

Towards the Design of the Professional Profiles in an Industrial Engineering Curriculum

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Abstract - Since 1955 the Industrial Engineering undergraduate program at Universidad de los Andes has been oriented to the construction of knowledge of engineering contents. In 2003 the Engineering School began a self-evaluation of its programs; consequently the Faculty decided to redesign the curriculums. One purpose of the Reform is to consolidate the development of engineering competences and skills. The previous curriculum of the Industrial Engineering program had 4 knowledge areas and 158 credits, where the students selected 2 of these areas. The current one looks for different profiles: double undergraduate programs, integration of undergraduate with masters programs, international academic experiences and internships. It gives the opportunity to obtain double graduation with outstanding universities around the world and strong specialization in industrial engineering topics. The current program was conceived with 137 credits, where the student takes 63 elective credits to configure his/her profile: 9 in Sciences, 24 in Social Sciences and Humanities, 18 in special topics of Industrial Engineering, 6 in free courses, and 6 in application projects. This article attempts to illustrate the current profiles and the way this conception of competences and skills will respond to the requirements of the engineers of 2020 and the stakeholders of the Engineering School.

Index Terms - Curriculum Reform, Engineering Abilities and Skills, Industrial Engineering Profiles.

INTRODUCTION

Different prospective works have been carried out around the world trying to determine what conditions the society will have to face in the years to come. Regardless of the time horizon observed at the present time, there is consensus that the constant factor for the next decades will be the continuous change. Therefore, the academic programs for any discipline must adequate their curriculum to develop competences, capabilities, abilities and skills in their students so as to ensure that they will have full command of the basic contents of the discipline.

For the purpose of this paper, the document "The Engineer of 2020" [1] was taken as the benchmark; it defines the breakthrough technologies and the technological changes expected for 2020, and, on the other hand, a work developed

by the Departamento Nacional de Planeación (a governmental office in Colombia) called "Visión Colombia 2019" [2]; it defines a series of goals that the country must reach by that date.

As far as the Engineering Department of the Universidad de los Andes is concerned, it is clear that graduates contribution to the country must be to support the transition in order to evolve from a pre-capitalist economy with feudal characteristics, based on raw materials exploitation, into an economy based on manufacturing processes with a high technological content [3], within the world context of a Knowledge Society [4]. The contribution of the industrial engineers under the conditions of year 2020 demands a new approach on their education with a curricular structure that allows the creation of culture of knowledge production that is subjective, socially and universally new, by the students and the community throughout the entire life.

The Curricular Reform that the Engineering Faculty has been developing since 2003 approaches a structure that, in the case of Industrial Engineering, expects especially to consolidate a series of different profiles in this discipline. In this regards, the aim is to have these profiles certified so that the graduates can obtain a higher degree of differentiation in the marketplace. In addition, this profile structure is aimed at responding to the objectives associated with competences, skills and abilities, proposed by the ABET 2000 criteria [4], particularly in what relates to the "Program Outcomes and Assessment".

This article presents the profiles defined in the new curricular structure and the way in which such profiles respond to the education requirements expected for the engineers of year 2020, who are presently attending the University's classrooms. This presentation is made within the evolution context of the Industrial Engineering Department and emphasis is placed on the curricular structure. It should be highlighted that this structure responds to the requirements perceived in the country's context on each given time.

EVOLUTION OF THE INDUSTRIAL ENGINEERING PROGRAM DURING THE LAST 40 YEARS

The transformations undergone by the Universidad de los Andes' Industrial Engineering Program throughout its history

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have aimed at responding to country's requirements for professionals under this discipline at each given time. Likewise, these transformations have involved trends in engineers' education which are defined by outstanding engineering schools worldwide.

During the 42 years of life of the Industrial Engineering Department, four phases can be identified, with different curricular structures to respond to the diverse requirements of the environment at each time. They are:

PHASE I. Joint Education between Universidad de los Andes and American Universities

During this phase that starts in 1955 and goes through 1965, nine graduates from Industrial Engineering participated in the "3-2 Program" which consisted of completing their basic studies at the Universidad de los Andes during three years and performing deep studies within a specific discipline at an American university during two years. The first three-year education followed a general approach to engineering, while the two last years were aimed at developing skills and at providing specific knowledge within the context of each engineering program. The characteristics of the professional training were defined according to the system of the university where the final phase of the program was developed. During this period, the country was shaping the companies that presently comprise the production and service sector, and thus, the professionals from industrial engineering enjoyed multiple choices for work opportunities. The program was small as compared to other engineering programs and its "return" was particularly high at the undergraduate training level during this phase for any graduate from this type of programs.

PHASE II. Education Oriented towards Learning Industrial Engineering General Content

During this phase, which runs from 1966 through 1998, 2420 students were graduated from the program. The curriculum structure during this phase was aimed at having the student face the different realities of Industrial Engineering, without major approach in the configuration of him/her professional component. The study program had 177 credits within a structure with fairly low flexible levels and where the Industrial Engineering fundamentals were dispersed throughout different courses. During this period, the country strengthened its industrial sector and during the 90s it was faced to economic opening processes. Colombia enjoyed years of prosperity and economic wealth resulting from the good performance of the private economic sectors [6], but further on it faced structural transformation processes caused by a general crisis which strongly impacted the country's development.

PHASE III. Education Oriented towards Learning Contents by Selecting Major and Minor Areas

During this period which goes from 1999 through 2005, 1780 industrial engineers completed the program and were

graduated. The studies program was made up of 155 credits with a higher flexibility level and the possibility for the student to select one major area and one minor area to go into the Industrial Engineering topics. These education areas were defined to the teachers' work topics, which are: Operations Research and Statistics, Production and Technology, Organizations Management and, Economy and Finance. During this period an adjustment process took place in the economic sectors and the industry defined a new dynamics concurrent with the country's new conditions.

PHASE IV. Education Oriented towards the Development of Competences and Skills in Engineering and the Creation of Diverse Professional Profiles

This period starts in 2006 and to date there has been no graduates under this new education scheme. The studies program is made up of 137 credits where the aim is to provide to the student the possibility to benefit from the elective component of the program to create a certified profile that will meet his/her interests and will make a difference within the marketplace. The objectives of the studies program are oriented towards the development of competences, abilities and skills required by engineers in year 2020. Diverse studies on the professional development of the graduates, the perception of the industry employers, the perception of teachers and students, as well as diverse studies on the learning culture and habits of the students, have been taken into consideration for the creation and design of the program structure. Furthermore, diverse international references were taken into account, including: The orientations and criteria of ABET [1], CDIO [7], TUNING agreement documents [8], among others.

CURRICULUM STRUCTURE DURING THE DIFFERENT PERIODS

For the purpose of the analysis presented, six categories of courses are defined, which have been kept in the studies program and that correspond to the following:

Integral Education

These are courses in disciplines other than Engineering that provide the student with supplementary training to his/her discipline and that are aimed at giving a humanistic view of his/her professional performance. It includes language courses, arts, humanities, social sciences, basic sciences, technology, among others. The regulations for these courses are identical for all the University's students.

Free Selection Courses

These are two courses selected by the student between all the courses offered by the University in all the current programs.

Science Education

It addresses the basic knowledge of mathematics, physics, life science and/or chemistry. Historically, the science

education has been almost the same for all students in the Engineering programs.

Engineering Fundamentals

Covers the subjects offered by other Engineering departments, which are part of engineers general education, regardless of the specialty.

Industrial Engineering Fundamentals:

It involves an education in concepts, contents and tools inherent to Industrial Engineering. This specific education for the specialty is identical for all students in the program.

Engineering Electives, including Industrial Engineering:

Covers professional subjects taken by the student according to his/her interests. The scheme of the professional education where the student takes these subjects has been associated to the structure of the studies program on the given time.

Projects:

Have to do with academic credits for the autonomous work, where the student dedicates his/her efforts to solving open and non-structured engineering problems. Historically, the aim has been for these projects to be spaces for the student interaction with the environment where he/she will be developing his/her professional activity.

The Table I presents the evolution, in terms of credits, of the studies program for Industrial Engineering during the phases where the Universidad de los Andes has completely educated the students. Phase II presented corresponds to the period covering years 1966 through 1998, Phase III corresponds to the period between 1999 and 2005, and Phase IV corresponds to the period started in 2006. On each of the phases the total credit distribution in the different education areas (T) is presented, as well as the mandatory credits (O) and Electives (E) on each of them.

TABLE I
EVOLUTION OF THE INDUSTRIAL ENGINEERING CURRICULUM

PHASES EDUCATION AREA	II			III			IV		
	T	O	E	T	O	E	T	O	E
Integral Education	27	0	27	24	6	18	24	0	24
Free Selection Courses	6	0	6	6	0	6	6	0	6
Science Education	35	35	0	31	28	3	29	20	9
Engineering Fundamentals	27	18	9	27	18	9	21	18	3
Industrial Engineering Fundamentals	56	53	3	33	33	0	36	36	0
Engineering Elective Courses	18	0	18	33	0	33	15	0	15
Projects	3	3	0	4	4	0	6	0	6
	172	109	63	158	89	69	137	74	63
		63%	37%		56%	44%		54%	46%

The transition between Phases II and III, from a training general structure in Industrial Engineering to a structure oriented towards learning Industrial Engineering contents with a specific focus, is characterized by a 41,07% reduction in the Industrial Engineering Fundamentals, a reduction of 11.4% in the Science education and a 83,3% increase in Engineering electives courses (this increase includes only Industrial Engineering courses). The increase in electivity of

the professional education cycle was structured in accordance with Industrial Engineering academic areas offered by the Industrial Engineering Faculty: Operations Research and Statistics, Production and Technology, Organization Management and, Economy and Finance. The organizational structure supporting this curricular scheme by areas was gradually oriented towards the creation of research groups increasingly aligned with these subject areas.

Within the curricular structure of Phase III, the students start raising some differentiation attempts. The elective component of the program (44% of the credits) were used for this differentiation as well as the similarity between some education areas, were identical to other programs offered in the University. As evidence of this differentiation attempts, the choices selected by the students of the last six cohorts of graduates in the program are presented in Table II.

TABLE II
CHOICES SELECTED BY STUDENTS IN BY GRADUATES

	ONE ACADEMIC OPTION	TWO ACADEMIC OPTIONS	THREE ACADEMIC OPTIONS	DOUBLE UNDERGRADUATE PROGRAM	ENTREPRENEUR PRACTICE	SOCIAL PRACTICE	EXCHANGE
200420	16,49%	4,12%	0,00%	19,59%	1,03%	5,00%	7,22%
200510	24,74%	2,06%	0,00%	16,49%	36,08%	1,86%	8,60%
200520	25,77%	2,06%	0,00%	27,84%	36,08%	2,47%	8,20%
200610	15,46%	2,06%	0,00%	13,40%	43,30%	4,46%	3,85%
200620	17,95%	0,85%	0,00%	11,11%	38,46%	8,55%	5,98%
200710	17,46%	2,38%	0,79%	26,19%	48,40%	6,34%	10,31%
MEAN	19,99%	2,26%	0,13%	20,70%	33,89%	4,78%	6,77%

During the transition of the curricular structure from Phase III to Phase IV, an approach oriented towards the development of Engineering competences is adopted, creating profiles according to the students interests, taking advantage of a flexible structure and the regulation in force at the University. This new structure is under a consolidation process and responds to the interests shown by the students to participate in education processes throughout the entire life, and to develop skills in more specialized topics.

As far as the curricular structure is concerned, modifications to the credits in each of the training areas are made, although the aim is to have elective courses so that the students can create transversal profiles involving courses in each of the training areas, but oriented towards one or more deep subjects. Details on this new structure are presented in the following section.

CURRICULUM STRUCTURE DURING THE DIFFERENT PERIODS

As part of the conception of the studies program oriented towards the development of competences, a change in the learning culture of students has been promoted. This change process has been designed to be implemented in various phases, starting with a general design of the studies program structure and ending with the restatement of the courses, contents and methodology. It should be highlighted that the

Reform Process is part of a macro project known as the Renewal Plan for the School of Engineering and in this regards, the academic component is integrated with infrastructure elements, teachers training, and integration with research activities, among others.

In the Industrial Engineering Department it is necessary to provide the curricular structure to allow each one of the students registered in the program to certify at least one profile to complement his/her undergraduate training, meeting various premises, as follows: 1) the profile must fit his/her career interests at the professional level; 2) must include interdisciplinary education that takes components from other programs offered by the University; and, 3) must turn into the first learning experience that he/she will have throughout all his/her life. Different profiles have been determined, as follows:

PROFILE I. Double program with another undergraduate program offered by the University

The aim of this profile is for the student to complement his/her training in Industrial Engineering with disciplines that will grant him/her a difference recognized within the marketplace. Some programs have more complementary possibilities than others. For example, the Engineering, Mathematics, Economics or Business Administration programs have more intersections than programs such as Music, Anthropology or Philosophy. As part of the structure of the studies program, the minimum intersection with another program is of 24%, while the maximum is of 67%, and thus, the realization of a double program will imply a dedication from the student of 182 to 241 credits, as applicable. With former structure and without major efforts to promote this profile, an average of 20.7% of the students of each of the recent 6 cohorts performed the Industrial Engineering studies simultaneously with a second program.

Observing the elective component of the program, in creating their profile, the students can use 27 of the 57 elective credits in the worst of the cases (47,36%) and 42 of the 57 credits under the condition where the major possible intersection takes place (73,68%).

PROFILE II. Double graduation with another program offered by an outstanding university worldwide

From its inception, the Universidad de los Andes has had the fortune to enjoy the support from foreign institutions allowing for the consolidation of several of its programs during the first years. At the present time, the Faculty has double graduation agreements with French and American engineering schools, where the students perform the first six semesters of the program at the Universidad de los Andes and the last year of the career in a foreign university. During the last years, 3 students have been under this mode.

PROFILE III. Coterminal with Master Programs

The School's students have the chance to take as part of his/her undergraduate elective courses up to 4 courses from the Master program. The student can receive his/her degree as Industrial Engineer and have attended to 40% of the Master program. In master's programs with 40 credits, as the ones offered by the Universidad de los Andes, to have attended a 40% implies carrying out three additional courses and a research thesis to received in a year and a half a graduate Master degree. At medium term, the Master offer will be extended, complementing the present research approach with a professional focus.

PROFILE IV. Performing Academic Options in Engineering Deep Subjects or other Areas of Knowledge

The University has groups of courses in a specific discipline that are named as an option, which can be taken by an undergraduate student and are certified at the graduation time. As of this moment, it is a concept used by students in fields other than their own program, although students are also allowed to take options within the same department. Presently, there are 41 academic options in the different faculties in the University and in the recent 6 cohorts, 20% of the students have performed one option; 2.27%. two options and 0.13%, three options.

Taking advantage of this scheme, set of courses are being designed in Industrial Engineering subjects which can be addressed with an interdisciplinary approach and which the student can plan making use of his/her elective subjects. The design of an option responds to the following structure: Two elective courses taken in the Sciences Faculty, two courses taken in departments other than Industrial Engineering, two courses offered by the Industrial Engineering Department and a project where a real problem is solved in the option's area of knowledge. The option's project is valid as a graduation project. This approach will allow a better benefit from the courses, which in present structure respond to a scheme of knowledge areas in Industrial Engineering, in order to turn to a scheme oriented towards specific topics which are transversal to the knowledge areas. It has been found that as part of present course offer, group of courses can be configured to respond to subjects relevant to the professional performance of industrial engineers within the Colombian context.

In this structure, courses taken by students as an option can be used to complement additional options where the person would like to go deeper, trying to improve his/her profile and make a difference in the marketplace. It is important to highlight that options can be performed and/or completed further to the students graduation. At the organizational level, the options are managed by the academic areas presently available. Plans call for consolidation of approximately 25 different options during the next five years.

The options presently available to students in Master's Program include the following ones: Mechanical, Civil,

Environmental, Systems, Electrical or Electronic Engineering, or the Master program in Economics.

PROFILE V. Combination of Former Profiles

One of the characteristics of these profiles is that they are not mutually exclusive and the students can carry out as many combinations as they desire. The structure being used to design the studies program will allow the students to find synergies as they involve more than one profile in their training. At the present time students make use of these figures but in an isolated manner, and by own initiative. It is expected that with the new structure this will be a result led by the training conditions offered to the students.

In addition to the profiles, the students can realize internships and exchanges in foreign universities. The purpose of the internships is to provide the students with the possibility to face a situation where a training process is developed in an organization outside and different from the University. Following are the types of valid internships within the Studies Program: Business internship, social internship and entrepreneurship initiative. In the business internship the student works during a semester in a national or international company, exclusively dedicated to work and performing the functions assigned concurrent with his/her condition as trainee. In the social internship, the student is expected to support a deprived community in the solution of its problems, preferably applying his/her training as industrial engineer. In the same way, during the entrepreneurship initiative the student is expected to dedicate an academic semester exclusively to the implementation of a business idea and the creation of his/her own company. The performance of this type of internships is recognized with 6 credits in the student's training program. In the last 6 cohorts of graduates, 34% of the students performed business internships, and 5% social internships. It is necessary to shape the entrepreneurship initiative program to benefit from the advantages it offers in training the program students. The experience of taking part of the academic training in universities from other parts of the world increases the differentiation possibilities of students, although being a profile that cannot be certified at the moment of the student's graduation. In the last six cohorts of graduates, 7% of the students, on average, performed some type of international exchange.

CONCLUSIONS

Changes made to the Studies Program structure were oriented towards providing responses to the requirements that the marketplace will be demanding from future graduates from the program, which might be defined based on the document "The Engineer of 2020" prepared by the National Science Foundation (NSF). Furthermore, based on the program's structure and the profiles adopted by the graduates, development of abilities and skills set in the criteria assessed by ABET must be guaranteed, particularly what relates with Program Outcomes and Assessment.

According to the areas of study for Industrial Engineering and its action field in Colombia, graduates' work under the new structure will influence the industry consolidation and the business opportunities based on life sciences, biotechnology, nanotechnology, material sciences and photonics. During the implementation and display of these technologies, Industrial Engineering can provide the support for its business development, but surely will not have the necessary tools to perform the technical components, strictly speaking. A different condition is present in the case of Information and Communications Technology, the Explosion of Information and the Logistics, where Industrial Engineering own tools will allow for a huge contribution to the development of mechanisms and processes to incorporate these new technologies into the world.

Likewise, the profiles defined will facilitate the capture of the contents and tools of each of these technologies and to deal with the problems that will very likely be necessary to face during the following years: The need to develop the physical infrastructure for urban settlements, the development of information and telecommunications infrastructure, concerns on the deterioration of the environment and the need to create the technological developments to service a population with higher age averages.

With the double programs and the Coterminial program with the master's degree the space is open to train engineers with complementary skills that may have a better understanding of the new technological advances from the individually new knowledge that have been created in different disciplines. This better capability to understand and deal with the problems was also developed with the options taken in subjects of interest to Industrial Engineering, using an interdisciplinary focus granted by the training scheme raised for the options.

On the other hand, our students' contact with the reality of other economies will facilitate the exchange of ideas for the solution of the problems and the socialization of new technological development in the defined areas. We expect that with the exposure to education systems with international components, as is the case with double graduations, and the exchanges with outstanding universities, future graduates will be prepared to confront the globalization conditions to come in the following years for the Colombian emerging economy.

With the internships profile the student will be exposed to the reality of a company that is being impacted by the new technologies, where he/she can improve his/her ability to solve these new problems. On the other hand, the entrepreneurship initiative can be a source of development for new businesses or goods/ services providers that will use or facilitate the development of the new technologies.

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