

PARADIGMS IN ENGINEERING UNIVERSITY PROGRAMS: THE CASE OF MEXICO

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Abstract

A critical review of the relevant aspects of engineering educational programs in Mexico is presented, within the historical background and the near future tendencies of industrial activities. The traditional way of teaching and learning engineering at the Mexican universities, derived from the socioeconomic development during the second half of the twentieth century, is contrasted with the needed education for engineers at the beginning of the new millennium. The case of Mexico is examined: A country that rapidly changed from a rural and pre-industrial society prevailing up to the 1940 decade, to a modern industrialized nation consolidated in the 1950-1970 period. Several issues are considered, as: the educational programs based mainly on a generalist type of engineer suitable for the industrialization period, when the economic policy was based on the substitution of imports; the huge increase of the number of universities and educational programs during the 70's and 80's; the participation in the fully open market and the global economy characterizing the last two decades of the last century; etc. Within this context, the paper considers the role of engineers at present, addressing the necessity for new educational programs with different contents and shorter duration, according to an era with new and deeper knowledge, rapid changing technology, and unforeseen possibilities for informatics.

Introduction

This paper, with additions and modifications, is part of the preliminary documents that were prepared and submitted by the author to the Faculty of Engineering of the National University of Mexico (UNAM), to frame the most recent reform of the programs for the B.S. degree in engineering, conducted in the years 2004-2005.

The review and modification of the educational programs that offers any school of engineering should be based on a methodological and careful diagnosis that clearly takes into account the characteristics of each specialty of the profession of engineer. These are derived, on the one hand, from the proper self-evolution of the profession in response to the economic activities of better profit value in a market economy; and on the other hand, of what should be the main motivation for the general progress of the society: the satisfaction of the socioeconomic needs and the general welfare of a growing population.

Before any consideration of modification of a plan of study it is necessary to perform a diagnostic exercise. Without the diagnosis, the modification of the plan can turn out to be inappropriate and sterile perhaps. It might even serve to create false expectations based on the tradition of the profession or in the history of a particular school. It would only reflect personal conceptions.

The diagnosis carried out in appropriate form, may raise unexpected conclusions, like for instance, the need to modify radically a plan of study by its obsolescence with respect to the technologies and techniques associated to the practice of the corresponding profession; or the consideration that a specific program is no longer necessary by saturation of the labor market or as a because it is satisfactorily offered—in terms of both, quality and quantity— by other institutions of higher education. It requires in any case, a deep analysis that take into account the problems and expectations of the economic activity where is situated.

Historical Background

A brief description of the history of Mexico must include the original settlements, enduring in large territorial extensions, of important civilizations like the Toltec, Maya and Aztec people with great achievements in astronomy, construction, water works and agriculture, that certainly impressed the Spanish conquerors in 1521. Three centuries as the most important Spanish colony in terms of trade and

production of agriculture and mining products, as well as some industrial goods, together with a long term social mixing, helped to shape the Mexican culture with an overwhelming majority of mestizo population, a single religion and a single language. Mainly derived from economic disagreements with the metropolis and influenced by the European Enlightening age and the American Revolution, the colony changed to an independent nation, taking the opportunity favored by the Napoleon invasion to Spain.

The remaining of the 19th century served as the scenery for internal wars between liberals and conservatives and foreign interventions that ended with the lost of half of the territory. At the same time, advanced political reforms permitted to sign a modern constitution for the young nation. Nevertheless, important socioeconomic changes have to wait until the 10's and 20's years, when a long and violent internal civil war finally ended with the colonial practices, especially those connected to the land exploitation. The basis for agriculture reform and for industrialization was then settled down.

The first formation programs of engineers (in the modern sense of the word) in Mexico, date from the times of president Benito Juárez (1861-1872), but it is up to the middle of the 20th century that this profession acquired its presence as part of higher education. During the 30's and 40's, large irrigation works for agriculture and extensive electrification begun, within long term governmental plans to develop the economy. Expansion and improvement of education for everybody and at all levels, was a very important objective at those times, since without them, the benefits of progress would not be extensive to the whole society.

The profiles of engineering graduates were clearly oriented to the needs that required the development of the infrastructure and the industrialization of the country, in an economic model of replacement of imports: engineers with extensive capacities for the construction and building of civil works, the production, installation and maintenance of equipment, the abilities for the adaptation of technologies —although this word and this concept were not utilized in that epoch—, and the administration of large projects.

Therefore, the engineering educational programs were mainly based on a generalist type of engineer suitable for the large public works (irrigation, roads, and the like), and the electrification and industrialization activities. There was a huge increase of the number of universities and educational programs during the 70 and 80's as part of this growth.

The second half of XX century was mainly characterized by the cold war and by the very fast emerging technology changes that humanity is experiencing, especially in the last decades. This is a result among other things, of the semiconductors industry development that tremendously impelled informatics and telecommunications. It had as a consequence an impact in economies that derived in the global economy, and in many important political issues in the World context. Mexico was not excluded from this situation as part of the western hemisphere, except that its economic policy was based on the substitution of imports during the 50, 60 and 70's, and changed almost abruptly to an open market and embedded into the global economy in the 80 and 90's. Noticeable in this context is the signature of important free trade treaties —NAFTA among them— with some countries.

At the beginning of the 60's, the National University of Mexico (UNAM), the National Polytechnic Institute (IPN) and very few schools and technology institutes in the provincial states, provided the demand of engineers of the country, may be not enough in terms of quantity for the fast industrial growth of those days —there are not totally dependable statistics in this respect—, but apparently in satisfactory form as for quality. Therefore, UNAM represented something as the 40% of the total national number of registered students, in programs heavily influenced by civil engineering, one of the traditional careers.

In 1968, a hundred years after founded the National School of Engineers (the first school of engineering, today part of UNAM), the country included 70 schools of engineering and 44,000 students registered in 19 programs. It was taught engineering in 24 universities and 14 technological institutes distributed in 25 states of the federation.

In 1983 the engineering students registration passed already from 248,000 students in approximately 150 careers with different names, offered by 160 schools distributed around the country, as a consequence of the strong impulse to education, given in the 60's and 70's¹.

In 1998 there existed in Mexico 1,259 programs of engineering classifiable in 250-300 programs with the typical name (i.e. There has been a tendency to call the programs with different names like *Mechanical Industrial Engineer* or *Mechanical Administrative Engineer* to specify a typical program of Industrial Engineering, etc), offered in 237 schools. In these programs a total 447,000 students was registered and they graduated 51,000 in that year.

And in the year 2000, the total registration of engineering in the country was of 514,000 students with a graduation of 54,000 in 1999.

In this manner, UNAM represents today less than 2% of the national registration—with similar percentages in the number of graduates—in all branches of engineering taken as a whole. The demand for engineers is well-filled by many institutions around the country (like the fast growing private and public universities, the consolidating system of technological institutes, and new educational systems that are being created), with their own criteria, programs and operating structures to undertake the high educational needs in Mexico, with regional permanence of graduates, etc. Moreover, the large figures mentioned above might suggest that there is a risk for unemployment of engineering graduates. Apparently there is not as their professional skills allow them to adapt easily to many other functions in the employment market, like administration, sales, middle level teachers, etc. More field analyses are needed in this respect.

In this context, any action that may be carried out at UNAM will impact very little on the nationwide quantitative offer. However, it represents an opportunity in the qualitative sense, as UNAM comprises an influential high-quality academic staff, first-level research facilities and a well set physical plant. This university may keep its leading position to offer vanguard engineering education programs to the contemporary society and can induce other institutions (as it has done it in the past) for substantial advances in the way of teaching engineering.

Engineers Required At Present

An important contribution to the description of engineering activities, is the scientific advance in many areas of knowledge, and the technology innovations that succeed at an extraordinary speed in certain branches of industrial production and economic activity (telecommunications, data processing, materials, processes, manufacturing, etc.). These advances and innovations lead the pathways for the professional practice, either, as a consequence of the assimilation of different techniques, or due to the expansion of the market of goods and services.

It is also relevant for such a review, the analysis of the real offer and demand of engineers in each one of its specialities^{1,2,3}, that in our country should aim clearly towards the improvement of its professional quality and not—as has always been believed and diffused—, towards the increment of the absolute number of professionals.

Finally, it is necessary to add the consideration of the change that are having the professionals in the world context, within a global economy on the one hand, and with the treaties of free commerce among nations on the other hand, that may imply the possibility of the professional exercise without borders, as already happens in the European Union.

It is not appropriate then to say that it is only necessary to increase the number of engineers in the country, vision that only contributes to the false jobs creation expectation in a general market of work that does not seem to aim towards its expansion, but just the opposite⁴. It is neither proper to say, as it does very often, that engineers should have so extensive and diverse attributes, resulting in contradictory statements like that an engineer should be “an administrator capable to create technology”, and other similar concepts.

Moreover, it is necessary to understand that the engineering profession has changed in each one of its specialties and that it is required to redefine the mission of a prestigious university like UNAM for the next 25 years. The society in the 21st century is characterized by an extensive, sustained and continuous change in the use of technology, in a global market of enormous competence and interdependency, and with a capacity of communication never imagined before. This implies for engineers the challenge to offer to the society, new abilities that allow him to design, build, manufacture and operate goods with better aggregate value of technology and more efficient in their function, to the lowest possible costs. It requires deepening his knowledge of diverse disciplines, to expand his capacities of information and to develop his creativity, keeping in mind the extraordinary rhythm of change that technology has at present. In summary, there is a need for an engineer with aptitudes for the technology innovation in a global and interconnected world, highly involved in establishing a strategy of development for the society. The school of engineering at UNAM should collaborate in this goal, along with other essential actors as the associations of professional engineers in Mexico: “we shall have good and sufficient engineers only if the country search to have infrastructure and sufficient and good industry”⁵.

It is required then to clearly identify what are in reality the functions of an engineer in the society and which should be his real professional capacities. For the reform of the plans of study offered by UNAM it is of great importance to consider with care, what an engineer should know. It should be raised questions like⁵: Which are the intellectual processes of engineers?, In what context do engineers exercise their profession?, In which they learn?, What know-how and capacities require?, How some are acquired and how do engineers develop others?, What curriculum contents, methods and environments of learning are suitable?, What can be learned in the school?, What can be learned only in practice?

Reform of Engineering University Programs

The diagnostic review of an engineering program and the consideration of the role of engineers in a changing society, point out to a necessary modification of the plans of study. This is generally based on educational models that can be taken from diverse institutions in different countries and universities. However, educational models by their very nature and due to the philosophies that support them, can turn out to be very numerous, with substantial or subtle differences, and possibly framed in opposite opinions, as they can include subjective values, additional to purely methodological questions. In any case, their consideration in the frame of reviewing and renewing a plan of study, may conduct to discussions and very extensive analyses. For these reasons, in this document only general statements are proposed that may contribute to the revision of a plan of study.

The prevailing forms of teaching at many educative institutions in Mexico, can be summarized by the following characteristics and attitudes:

- An inflexible core curriculum where there is not an opportunity for students to take courses in different sequence as it outlined in the program, nor to consider subjects from different departments like Physics or Economics that might be helpful in his education. Obviously, no student mobility to other institutions exists.
- Professors on the other hand, are mostly limited to lecturing and they are revered for this; they may develop some times, an authoritarian manner. The objective then is to transmit knowledge with an encyclopedic attitude. Education consists only of transmission of the professor experiences that may be far from reality.
- The eyewitness classes are essential. The students are receptive and passive (obedient). Classes are repetitive and monotonous. Very often, teaching is mainly based on exercises and grading is the only measurement of learning. Indifference before political, economic and social situations is common. At the end, students are only interested in approving subjects.

A conservative, traditional modification of the plans of study is common in many Mexican universities. This is a restrictive option and of short range; it is properly like an updating of the programs of study and the contents of some subjects, with very few curriculum modifications, probably some of them badly needed. It is based on the profile of the engineer that pursued since the years 70; something that is frequently repeated in the speech, each time that is called for the convenience to modify an engineering curriculum: the objective to produce an engineer with an accumulation of attributes and possibilities of professional development, to comply an extensive assembly of needs of the country, and with an excessively optimistic and insufficiently clear vision that UNAM will satisfy the demand of the labor market of engineers and will give answer to the needs of the country for this profession.

Only adaptations are required to be approved by the Faculty and the university authority bodies, without a deep educational discussion. The result would be practically the same program of today, with a conservative orientation, a limited operating structure and would continue with the stiff attitude in the teaching-learning process, accord with the old-fashioned, traditional education in Mexico. The results of this would put the school of engineering at UNAM in a few years, in a situation of clear disadvantage with respect to the other institutions —public and private— with a wasteful of the present staff of professors of good level and the exceptional laboratory and mechanical shops, that currently make this institution very attractive. In the best of the cases, the program at UNAM would be in a more devalued condition — situation that already is observed in some of the careers that offers—, inside a vicious circle with less resources, being converted our programs in an offering very limited with mediocre results. If worse comes to worst, it would have a serious threat to the continuance of the careers.

A substantial and meaningful (radical) modification is possible and necessary today, if good, skilful and adaptable engineers are sought for a changing society. This implies a plan of study that focus on learning and not on teaching.

An extent of no more than eight school semesters with a total of 64 hours of coursework per subject each semester with 6 simultaneous subjects a semester, including laboratories, totalizing more than 3,000 hours. This fulfils most of the international academic standards. Nevertheless, it is possible to reduce these numbers due to the time reduction in the use of informatics, libraries, etc., as it is happening nowadays in some European educational systems.

The academic staff must include, (a) full-dedication professors for the basic and engineering sciences (both kind of subjects should be thought by engineering professors), with participation (but not only) in research activities; and (b) highly scholar professional engineers for those applied subjects connected to the practice of engineering.

A student should capture new techniques of communication. He must prepare and analyze oral presentations, by improving his oratory abilities. He also should extend his work with other students as a team, etc. To accomplish this, it is necessary to abandon the traditional reticular kind of arrangement of the classrooms and to change toward one of mobile seats and communal tables, in more reduced groups offering more opportunities so that the students leasing, process and redefine information transformed into knowledge.

It is recommended that some subjects related to engineering practice and applied science, could be offered to freshman students right from the beginning. These subjects should initiate the student in engineering principles as systems modeling, optimization, global vision and the social impact of engineering.

In any subject, is especially important to prioritize the skilful aspects against the pure informative ones. The syllabus and the teaching practices should promote the pursuit of students projects, prompting aspects such as the oral and written communication, the teamwork, the ethics and the professional performance, the creativity and the resolution of problems.

A plan of study should contemplate students mobility to other universities, with flexible criteria in their syllabus. It is desirable that, as part of his optional subjects, a student can take courses of his interest that do not necessarily belong to his own program. It is highly recommended that students have the mobility to study during one or two semesters, in other prestigious universities, either domestic or abroad, with curriculum recognition from the part of the school where he is registered. In the last semesters they should be considered curriculum activities of professional practice with real linking with the productive sector of the country, of the ones that derive up-to-date and pertinent engineering topics, that serve for their final projects and degree granting. A open involvement in socioeconomic issues is desirable.

But above all, a truly reviving educational attitude is required that include the participation of all the actors, especially the student, that contemplate technical innovations of teaching, self-learning, use of informatics and stimulation of creativity.

Concluding Remarks

It is a matter of taking advantage of the circumstances of the moment —especially the situation of university reform—, to undertake a true transformation of the plans of studies: that foresees a realistic vision of the socioeconomic environment of the country and its perspectives to medium and long time; that considers the tremendous technological change in which we are immersed; that takes advantage of a dynamism that is possible to impel the teaching methods; that incorporates the advance of science; that permits, in short, to offer high-quality engineers that compete for the vanguard of the development of the country. It should be established an international-class engineering vision, that defines that we want to be among the better of the world in few years, with an appropriate evaluation and certification. It is important from now on to define the parameters of performance that measure how well we approach our goal, and to establish who is to tell it.

This can be achieved if there exists a clear vision of the real demand of professionals and of the characteristics of the educational offering. It would be of interest that UNAM would offer graduates in engineering no only for the traditional professional activities of exploration, construction, installation, maintenance and production of goods with conventional technologies. These requests are covered with efficacy, by the extensive variety of programs that offer institutions distributed along the country. It would

be better, to impact the economy with engineers qualified for technology innovation, to explore new know-how and its applications.

References

1. López-Toledo, A., "Education and Occupation of Engineers: Past, Present and Future", Journal of the National Academy of Engineering of Mexico, 3, 3, 183-323, 1984. (In Spanish.)
2. National Association of Schools of Engineering (ANFEI), "Strategic and prospective planning", Executive Committee, 1998-2000. (In Spanish.)
3. National Association of Universities and High Education Institutions, (ANUIES), Statistical Year 2000. (In Spanish.)
4. Forrester, V., *The Horror Economic*, Blackwell, Oxford, 1999.
5. Reséndiz, D., "Activities and formation of engineers", magisterial lecture presented alter the National Academy of Engineering of Mexico, México City, August, 2003. (In Spanish.)