The Education of the "Practically Oriented" Engineer

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Abstract

The Belgian approach to the practical oriented engineer. Master of science in Industrial Sciences and Technology (Flemish Community) and Master en sciences de l'ingenieur industriel (Industrial Engineer Master of Science, in the French Community are academic bachelor and masters of applied engineering. Industrial engineers are interested in scientific applications and engineering. They have a mathematical and logical mind. They are creative and motivated to learn how to design products, systems and processes. They make connections between their own specialty and related domains. But being an engineer they are able to give direction, to work in a team, take initiative, think innovatively and be communicative. In short, an industrial engineer is a polyvalent thinker. Adapting to new technologies over several decennia, industrial engineer training has become increasingly demanding. Based on a survey of firms, university colleges have built a new structure for their education including significant periods of professional insertion. For a period of 5 years and with a level of Master, this structure fits perfectly into the process of European harmonization of higher education, the Bologna process. The historical context will be discussed followed by the organization of the different education spaces in Belgium. The formation of the industrial engineers in the Flemish and French Community are discussed in detail as well as the difference in education profile between the industrial end civil engineers.

The VIK and UFIIB (French counterpart of VIK) mission is to defense the industrial engineers at the international and national level, but also to promote and do research in their professional development for their training as well as for the profession. VIK also organizes courses and symposia in the perspective of the long life learning program.

Keywords: Training, European Harmonization, Engineer, Industrial Engineer, Master, Bologna process, Industrial Sciences and Technology

Professional organizations

Belgium has two engineering profiles: that of a civil engineer and an industrial engineer. The number of engineers is estimated at 140,000. Both the French and the Flemish Community engineers are united in separate organizations. For the Flemish civil engineers there is the KVIV, "Koninklijke Vlaamse Ingenieurs Vereniging" (Royal Flemish Engineers Society), for the Flemish industrial engineers there is the VIK, "Vlaamse Ingenieurskamer" (Flemish Engineers Chamber). FABI unites the French civil and agricultural engineers. UFIIB unites the French industrial engineers. FABI is an acronym for the Royal Belgium Federation of the Association of Civil Engineers, Agricultural Engineers and Bioengineers. UFIIB is an acronym for "Union Francophone des Associations d'Ingénieurs Industriels de Belgique" (Association of French speaking industrial engineers of Belgium).

Since a few years, there is also a joint consultation, the "Comité des Ingénieurs Belges , Belgisch Ingenieurs Comité" (Belgium Engineering Committee), abbreviated CIBIC. CIBIC represents the Belgium engineers at FEANI.

Historical Context on Higher Education

Structure and content of higher education in Belgium undergo roughly every thirty years a major change. This includes the training of industrial and civil engineering (the term industrial engineer includes several finalizations). Social evolution and changes in state structure play an important role as well. Another cause is the intent in 1998 of the Education Ministers of France, Italy, Germany and Britain to align the European higher education space. By successive constitutional amendments the unitary Belgium evolved since 1830 into a federal state with three regions and three communities. This led to the creation of a Flemish and French Community and the Regions. The first reform of the state took place in 1970. In the second reform in 1980, the Communities and Regions were given their own government, that is separate from the national government. Only after the third state reform (in 1988-1989) were the Communities given the jurisdiction over education. In the Flemish and French Community education at university colleges and universities are governed by separate decrees. This results in a possible different way of organizing higher education [1].The higher education space in Belgium includes three possibilities. Academic bachelors and master at a university. Academic bachelors and masters at a university college (hogeschool in Dutch) and a professional bachelor at a university college. This structure with academic level education outside the "university buildings" is sometimes difficult to understand for foreigners. Due to the Bologna reform the academic bachelors and masters at the university colleges will be integrated in the universities in the Flemish Community (decision taken in July 2011 by the Flemish government). In the French Community they remain at the university college. But this can change in the future.

Organization of higher education for engineers in Belgium

Before 1977, training of engineers in the fields of applied science and industrial sciences and techniques correspond to two separate streams. Universities represented civil engineers (ir) in 5 years, while many university colleges (institutes for higher education) in the Flemish- and French community, formed the technical engineers in a 3 or 4 year cycle. The Act of February 18th, 1977 created a new rank and title of industrial engineer (Ing.) at university (academic) level with a 4 years cycle.

Organization of higher education in the Flemish Community

The decree of the 4th of April 2003 "on the restructuring of higher education in the Flemish Community '(BS 14 August 2003) stipulates that education in the higher education space will lead to the degree of bachelor, master or doctor (PhD). Bachelors are either professionally oriented (former graduate courses) or academically oriented. Only in the context of an association are university colleges allowed to organize academic education that will lead to the degree of bachelor and master. An association is a non-profit organization with one member that is responsible for a university and at least one other person in charge of a university college. Flanders counts 5 associations and 13 departments of industrial sciences and technology. The quality of the academic education and the accreditation is organized by the Dutch-Flemish Accreditation Organization (NVAO).

As part of an association, university colleges in academic education training can organize the degrees of bachelor and master in the study area of "Industrial Science and Technology (industrial engineer, Ing.) and for the study area" biotechnology "(also industrial engineer). 3 year bachelor and 1 year master. Some university colleges already use "Applied Engineering Sciences" for the study area as this reflects better the real context of the study area in comparison with "Engineering Sciences" which is used by the faculties of the universities to describe the study area of the civil engineers. Since December 2010 we can also add the international current title of Master of Science, (MSc), for both engineering profiles.

Currently we have: Master of Science in Engineering Sciences (3 years bachelor and 2 year master), abbreviated with ir for the study areas of civil engineer (which includes several subdivisions), civil engineer-architect and Master of Science in Bio-Engineering Sciences bio-engineer. Master of Science in Industrial Sciences and Technology (3year bachelor and 1 year master), abbreviated Ing.(Industrial Engineer) and Master of Science in Biotechnology, abbreviated Ing.(Industrial Engineer).

The Flemish government decided on the 16th of July 2010 to integrate the academic masters in the universities during the academic year 2013-2014. Subsequently the universities will be responsible for the diplomas, the education and research policy, the quality of education and research and the human resources. Integration can be in the same faculty of engineering sciences or in a different one like applied engineering sciences. Rationalization and relocation are possible. After this integration a reform to a two year master will be necessary. Not only because the French Community in Belgium already has a 2 year master, but because the equivalent of the industrial engineer in other European countries has a 2 year master [2]. The 2 year master can even increase the specificity of the industrial engineer in comparison to the civil engineer. Furthermore the 2 year master is a logic consequence of the Bologna reform

and it will be necessary to exchange students and it will solve the problem of the acknowledgement of the industrial engineer in other European countries.

Organization of higher education in the French Community

Since 1995 the university colleges, 11 in total, in the French Community or regional organized (provinces). The Decree of 31 March 2004 of the French Community brought the training of industrial engineers in the French Community from 4 to 5 years (3 years Bachelor + 2 years Master) which corresponds to the study of the engineers in France (BAC + 5). Associations like in the Flemish Community do not exist in the French Community. Collaboration between universities and university colleges is organized by academic centers, the so called "Academic Poles". Research collaboration is one of the main objectives. In the Flemish Community the quality of the academic education and the accreditation is organized by the Dutch-Flemish Accreditation Organization (NVAO). In the French Community, the Ministry of education is responsible for the accreditation. Therefore the costs for accreditation are equal to zero, for the Flemish Community costs are substantially. A remark we often hear in the French Community is the fact that the Flemish Community developed a lot of new structures, which they doubt are useful, due to the Bologna reform.

The formation of industrial engineers after the Bologna reform in the French Community

Over time, technological developments led institutes to increase the number of contact hours for students. This increased to the statutory maximum of teaching hours, on average 840 hours per academic year, except for the weeks of internship in business placed outside of times of course, that is practically during academic vacations. It is noteworthy that among all the training in high schools, the decree provision is only applicable for an industrial engineer.

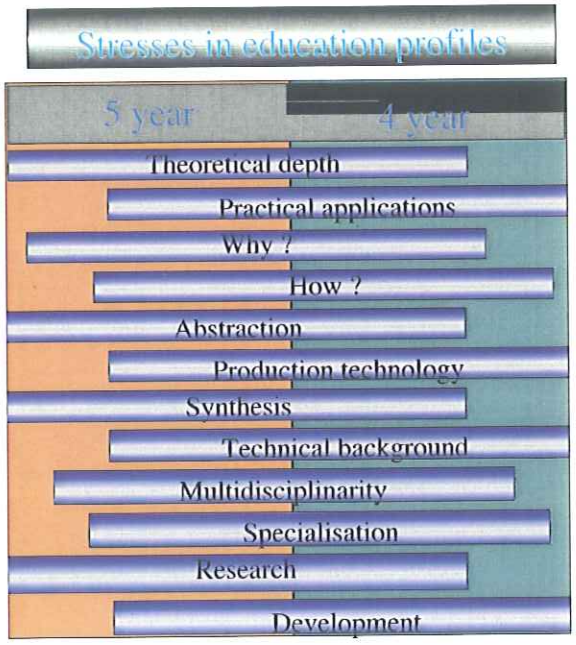
On the one hand, these studies have become demanding in the extreme, even elitist insofar as, for students who finance their studies themselves, this "obstacle course" is not easily accessible, periods of internship in business on holiday during which they work. On the other hand, for an industrial engineer, it seems paradoxical that employability activities are reduced to a few weeks of internship during the holidays. The professional industrial engineer societies (VIK, UFIIB) in Belgium had already mentioned the idea to extend the duration of

the studies, but it truly is the process of Bologna, acting as a catalyst, leading reform of studies we know today with the adoption of the Decree of 31 March 2004, that changed the studies from 4 years to 3 + 2 years in the French speaking part of Belgium. This reform is planned after the integration into the universities of the industrial engineers in the Flemish speaking part of Belgium. The reason for this difference is the fact that education has become a authority of the French and Flemish governments [3].

The double chain engineers

The increase from 4 to 5 years for the studies of the rank of an industrial engineer led naturally to a fundamental question: is there still place to organize two courses to form engineers in a 5 years program in Belgium?

Indeed, industrial engineer and civil engineer formations largely share common goals, first among which is the concern of a certain versatility, which constitutes a fundamental requirement to keep a certain "employability" on the job market. [4] However, the existence of two courses of training, industrial engineer and civil engineer, allows to achieve an effective balance of skills. The formation of a civil engineer is more focused on theoretical aspects, abstract and deductive methods. Civil engineers are engineers scientists, especially prepared to be active in the domain of research and development. The civil engineering sector is also the normal route of access to doctoral studies in applied science (although it is also open to industrial engineers under certain conditions) in the French Community. In the Flemish Community there will be a direct access to it due to the integration in the universities. Training in Industrial Engineering emphasizes the practical, concrete and inductive methods. Focusing more on students understanding of the principles of operation of devices and studies that describe their properties and characteristics, it enhances their adaptability and are armed to cope with technological changes to come [5]. The industrial engineer is to caricature, a production



between civil

engineer who develops an intelligence capable of grasping the real interdependence, often complex factors within various technology areas. He is able to implement and realize the applications of science and technology, make technology choices of technical equipment and industrial installations. A good overview of the different educational profiles can be seen in figure 1. Both engineering profiles are complementary, in terms of their training and exercising their engineering profession. There is no difference in level as they are both at the academic master level.

Opinion of the industry

To question the relevance of the dual system of training in 5 years to businesses, potential employers of industrial engineers and civil engineers, met to discuss it. It was decided that a survey be prepared on an overall view of the formation of the industrial engineers and it was only presented to the companies of the French Community of Belgium. Participants of this survey were AGORIA (Federation of the Technology Sector), ADISIF (Association of University Colleges, industrial engineers) and UFIIB (Professional Federation of the Industrial Engineers).This 2002 survey emerged the following [6]:

- Regarding the profession, the companies surveyed believe that the industrial engineer meets a need in Belgian (98%) and Europe (86%) and that the two-track civil engineering & industrial engineer is useful (90%).
- Concerning the European harmonization, the companies believe that a European recognition of Belgian engineers is essential (95%) and should be recognized at the Master level (78%).
- Regarding employability activities (internships), the companies believe they must h a significant period of 6 months (91%) and be organized on two cycles (84%). This integration promotes collaboration between academia and industry (92%) and is beneficial for a rapid integration of young engineers (94%).

Other questions were also asked about the areas where the shortage is felt in engineering and expectations of engineering education. Obviously, companies want to continue to meet industrial engineers and civil engineers on the job market . The reflection by the companies on the formation of industrial engineer are taken into account of the Bologna reform.

Adapting training to the Bologna Process in the French Community

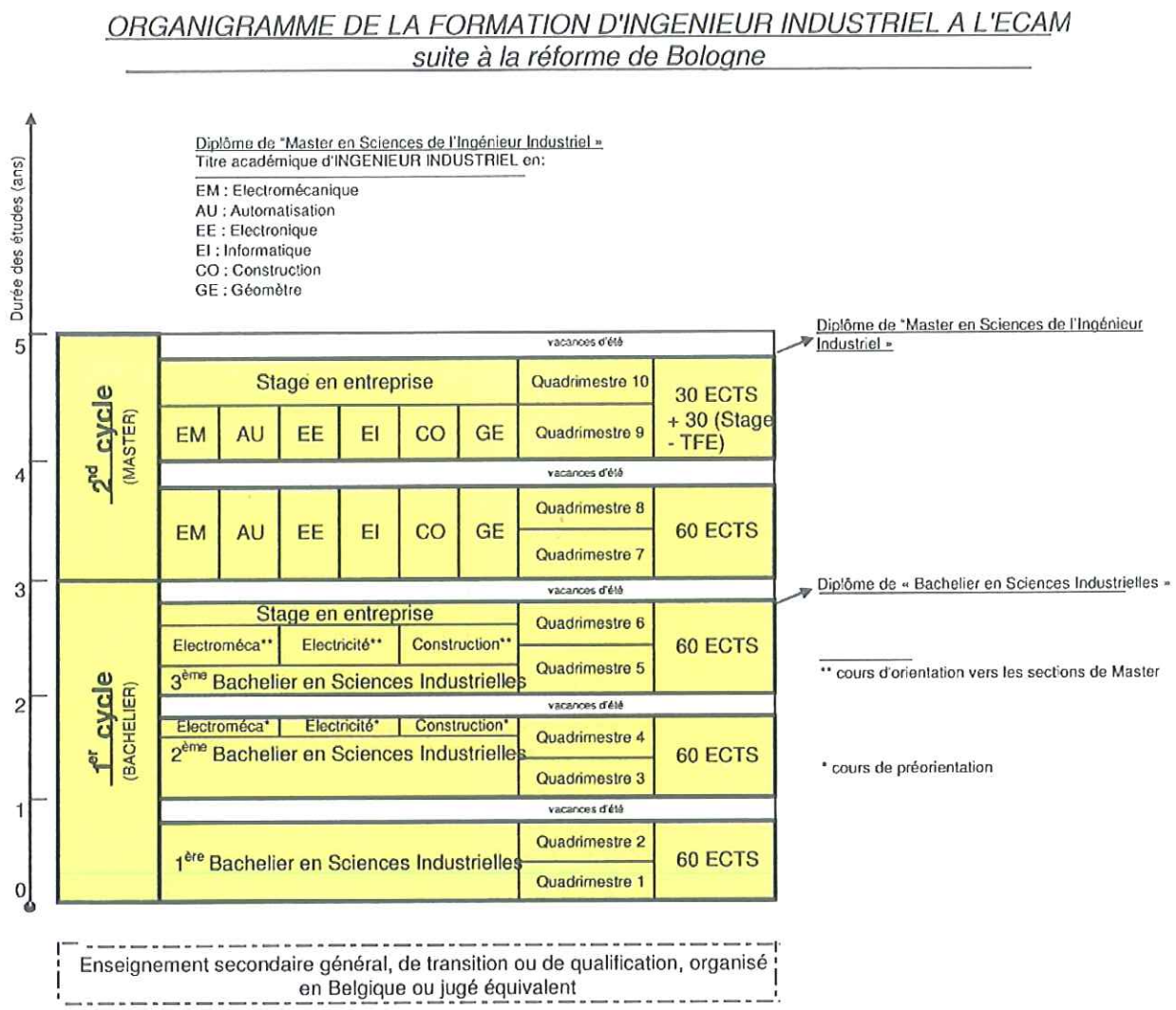
As everywhere in Europe, the Bologna Process has created a dynamic forcing us to rethink the system of higher education in Belgium, with in particular the problem of bringing training from 4 years to a system type 3-5.

The new degree structure

A training program was developed for a five years course that would be in pace with technological developments while maintaining a degree of versatility. [7] With the decree of 31th of March 2003 [8] the French Community introduced the change in formations of type long to 5 years, with (see figure 2):

– A first cycle of 3 years (180 ECTS) leading to a degree of Bachelor, the undergraduate program constitutes a basic education and ensuring a transition to one or more areas of the second cycle

– The second cycle of two years (120 ECTS including an internship and a thesis worth 30 ECTS) is a comprehensive training leading to the degree of Master



Figuur 2: Formation of the Industrial engineer in the French Community.

In detail (see figure 3 to 9) [9] [10] :

A first cycle of 3 years, Bachelor, contains 705 to 735h (60 ECTS) per year:

– The first year is totally versatile.

– The second year comprises predominantly versatile pre-orientation of 105 hours for students to try their hand at one of five industrial sectors described in the following table. This choice is not decisive for further studies.

– The third year is directed at one of these 5 industrial sectors and has a professional immersion for a period of 6 weeks.

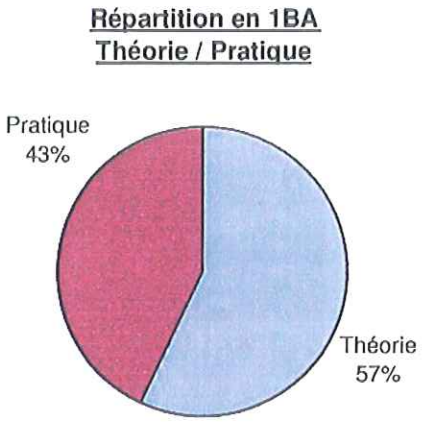
After these three years, the candidate will carry the rank of Bachelor in Industrial Science.

The second 2-year cycle, the Masters, takes place in the different specializations.

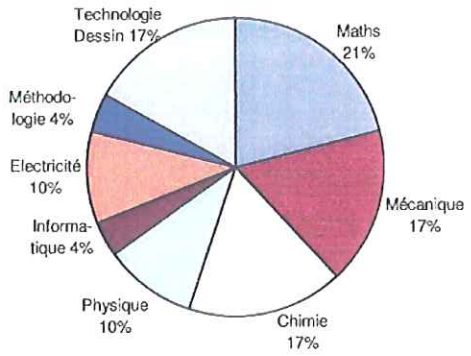
The Bachelor in Engineering Sciences, follows a long training insertion in a company. The

placement has a minimum of 13 weeks and the work of graduation correspond to a total of one semester (30 ECTS).

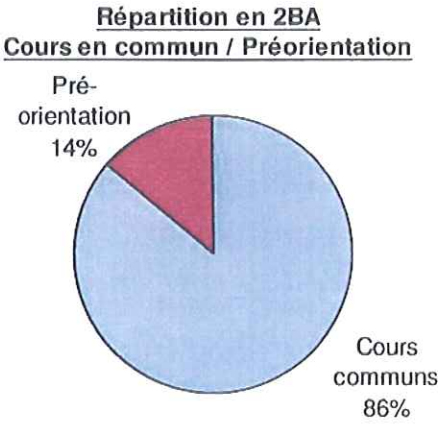
At the end of 5 years, the candidate will carry the rank of Master of Science in Industrial Engineering and the title of Industrial Engineer.



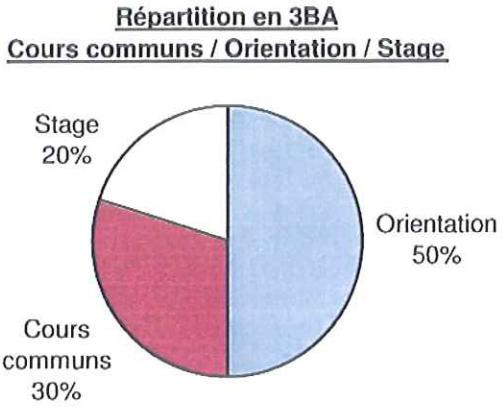
Figuur 4: 1Ba repartition between theoretical and practical courses



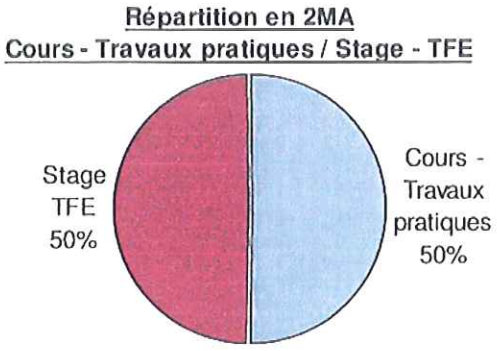
Figuur 3: 1Ba Repartition between courses.



Figuur 6: 2Ba repartition between common and orientation courses.



Figuur 5: 3Ba repartition between common and orientation courses and internship.



Figuur 7: 2Ma repartition between theoretical and practical courses, the internship and the master thesis.

Les examens sont mentionnés sur fond grisé			
Intitulé cursus	Volume horaire	CREDITS PONDERATIONS	Prérequis
SOCIO-ECONOMIE	30	2,5	
ANGLAIS APPLIQUE	30	2,5	
AUTOMATIQUE ET EXERCICES	60	4	
LABORATOIRE DE REGULATION	15	2	Oui
LABORATOIRE D'AUTOMATISATION	30	2,5	Oui
MATHEMATIQUES APPLIQUEES	30	2,5	
ELECTRONIQUE	30	3	
LABORATOIRE D'ELECTRONIQUE	15	1	Oui
MACHINES ELECTRIQUES	60	4,5	
LABORATOIRE DE MACHINES ELECTRIQUES	15	1	Oui
MACHINES MOTRICES 1	30	2,5	
THERMODYNAMIQUE APPLIQUEE ET BUREAU D'ETUDES	60	5	
RESISTANCE DES MATERIAUX	30	2,5	
METHODES DE TRANSFORMATION	30	2,5	
TECHNIQUES D'EXECUTION	45	3,5	Oui
TECHNIQUES DE MESURES	30	2,5	
LABORATOIRE DE MESURES	30	2,5	Oui
INFORMATIQUE	15	1	
LABORATOIRE D'INFORMATIQUE	30	2,5	Oui
STAGE	120	10	Oui
TOTAUX	735	60	

Figuur 8: Example of a 3Ba.

Les examens sont mentionnés sur fond grisé			
Intitulé cursus	Volume horaire	CREDITS PONDERATIONS	Prérequis
ASPECTS ENVIRONNEMENTAUX DES TECHNIQUES DE PRODUCTION	30	2	
GESTION	30	2,5	
Sciences humaines, gestion sociale	15	1/2	
Gestion entrepreneuriale	15	1/2	
LANGUE MODERNE	30	3	
AUTOMATIQUE INDUSTRIELLE	30	2	
LABORATOIRE D'ENTRAINEMENTS ELECTRIQUES	15	1,5	Oui
PROJETS DE CIM ET PRODUCTIQUE	30	3	Oui
BUREAU D'ETUDES ELECTRIQUES - PROJETS	30	3	Oui
RESEAUX ET APPAREILLAGES ELECTRIQUES	30	2	
APPLICATION INDUSTRIELLE DE L'ELECTRICITE	30	2	
CONSTRUCTIONS INDUSTRIELLES	30	2	
MECANIQUE APPLIQUEE	30	2	
INSTALLATIONS OPERATRICES	15	1,5	
LABORATOIRE DE MECANIQUE	15	1,5	Oui
OPTION	30	2	
INSERTION PROFESSIONNELLE	180	10	
TRAVAIL DE FIN D'ETUDES	180	20	
TOTAUX	735	60	

Figuur 9: Example of a 2Ma

Correspondence between the areas of undergraduate and purposes of the second cycle

In the structure in 4 years, the first two-year cycle was considered versatile. The student actually chose his section and its purpose in the third year. In the new structure, it was not possible to arrange as many third years of graduation purposes, for obvious reasons of economies of teaching methods.

Different goals have therefore been grouped into different sectors and a correspondence between the five sectors of the 1st cycle and the 14 goals of the second cycle was defined (Table 1). The choice of a sector in the third year of the first cycle involves the de facto monitor of the aims corresponding to the second round.

Bachelor	Master
Chemistry-Biochemistry	Biochemistry
	Chemistry
Construction	Construction
	Geometer
Electromechanical	Automation
	Electromechanical
	Mechanical
Electrical Engineering	Electricity
	Electronics
	Computers
Engineering Technology	Packaging and wrapping
	Physics and Nuclear
	Textile

Table 1: Correspondence between sectors (Bachelor) and specializations (Master)

Added value to the formation of industrial engineer after the Bologna reform

In the opinion of all those involved in this project, this study reform undeniably brings a real added value to the training of industrial engineers:

- The curriculum whose foundation has been established over 25 years in particular have been redesigned to enhance the skills of future industrial engineers in the field of non-technical aspects of the engineering profession. (The business survey had highlighted the weakness in comparison to the scientific and technical knowledge found it excellent.)
- Longer studies allow a better spread of the workload for the students. The decrease of the annual load of courses makes it possible to demand more personal work to appropriate the study subjects, which should lead to a better success rate.
- The postponement of basic and applied sciences at the second cycle and the return of more technical courses in the first cycle will better balance the acquisition of skills throughout the 5 years of training.
- An amplification of the specificity of the formation of industrial engineer complementary to that of the civil engineer will respond even better to the needs expressed by companies. The operational status of graduate and rapid integration into a job as an industrial engineer will improve categorically by including in his training:
    - A minimum of 40% practical work (exercises, labs, project-based teaching and teamwork for consultants, seminars).
    - Strengthening of interdisciplinary subjects in entrepreneurship, communication and language, socio-economic management of businesses, training in management and in quality.
    - Insertion in real businesses (unlike in the past where it took place furtively for 3-week holiday periods): 6 weeks in 3rd year and at least 13 weeks last year in association with an industrial project
    - Mobility of students between institutes and within Europe through courses of significant duration and harmonization to 5 years this will be part of the European mobility programs such as ERASMUS, LEONARDO and SOCRATES, and this with more flexible than at present.
- The reform strengthens the collaboration with industry and between the university colleges in both the academic field as services to society and applied research in which they have the mission.
- The reform enables visibility and real restructuring in the organization and delivery of training. The 11 university colleges have established the details of training schedules in a way never achieved before. Up to 90% of the grid is common in the 1st year, over 75% in 2nd year and 60% in Grade 3 while offering courses to choose groups organized in five industrial sectors. This is the guarantee of a genuine desire for synergy and collaboration

between the colleges, as a sustainable source of economy, and for efficiency and transparency of higher education.

In June 2009 the first promotion of industrial engineers of the 3 +2 cycle finished their education.

Adapting training to the Bologna Process in the Flemish Community

Many of the previous mentioned methodologies apply for the Flemish Community. We will therefore restrict this paragraph to the differences. It is obvious that due to the integration in the universities of the industrial engineers in Flanders, and due to the current change to a 3+2 bachelor master system for the different faculties at the Flemish universities, subsequently the implementation of the 5 year program will be only a question of time.

Academic Bachelors

These programs prepare the student directly for a Master degree, but can also be validated on the labor market. An academic Bachelor is 180 ECTS credits, which corresponds to a traditional three-year curriculum.

Academic Bachelors grant direct access to the corresponding Master. In some cases, however, access is conditional and the student will have to undertake a preparatory program first, i.e. when the student does not have the right Bachelor degree to be admitted to a specific Master program. Academic Bachelors can also enroll for an advanced Bachelor.

Masters

These study programs are the continuation of the corresponding academic Bachelor, and are occasionally open to professional Bachelors as well. Academic Bachelors have direct access to the corresponding Master and indirect access (via a preparatory program) in other cases. Access for professional Bachelors is restricted and conditional. Masters are usually 60 ECTS credits and correspond to a traditional one-year curriculum

A Master will give access to an advanced Master and/or Ph.D. Professional Bachelors are offered at university colleges only. Academic Bachelors and Master degrees are offered both at universities and at university colleges associated with universities.

New concept of teaching [11] [12]

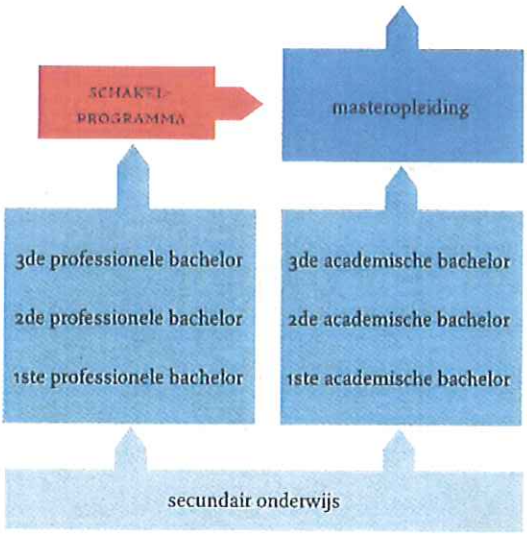
Businesses do not only ask engineers that are technologically strong and confident. They also must give guidance, work in team, develop initiative, have a innovative mind, be creative at

This new concept represents an innovative program as leverage for the formation of new generation of engineers. The program tries to make a student life more interesting within the university walls, to not always having to listen to classical ex-cathedra lessons, not always ready-made exercises to do during practice sessions and labs.

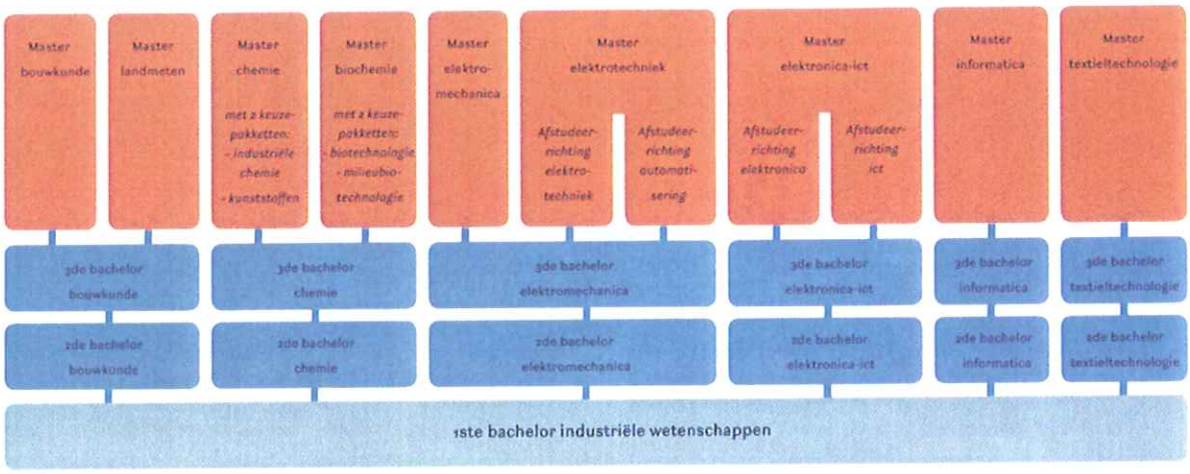
They learned not to creatively solve problems, invent new concepts and design new products. In addition the business community wanted more social skills, teamwork and communication skills which were not much practiced in the engineering education. MIT subsequently together with Swedish and Danish universities figured out a new training system. Academics, educators, engineers, students and people from the industry gave this input. The end result is a new vision of engineering education. Different subjects previously taught in isolation from each other, are now taught in an integrated manner as an interdisciplinary education. The experiential learning methods are for example: active lectures and group work. Technical and theoretical knowledge are acquire in 'activated' classes and labs.

Students are given specific assignments. Students are ask to make a device that automatically and every minute drops a ping pong ball from a tube. Electrical or electronic components may not be used. The end product is finally tested to the public. In addition, students also provide a written report, and a log of notes of their full discovery. On the basis of an oral presentation, they describe their achievements. Finally, students assess the writing performance of their team members which is based on assessment techniques.

In the following figures and tables one can find an overview of the structure and an example of course programs [13].



Figuur 10: Ba 3 year and Ma 1 year education system in the Flemish community.



Figuur 11: Overview of the different specialization in Flanders.

Master Program in Industrial Sciences: Construction Engineering (model path)

Course	Studypnt.
Civil Engineering 2	6
Construction	3
Construction Technology 2	3
Working environment and infrastructure	3
Stability 3	3
Materials Research	3
Construction law and construction administration	3
Internships and multidisciplinary project	12
Master Thesis	18

Option Package Master of Architecture (6 ECTS courses should be chosen.)

→ SCC	3
→ Traffic Engineering	3
→ Building Physics 2	3
→ Expertise & evaluation	6
→ Law	3
→ Calculation of structures 3	3
→ Business Management	3
→ 4 Stability	3
→ Optional within AUGent provided adoption education committee	3

Research Policy

The academic programs are supported by many applied scientific research. Most of these projects are coordinated from the various departments and are situated within a research association with the universities. PhD programs are generated and PhD students make an integral part of the research facilities. The research in global is focused on applied engineering and is in close collaboration with industries. Many university colleges already had a strong research tradition in some areas and boasted a number of research groups of international excellence, the Bologna declaration and the "academisation process" (Academisation process: upgrading of curricula and course programs in order to meet generally accepted academic standards as set by international accreditation and quality assurance bodies) increases the need for education embedded in a strong research environment, both qualitative and quantitative. Not only is the number of researchers at the university colleges increasing, the link with university in terms of research it also strengthened through the university association which both institutions are members of.

In order to ensure the quality of research and the efficient allocation of the internal financial means for research, an internal Research Fund was created. This fund allows a coherent research policy independent of the external funding that is granted to the researchers. At the same time a Research Council was set up consisting of active researchers representing the different faculties of the university college and representatives from the research council of the university. This council advises the management of the institution on the Research Fund's allocation, follows up on the academisation process and stimulates the coherence of the ongoing research. The valorization of research by patenting and spin-offs grows in importance and is certainly a challenge for the future.

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