Trends in Engineers training in Ibero-America

The expert panel held during the joint academic session work ASIBEI-ANFEI, successfully presented to attendees trends in engineering education in Ibero-America. At the meeting participated as exhibitors engineers Carlos Savio from Argentina, Ana Maria de Mattos Rettl from Brazil, José Carlos Quadrado from Portugal, Manuel Recuero Lopez from Spain, Alberto Ocampo from Colombia, Carlos García Franchini and Miguel Angel Alvarez from Mexico, and moderated by engineer Jaime Salazar Contreras, Executive Secretary of ASIBEI. Each presented his views on global trends in engineering education, and particularly, the present trends in each of their countries.

Among the Ibero-American trends in engineering education the ones that stand out more are: virtual training and new learning environments, the incorporation of Information Technology and Communication (ICT) in the classroom, ethics associated with decision making in engineering, the rapid growth of courses and designations of engineering, quality assurance of academic programs, and social contribution of engineering, among others.

The new information technologies are, undoubtedly, the axis of educational transformation worldwide, around which different trends are generated. In this sense, the engineer we need to think for the future should be projected in the medium and long term, continuous training and the availability of a sufficient infrastructure for science and technology that will lead to a sustainable regional development.
Training trends in Mexico

In his discourse, the engineer Miguel Ángel Álvarez, General Secretary of ANFEI, stressed out the importance of addressing matters related to strategic global issues (energy, food, environment, mobility) as one of the most important requirements in forming new engineers.

He also highlighted the problem of desertion (up to 43%) that is happening in Mexico, caused by the lack of vocation for engineering and the low level of previous training. To face these complications, it is essential to generate a strategic plan focused on issues of academic performance, in which students should be motivated to stay in their careers, the teacher's role is emphasized and policies should be establish to attract new talents that can replace the generations that are coming out of the labor market.

The engineer Carlos García Franchini, President of ANFEI, began his speech with a reflection on the implications in the actions of the engineers, and continued to emphasize on the importance of basic competencies that should be acquired by those who choose to pursue their careers in engineering.

New Engineer profile

The new engineering professionals should be formed under a simple basic premise: the engineer is a social being of global action. It is important to make the world understand that engineering professionals, although they are conditioned to offer favorable technical and economic results, their fundamental objective is to deliver solutions to social problems, hence the socio-economic and humanistic component is essential for management, design, planning and project development.

Physical boundaries are irrelevant when we talk about engineering; although engineers are formed in one place, its scope is global, because their decisions and developments may affect all humanity. This requires us to establish common frameworks to define the guidelines for each engineering specialty, and thus, have similar names to recognize and know what we do and where we are going headed.

Competences

The world is full of complex problems and phenomena that cannot be described accurately only by the resort to mathematics and sciences, thus engineering so often omits the study of complexity and is limited to the description of behavior. This inability to understand all problems requires engineering to address the complexity across all study programs and specialties, specifically in the area of modeling and simulation, without ignoring the implicit social language in the existing problems.
However, with today’s changing technological scenario, it is impractical to study with the necessary depth many of the current conditions of science, so it is very important to strengthen the conceptual basis, what is considered permanent (such as the processes of encoding information and information transfer), in other words  strengthening generic skills beyond specific skills (which are changing).

Because our world depends on future generations, it is essential also to set the competences of the new engineer’s ethical responsibility as a global behavior associated with engineering decisions, and not as an isolated course. No need to impart extensive knowledge of ethics, what we should do is to show that knowledge itself is embedded in ethics, and that it’s correct application depends on the essence of the human being.

The development of medicine and engineering for longevity requires the formulation of proactive processes to analyze and provide solutions to the problems we, ourselves, are creating (water shortages, overcrowding, increased demand for food) instead of focusing our efforts to resolve the problems that are already present. In this sense, engineering components need to incorporate new technologies to ensure the sustainability of the planet, new signposts for addressing the future and can be found by studying nature in more detail. The study should no longer focus on general, but on those exceptions that define the trends that will shape the future.

In order to have engineers with knowledge kept always up to date, we must strengthen its generic and systemic capacities within flexible environments. Institutions must accept that the flexibility of academic programs is the property that keeps the always-on engineering, promoting multiculturalism, interdisciplinary, multidisciplinary and transdisciplinary.

If we want the world to fully identify the Ibero-American engineer, we must provide common elements, giving courses to the entire Ibero-American academic community making use of virtually and all necessary means to reduce costs and gain international presence.

Trends in engineers training in Argentina

The engineer Carlos Savio, President of CONFEDI, focused his speech on the importance of quality assurance in engineering programs, both in the knowledge acquired by the new students and in the continuous improvement processes within schools. For Professor Savio, new trends in formation should be given in strategic areas and based on the development plans of countries, generating early vocations and improving training standards in science and technology from an early education.
Understanding the need to train professionals capable to meet the current challenges, engineering programs must be accredited under minimum quality components. The engineering programs in Argentina have gone through different stages of the accreditation process: self-assessment, academic peers visit, reporting, and building improvement plans (essential to meet the training requirements by defining activities). Also, It should be included as a strategy to have an "open" faculty able to prepare engineers integrated with awareness of sustainable resource management.

In addition to quality assurance, engineering programs must address issues strongly related to student dropout and academic quality of those entering university. To face the dropout problem and maintain the goal of training 10,000 engineers a year, there has been implemented in Argentina remedial courses to foster in students a primary responsibility to enter the Faculty of Engineering, and tutorials, financed by the Ministry of Education, to guide the first year students and strengthen their stay.

In the academic quality of new engineering students, CONFEDI (through workshops) defined skills of entry for students of engineering faculties. These skills have been brought to the Ministry of Higher Education and the Federal Council of Education, to be included in the average levels of education.

Additionally, starting two years ago it’s been applied a diagnostic test for students who enter the Faculty of Engineering, which is the approach of common engineering problems.

**Trends in Engineers training in Spain**

For engineer Manuel Recuero Lopez, former President of ASIBEI, success in training new engineers depends not only on the quality of its students and teachers, but also in the appropriate use of Information Technology and Communication (ICT) formation processes, to solve the problems of the communities.

Poor academic quality of students entering engineering programs is a great concern in training institutions. In most cases, higher education institutions, opt for the application of entrance tests and creating remedial courses that although divert valuable logistical and financial resources, contribute to obtaining better raw material conditions for the training of engineers.

Teacher training also has some issues in which we should pay special attention: the lack of clear training objectives consistent with the economic and social needs of countries, has confused, in practice, what are the real needs of future engineers; training engineers is more expensive than training other professionals.
ICT has transformed teaching in a way never seen before, affecting educational processes at all levels, from the validity of the content to the decision making of new professionals. Following the rapid change of knowledge caused by these technologies, they might be imparting knowledge that, at that moment, might be becoming obsolete. Therefore, it is essential to provide future engineers with a strong background in basic sciences, supplemented with computers, electronics, continuous experimentation, and to the accompaniment of the productive sector to bring their own experiences of practice to the classroom. This achievements guarantees, to some extent, that the capabilities of engineers will rise from present and future challenges.

The professional judgment of engineers has also been permeated by these technologies. In many parts of the world engineering programs are on the wrong path, they create a reliance on engineering tools such as algorithms, that while facilitating the design of engineering projects, don’t generate sensitivity in students to understand the world that surrounds them, and limit their creativity to a computer that resists everything. Technology is a tool for engineers, but not to an engineer purpose.

Finally, he emphasized that the world’s economic power determines government actions, not engineering. The engineers have not been able to use new technologies to create new forms of wealth, which allow you to guide policy development of nations. In this sense, the solutions to the needs of communities employed in the past, not worth for the future; we have to create new solutions to generate new jobs, new forms of wealth, and it disappears the current economic crisis. The response to the need to provide sufficient political visibility to engineering and to guide the development plans of countries can have an engineering that emphasizes the financial aspects.

**Trends and training of engineering expansion in Brazil**

Engineer Ana Maria de Mattos Rettl, Administrative Director of ABENGE, expressed great concern in Brazil for the exponential growth of Higher Education Institutions (HEI) and engineering programs that have been occurring over the past 18 years. The number of HEI imparting engineering courses increased from 150 institutions in the year 1996 to 625 in 2012, while the number of courses or programs increased from 500 in 1996 to over 2,800 in 2012. These alarming numbers are corroborated by observing the average annual creation of new engineering courses, that for the period 1989-1996 was 12 courses/year between 1997-2005 by 80 courses/year value from 2005 grew at a rate of 200 courses/year.
She also unveiled some of the most booming trends in higher education in Brazil, related to the emergence of new forms of engineering, distance learning and the new professional profile of the engineer.

**New forms of engineering**

As some anthropogenic activity intensifies, its complexity increases, and requires the application of more precise knowledge (such as mathematics and physics) for structuring and troubleshooting. The new reality of training and professional practice in engineering from the second half of the twentieth century, immersed in this scenario, determined the emergence of new forms of engineering due to the need to apply knowledge of basic science and technology in diverse fields such as health and applied social sciences.

As a result of this development, since 2005 Brazil’s GDP (Gross Domestic Product) has grown significantly, ranking seventh worldwide in 2012 with US $ 2.25 billion, of which about 23% are contributed by the industrial sector and 11.26% specifically for the processing subsector, one of the largest contributor to the development of technological products and therefore the most dependent of engineering. In this direction, the engineering has contributed to the development of better processes that enable an increasingly efficient and sophisticated production of goods and commodities in different environments, contributions that explain the large increase in production engineering and the proliferation of new forms engineering.

With the LDB (Law 9394 of 1996) and its subsequent revocation of the requirements as to the names of the courses and their specialization, the number of engineering degrees awarded nearly doubled. 32 engineering modalities existed in 1995 covering 56 engineering areas, Brazil today has more than 300 modalities. The increase does not happen by creating traditional careers as Chemistry or Mechanical Engineering, but by the appearance of new forms and Biochemical Engineering and Food Engineering.

Undoubtedly, one of the predominant trends in engineering education is the creation of modalities relating to environmental and health (Environmental Engineering, Food Engineering, Biochemistry Engineering, Genetics Engineering, Sanitary Engineering, etc.) and even issues relating to social sciences (management, job, security). These engineering emerge in response to the problems created by consumerism (continuous emission of pollutants, need to reuse waste products) and further exploration of the planet's natural resources for the development of new forms of energy. The dynamics of knowledge shows clearly that there are engineering degrees that ought to disappear and others that should emerge with solid foundations and clear objectives, under lifestyle and horizon development of societies.

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1 World Bank. GDP at USD at current prices. Source: http://datos.bancomundial.org
Distance Education

Long-distance courses have gained a significant presence in engineering education. The percentage of students who take these courses increased 4 times compared to those who choose classroom teaching, going from 470,000 enrolments in 2010 to 1.5 million in 2014. Today, Brazil has 26 long-distance engineering programs imparted in more than 750 institutions (in every 3 engineering courses imparted to foreigners, one is a long-distance curse). To ensure the consolidation of knowledge engineers trained this way, the Brazilian educational system requires a minimum of five years for each academic program, and the presence of students at least 3 times a week for practice (laboratories and other activities) within the university.

With the incorporation of long-distance education, teachers have also diversified their functions. Currently there are teachers (responsible for the academic part of the course), tutors (who perform the practical part of laboratories and help to solve problems), and mixed teachers (responsible for online courses and other tasks).

Despite the rise of long-distance education, it is relevant to consider that the study of desertion for new models of engineering education is an issue that must be addressed now, to prevent possible academic drop out in the future.

Engineer Profile

The professional profile of engineer has been altered, surpassing the previous condition of a professional expert in calculations, builder or troubleshooter, to a professional with skills, competencies and attributes that allow them to meet current requirements as a draftsman of multidisciplinary solutions to complex problems.

Countries require engineers to perform not only in their area of expertise, but also to direct and coordinate their activities with other sectors that are not explicitly part of their training, and decision-making at various levels of power, both private and public. In this aspect, the management of organizations is established as another trend set in the current engineering. The activities related to management, or organization, were empirically exercised by engineers, reason why disciplines in this area have come to be part of the curriculum of engineering courses.

The new engineers must be self-critical, and must diversify their actions to all activities that require the nature of knowledge developed during their formation. Basic sciences, social sciences (such as philosophy and psychology), and competencies related to structuring and problem solving, are part of the basis of formation of new interdisciplinary engineers prepared to meet the challenges of societies.
Trends in engineers training in Europe

In his presentation "Trends in engineers training in Europe", the engineer José Carlos Quadrado, IFEES President and former President of ASIBEI, gave an overview on the Bologna Process and the Lisbon Strategy as two important initiatives for projecting the solution to fundamental problems of European higher education.

The European Higher Education Area (EHEA)

The European Higher Education Area (EHEA) begins to be built under the principles of the Bologna Declaration of 1999, in which education ministers of 29 European Union Governments, expressed the importance of the role of universities in the creation of "Europe of Knowledge" and agreed to create a Common Framework for Higher Education in Europe.

After subsequent statements, with 47 nations subscribed and supported by programs such as ERASMUS+, the EHEA was established in 2010 as an integration agreement and cooperation for higher education systems, aimed at creating unified levels of education scenarios all over the continent, enabling accreditation and mobility of students and workers throughout Europe. This space has the fundamental mission of working with an interdisciplinary approach to generate and transfer knowledge as a contribution to the development of humanity, the socio-economic fabric and the Higher Education System, using as strategy the creation of adaptable leaders responsible for promoting global leadership regarding engineering [1].

Although Bologna reform has been criticized for its limited funding, for deficiencies in the system of quality assurance and democratization process, and the commodification of public HEI, the changes generated in engineering education have been decisive. Before the creation of the EHEA, education was focused on content, university autonomy was limited (HEI required permission from government agencies to offer academic programs), and external quality assurance was voluntary.

With the EHEA, teaching has focused on skills, autonomy of HEI has become more relevant (HEI can create, responsibly, many engineering programs as they wish), and quality assurance is now mandatory to achieve accreditation of academic programs.

Continuous improvement and modernization of curricula

In a cycle of continuous learning, graduates of engineering programs undergo rapid obsolescence (despite professional experience) as a result of the downgrade in some of them, as time passes and new technologies arise. The reinforcement and leveling of this knowledge comes only with adequate investment in resources of different types; during

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2 The Bologna Process is a reform of higher education systems in 29 countries of the European Union, with the main objective of building the European Higher Education Area (EHEA). In this reform the main objectives aimed at achieving the approval of European higher education in order to promote the free movement of students and increase the international attractiveness of European education [1].
the last century, this investment was required every 20 or 25 years, but now, due to the constant regulatory changes, technological innovation and the need to address the crisis, they should occur every five years or less.

In order to academic reforms achieve their goals, it is necessary that HEI know themselves, and that they adapt to the needs of quality and certification, advancing to the modernization of their curricula. Based on the required reforms, flagged by technology and innovation, and as part of the modernization agenda for universities planned by the European Union in the Bologna Declaration of 1999 and the Lisbon Strategy 2000, three fundamental changes were contemplated:³

1. Curriculum reform: establish a common structure title, in 3 cycles, learning/teaching skills, flexible learning paths, development of mobility programs, comparable and understandable titles, and comparable credit system.
2. Governance Reform: autonomy of HEI, strategic partners (including companies), quality assurance and cooperation in ensuring this.
3. Financial reform: diversify funding of HEI, in order to promote equitable access and efficiency.

Final Thoughts

Higher education in Europe has an essential role in society, creating new knowledge, transferring it to students and encouraging innovation. With over 4000 HEI, 17 million students and about 1.5 million teachers, the European system of higher education is one of the largest and most complex in the world. While some European universities are among the best in the world, its potential could be even greater if they succeed to correct some of the deficiencies in their education systems.

Moreover, there are two key questions in the design of the EHEA: Can the EHEA actually generate adaptive leaders as required? Does the higher engineering education form adaptive leaders as it was expected in Europe? Although there are still no clear answers, it is clear that the success of these leaders will depend on the conception that universities have about their programs, projecting as a continuous learning process in which the most important innovation is the development of young minds, providing tools to understand the crisis as a combination between risk and opportunity, and to address problems creatively rather than knowledge.

³ While the Bologna Process focuses on curricular reform, the Lisbon Strategy aims to make Europe in an economy based on knowledge the most competitive and dynamic of the world.
Training engineers in Colombia: Current trends and future

To engineer Alberto Ocampo Valencia, member of ACOFI’s Board, trends in engineering education are aimed at turning classrooms into learning laboratories using ICT (Information Technology and Communication) as a methodological basis, and to change the formation focus thinking over the way classes are taught.

**Learning laboratories**

The Information Technology and Communication are revolutionizing the education sector, bringing learning experiences into a collaborative environment that goes beyond the curriculum, transforming the classroom into a learning laboratory. In this regard, some universities in Colombia have built classrooms equipped with a system of modular computer tables, where students work in groups to then develop a comprehensive discussion of the themes addressed in class through a main screen. This methodology, relatively inexpensive, facilitates individual and cooperative analysis, and allows students to take ownership of content more effectively by using computational models in the teaching method.

The systematization of engineering education processes, enabled by ICT, brings a significant evolution of the task the teacher has undertaken so far, and a new way of inclusion in which all the students can participate actively in the classroom and interact with others. These efforts should be complemented by projects such as PDT⁴ so that technological development can shelter engineering professions throughout the region.

**Skills Training**

A trend that increasingly takes more strength in existing educational models, is the change of training by objectives to training by skills (basic, disciplinary and specific) that build an engineer technically skilled, innovative, entrepreneurial, multicultural knowledge and knowledgeable of the world markets.

Following this proposal, we are managing some initiatives in Colombia to compare the results of students completing secondary (high school) with students that ended engineering programs, and determine the knowledge acquired during their training period at university, in terms of generic skills. While the comparison depends on the evaluation form and the type of skill, for this purpose are considered generic skills those related to solving problems, critical thinking, interpersonal understanding, written and spoken communication skills, and civic skill as an additional element.

On the other hand, it is important to consider the disciplinary skills as those related directly with the professional practice, among which the ability to "govern" phenomena, solve problems, and to design, assess and evaluate. The possibility of studying abroad and

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⁴ The ANR Technological Development (PDT) project is an instrument of the Argentine Technology Fund (FONTAR) to finance projects of technological development to improve production structures and innovative capacity of SMEs companies [3].
studying languages, are also key elements that should be part of the skills of every engineer.

**Quality Assurance**

Quality in higher education is a substantial issue for engineering education in the XXI century, so its certification (through processes of accreditation of programs) has become very important for HEI. In the case of Colombia, the National Accreditation Council (NAC) is the agency responsible for recognizing the quality of programs, using factors and indicators, which mostly match the quality criteria ASIBEI for Ibero-American engineering education. Among these factors are: management and institutional projection, students, teachers, academic process, institutional welfare impact of graduates in the setting, physical and financial resources, national and international mobility, research, innovation and artistic and cultural creation.

Among the new challenges of education we can point out not only the quality assurance or the use of ICT as a complement to the classes (offering important advantages as using modeling software to visualize machines closer to reality), but also the need to move from a teacher-centered teaching to a student-centered teaching, picking tools like Bloom's Taxonomy\(^5\), to estimate what level of complexity of thought students are working. It is also a very important aspect to permit each content to be learned in practice, because only like this we can achieve internalized knowledge, as well expressed by Confucius: "They told me, and I forget. I saw and I understood. I did it and I learned it ".

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**Panel National Association of Colleges and Schools of Engineering –ANFEI - Mexico**

As part of the XLI National Engineering Conference "Training of Engineers in Mexico", ANFEI developed in June 5\(^{th}\) 2014, a panel related to the thematic trends of great importance for engineering education in the region. It was discussed, with particular concern the lack of preparation of HEI and their teachers to adapt teaching to new technologies, and the threat posed to the graduates of engineering programs, the growing interference of world economic powers under free competition and future labor market.

**Global trends in engineering education: China and India**

According to the Organization for Economic Cooperation and Development (OECD), investment in science and technology in a country is highly correlated with its economic development. This can be evidenced by observing countries like China and India, whose

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\(^5\) The taxonomy of educational objectives is a classification that includes the objectives and skills that educators can offer its students. Bloom's taxonomy is hierarchical, because it assumes that learning to higher levels depends on the knowledge and skills acquired at lower levels. At the same time gives an overview of the educational process to consider three dimensions: affective, psychomotor and cognitive [2]
investments in research and development are much higher than those of most Ibero-
american countries (Mexico, for example, spends only 0.45% of GDP). The support for
science and engineering, product of a harmonious work between private and state
agencies, is undoubtedly one of the determinants factors for obtaining the highest level
professionals.

The amazing scientific and technological present of China is not a coincidence; it is the
product of a well thought plan over 15 years and projected for the next 25. This plan not
only includes planning technologies that spearhead the development of the nation
(biotechnology, information technology, robotics, etc.), but also defines the strategies for
success. According to the ASEE, training of engineers in China is focused on the following
principles: reform radically engineering schools, critical thinking, focus on manufacturing
towards innovation, being world leaders in technology, making large economic
investments in the engineering education.

As for engineering programs, China has rethought their duration, reducing from 5 to 4
years, not to reduce costs but because they urgently needed new engineers in the country
workforce. In addition, the curriculum (with a similar program at MIT academic level) are
designed to have a duration of at least 30 years and are shaped by 50% in core subjects,
25% in mathematics and science, and 25% of social sciences.

Alongside with the technological disadvantage that results from comparing us with China,
there is a manifesting labor problem for the engineering associated with population terms.
India currently has a little over 1,200 million citizens, and by 2020 will have the largest
trained workforce worldwide, with 200 million professionals (whereas Mexico only
graduates 100,000 engineers every year), who dominate English language and who seek to
live in other countries to earn lower than those paid by local professional salaries. This
represents a major threat that can only be reversed if we are better prepared than them.
Foreign investment in each of the countries does not give priority to local engineers, but
those who have the best training and that represent lower costs. It is necessary to define
specific goals and focus efforts on preparing our professionals to get them, making the
best use of technology.

**Skills of the new engineers**

The high dynamics of knowledge and technological advances and drastic changes in the
lifestyles of societies, force engineers to be updated continuously to ensure sustainability
in their engineering actions. Some of the capabilities that professional engineering of the
XXI century must have are:

- Overview thinking about sustainability and environmental care.
- Strong background in science and mathematics.
- Analytical, critical and divergent thinking.
- Domain of information technology to receive and transmit information faster, and
  apply knowledge effectively.
- Take advantage of social networks to exchange experiences and knowledge.
- Leadership (the leader makes things happen).
- Ability to approach projects in all stages, from design to implementation.
- Ability to assimilate the foundations of other disciplines, and improve communication within multidisciplinary teams.
- Creativity and innovation.
- Fluent in English and/or Chinese (90% of the knowledge generated in the world is translated into English, and 40% Chinese).
- Permanently updated: prepare for further learning.

Moreover, much has been said about the role of industry in the definition of the skills required by professionals. Overall, the productive sector does not know what it needs to grow, only companies with extensive experience know it; they must participate, but their judgment, often limited, should not be the only one that define skills training of engineers.

It is important to identify the needs of the productive sector: in the short term, to design work training and continuing education programs (collecting information through surveys), and in the long term, to define the required skills and designing undergraduate and graduate programs. According to current projections, we must prepare new engineers to take on the challenges they will face between 2022 and 2037, not only to solve the problems we have nowadays, but to anticipate future needs which is even more important to overcome the current requirements.

**New Training Trends**

Teaching methodologies and preparation of teachers are also required to transcend to new forms of teaching. Thanks to new technologies and the ability to exchange information instantly, teachers and IES have tools never seen before to redesigning curricula, content and methodologies to teach classes, so that students learn easier and quickly. Training schemes should also be modified, making possible joint courses and graduates continuing education, job training and skills development for the medium and long term training undergraduate and graduate students.

The training of teachers, in addition to addressing the incorporation of skills for the use of new technologies, should start thinking about a generational shift, attracting graduates that are more related to these innovations and with the most appropriate skills to meet future challenges of engineering education.

Operating schemes HEI’s should also be adapted; taking advantage of the availability of information and ICT’s to reduce the time spent on individual request in classrooms, and use it to develop capabilities that have to be in person as teamwork.
References

