to that of the sewerage-drainage system, thus increasing the underground water level.

As regards rainwater drainage (drainage pipes and street gutters), urbanization brings about not only a substantial increase in surface run-off that exceeds the capacity of the sewerage system but also a marked rise in peak flows of flood hydrographs, which impacts on drainage infrastructure costs.

The Chapter concluded that the solution to these complex problems of water and urban sanitation require the committed action of municipal, provincial and national governments, working together in a very co-ordinated way so as to ensure infrastructure planning and management and that of social sectors so as to create a new water culture. This means modern ways of understanding water and sanitation policies and their implementation so that new social stakeholders and environmental organizations are able to participate actively in decision-making processes. Engineering can contribute in all these areas to achieve sustainable development of water, sanitation and drainage infrastructure.

4.4.3 Transport

Due to the great impact of transport in large cities, the Chapter set forth the need to implement policies and measures to promote the use of technologies and transport means that enable fossil fuels to be replaced by other renewable and less polluting sources. This will contribute to the reduction of greenhouse gas (GHG) emissions and of urban traffic congestion.

Among others, recommendations were made regarding the definition of the type of vehicles and fuels for public automobile transportation, advisable for a gradual fleet conversion as well as possible penalties for privately-owned vehicles due to their high GHG emissions.

It will be necessary to raise awareness and develop strategic planning in all communities to avoid these problems from growing faster than the technical solutions and investments the community and the government can contribute, agreeing on and coordinating reasonable policies and measures to improve transport supply, quality and efficiency in megacities and to promote the decentralization of activities.

4.5 Engineering Education for Sustainable Development (EESD)

The Chapter aimed at analyzing engineering education for sustainable development met together with the 8th WFEO World Congress on Engineering Education and 7th Argentine Congress on Engineering Education, with a common agenda for the three meetings.

There was unanimous agreement that engineers' education should aim at an integral training of professionals, with a solid scientific-technological base, management and administration skills, and clear criteria of environmental, social, cultural and ethical responsibility. It was stated that graduates should be prepared and motivated to integrate into the environment in which they work, to understand its characteristics and to communicate and explain their own proposals so that their contributions are considered a key element to promote the physical aspects of socio-economic development and the integration of the population, overcoming inequalities and situations of isolation or lack of services.

In addition, the Chapter pointed out the relevance of governmental action to promote a wider dissemination of engineering potentialities and to support and finance better training of engineers as well as the adoption of evaluation criteria as regards their courses of studies to ensure high graduation standards and international recognition of their professional practice.

It also emphasized the importance that, during their courses of studies, future engineers strengthen their entrepreneurial capacity so that, once graduated, they are able to choose, create or use sustainable technologies, to have an active relation with productive sectors and to develop the necessary skills to organize technology-based firms, either of their own, working independently, or as employees of already existing companies, in their capacity of innovation agents.

4.6 Professional Practice of Engineering (PPE)

This Chapter analyzed different aspects of professional engineering practice, working independently as consultants or entrepreneurs of new firms, as employees of already existing organizations, engineering offices or producers of goods and services, or in technical agencies or departments at the different levels of local, provincial and national governments and in international institutions.

In all the aforementioned alternatives of professional practice, the Chapter stated that engineers should perform their tasks with the highest efficient, updated and periodically accredited scientific-technical level, without accepting works that exceed their competence, committed to contributing to the sustainable human development of their community and with a very active participation in the institutions that represent them and in the organization of society as a whole.

The Chapter also discussed the proposal of establishing a periodic technical-professional accreditation, a system that, with different modes of operation, has had good results in several countries. There was agreement on the statement that engineers should perform their duties with strict transparency and that they should submit to the control of correct professional practice. The Chapter also agreed that it is advisable to establish a framework for the professional practice of engineering with the enforcement of Codes of Professional Ethics, approved with the participation of institutions representative of engineers, which ensure the observance of ethical rules and the protection of public safety.

The Chapter also decided to submit to the consideration of WFEO, national governments and international organizations the need of promoting, with the corresponding regulations, professional practice of engineers in developing countries, retaining professionals in their own countries so as to build in each of them a critical mass of engineers with a thorough knowledge capable of encouraging with reasonableness and commitment the development of their own countries, leading local studies and processes, without neglecting, but rather promoting when necessary, the support and collaboration of professional experts from other countries.

4.7 Forum: "Women in Engineering and Business" (WIE)

The Forum "Women in Engineering and Business" was an open space for discussion on the role of women in engineering. The Forum pointed out that early vocations of young students for hard sciences are a key element at the moment of training new experts in technical topics, particularly in countries where these resources are scarce.

In this sense, awareness that engineering offers new possibilities of professional development to men and women as well is of great impact and social importance for the productive sector of all countries.

In rural areas, this is foreseen with more emphasis since human resources are even scarcer and developing countries base most of their economies on the agricultural industry.

The Forum also highlighted the challenges that women engineers encounter when they practice their profession and concluded that, when all productive sectors understand the importance of having skilled human capital, this deserves a just and equitable career development, regardless of its gender.

Finally, the Chapter considered important that the development on which new women professionals will focus should be integral and sustainable.

4.8 Forum: "Young People in Engineering and Business" (YPEB)

The Forum set forth the expectations of young professionals and the importance they place on having a timely guidance on professional perspectives; in this sense, governments and universities, together with engineering associations and firms, should analyze and make known the requirements of the labor market to enable their entry into it. There was also a call for an action on the part of the government and of the private sector to encourage vocations for technical studies and engineering.

In addition, the Forum emphasized the need of promoting innovation and entrepreneurship activities in the new generations of engineers and of sponsoring contests which promote these activities and spread their results.

The Forum agreed on the need and relevance of engineering projection towards the future, finding and disseminating the trends of technological and social evolution, within each country and worldwide.

CONCLUSIONS AND RECOMMENDATIONS

1. Towards an Economy based on the Knowledge Society. The prosperity of countries and societies is increasingly linked to the capacity to innovate which, in its broadest sense, implies applying knowledge and new technologies to meet the growing needs and demands of sustainable development. In this process of innovation, particularly in developing countries, engineering and engineers have a key role to play between new knowledge and its transformation and implementation in applied technologies.
2. Better Linkage in the NIS. It is necessary to strengthen and promote new instances of articulation between public and private stakeholders as well as to search for a more dynamic relationship between the several governmental areas, within each other, and with universities, professional organizations and firms, to boost investment in local technology-based projects, and to direct the purchasing power of the state to promote challenging and representative projects which develop endogenous technological capacities.
3. Engineering and Sustainable Development. The use of engineering should be strengthened to minimize or mitigate the consequences of natural disasters (floods, droughts, tropical hurricanes, earthquakes, and volcanoes) which are a priority in Latin America and the Caribbean. Social inclusion and the accomplishment of the United Nations Millennium Development Goals (MDGs) should become cross-cutting issues in every engineering work, design of new technologies and productive innovations resulting from research for sustainable development.

4. Engineers' Education. Capacity- building in engineering, technology and young innovative entrepreneurs, focused on the production of goods and services with "added personal knowledge", directed towards state-of-the-art areas needs to be promoted (particularly) in developing countries.
5. The Incorporation and Institutional Development of this Issue. This issue should be institutionally assumed by WFEO by transforming its Committee on Technology into one on Science, Engineering and Innovation and including this topic in future world conventions, to be held in Switzerland (2011) and Japan (2015). It is also recommended that it should be included in the forthcoming UN Rio+20 Conference in Río de Janeiro (2012). The ISTIC-UNESCO-WFEO Workshop "Science, Engineering and Industry", supported by the UNESCO Regional Office for Science in Latin America and the Caribbean, will issue partial progress reports on the advances achieved and difficulties encountered in the implementation of these recommendations, including suggestions to contribute to their solution, with the assistance of the Argentinean Union of Engineering Associations (UADI), the Argentinean Engineering Centre (CAI), the National Academy of Engineering, university faculties and other organizations.

Buenos Aires. October 16, 2010.

5. Presence of Brasilia 2008 and Kuwait 2009 Recommendations and of the Topics for Geneva 2011

The World Congress and Exhibition "Engineering 2010 - Argentina: Technology, Innovation and Production for Sustainable Development", has affirmed and expanded the continuity of the world meetings sponsored by the World Federation of Engineering Organizations, both the Conventions (2000 in Hannover, 2004 in Shanghai, 2008 in Brasilia, and 2011 to be held in Geneva).and the technical meeting parallel to the 2009 General Assembly in Kuwait.

In Brasilia, the main theme was "Engineering: Innovation with Social Responsibility", divided into subthemes addressed by keynote speakers who delivered their lectures focused on: engineering beyond boundaries, ethics and social responsibility, innovation without degradation, ITCs for inclusion, advanced technologies with strategic vision. There were also panel discussions, a women's forum and a young engineers' forum and an exhibition on "energy for the future". The Declaration emphasized that engineering, as the driver of technological innovation, is of vital importance in sustainable human, social and economic development. Several calls for action were made to stress the importance and responsibility of engineering to develop a better understanding of policy-makers and that of the wider public and to improve engineering education focused on applications and solutions of problems. The Declaration is completed with a call for a joint action by WFEO and UNESCO to develop an "International Engineering Programme", with the purpose of advancing towards the accomplishment of those priorities, the promotion of engineering capacity-building and the effective achievement of its potentialities.

In addition, the purpose of the special technical meeting "Applications of Alternative Energy: A Choice or Necessity?" held in Kuwait in 2009, was to analyze and propose actions in connection to the main topic of energy, considering the increasing demand and the need of facing it, with a consideration of all energy options, including concerns about enhancing efficiency, the use of nuclear power, and the development of renewable energies. Special attention was focused on increasing global warming and the need for reducing green-house gases (GHG), pointing out that the impact of climate change is a serious threat for the infrastructure that supports economy and for the use of natural resources, particularly water. It was stated that the engineering community has the necessary knowledge and experience to use available technologies and manage systems taking into account climate change and the need to cope with it.

"Engineering 2010 - Argentina" considered and updated these proposals and advanced towards their achievement, at the same setting the conditions to enable contributions to be made to the "World Engineers' Convention" to be held in Geneva in 2011, exclusively aimed at addressing the key and critical problem of energy. With the theme "Engineers Power the World", the Convention will deal with issues such as how to provide sufficient energy for everyone around the globe and how to meet the energy needs of the world's population fairly.

Buenos Aires, October 2010

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