Council of Associations
of long cycle Engineers
of a University or a
Higher School of
Engineers of the
European Union

CLAIU-EU Annual Conferences

Report of the last three conferences, dedicated to Engineering Education in Europe

Engineering Master Degrees in Europe
Brussels - Belgium
12th–13th February 2010

The Formation of Engineers International Models
Rome - Italy
11th–12th February 2011

The Engineering Doctorate
Madrid - Spain
9th–10th February 2012

This report has been drawn up by Marc GOOSSENS, member of the Board of SEII (European Society for Engineers and Industrialists – Brussels) under the supervision of the present and past chairmen of CLAIU-EU, Sergio POLESE and Denis McGRATH.

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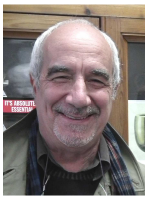

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Summary of the various themes

Structure of the summary

The last three Annual Conferences of CLAIU-EU – in 2010 in Brussels, in 2011 in Rome and in 2012 in Madrid – have been dealing with different approaches to Engineering Education in Europe, approaches that, for obvious reasons, do not exactly correspond to the structure of the three Annual Conferences of CLAIU-EU : there was some overlap between them and, consequently, between several presentations too, and it was of course impossible to tackle all of them in a deep enough and perfectly balanced way in three times two half days. We can classify these approaches as follows :

1. The difficulties linked with the implementation of the Bologna process in some European countries and the resulting programme structures, as compared with those existing in other European and non-European countries.
2. Aspects of Quality Assurance and Learning Outcomes, mainly Programme Accreditation, but also some reflections about competencies and mobility, for instance through dual and joint degrees.
3. The differences, but also the complementarities, between theory-oriented and application-oriented approaches in Engineering Education.
4. The Engineering Doctorate – which is not directly impacted by the Bologna Process – considered from the academic and institutional points of view.
5. The views of industry on the expected outcomes of engineering education, not only at Bachelor and Master levels, but also at Doctoral level.

In this summary, we will try to follow that classification, although some overlap cannot be avoided.

Implementation of Bachelor & Master degrees in Engineering

The situation in Germany

Jörg STEINBACH, in Brussels (2010), began his presentation with "his" university (Technische Universität Berlin) and provided the audience with some data about it : number of students (around 30,000, 1/3 female, 20 % international), staff (around 2,500, of which some 360 professors), budget (about € 460 million), the seven faculties and their curricula ; these ones are composed of 3-year curricula (180 ECTS |[1]|) leading to a University Bachelor degree (BSc), which can be followed by 2-year curricula (120 ECTS) leading to a University Master degree (MSc) ; this second part is also opened to other bachelors, either UAS or coming from abroad (the tree model).

He then gave some data, in the form of diagrams, for German Higher Education in general |[2]|, and showed that the system corresponds to what he said about the TU Berlin, with two Bachelor degrees – the BSc degree provided by universities and the BEng degree provided by UAS –, two corresponding Master degrees (MSc and MEng) and some bridges between both paths of studies.

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[1] European Credit Transfer and Accumulation System, defined by the European Commission in the framework of the Bologna process. One ECTS credit corresponds to 25 to 30 hours of work for the student.

[2] For instance, for the Academic year 2008-2009, out of 12,298 students beginning their studies, 9,234 (75 %) received their degree, of which 5,230 at Bachelor level and 4,004 at Master level.

Finally, he mentioned the German students' strike in June 2009, in protest against the excessive workload, the over-structured curricula, the lack of guarantee for Bachelors to become enrolled in Master studies and the insufficient job market for Bachelors. And he wondered : do we have to reform the reform ?

Introduction of the Bologna process in Italy

Alfredo SQUARZONI, in Brussels (2010), developed his presentation in four parts : before the Bologna process, the implementation of the Bologna process, the results of that implementation, and the reform of the reform.

Before the implementation of the Bologna process, and until the 80s, there was only the five-year, theory-oriented, "*Laurea*" programme, which provided students with a broad basic education ; the organization was centralized, with curricula essentially established by law and divided into various sectors and modules ; it corresponded to about 3,000 hours student's work : there was no selection or evaluation at entry, the drop-out rate was therefore very high (60 to 70 %) and, on the average, the length of studies was more than 5 years ; the graduates were highly appreciated on the market, though lacking enough knowledge in non technical applications.

This is why, in the late 80s, representatives of the job market recommended the introduction of three-year application-oriented programmes, called "*Diploma*", in parallel to the "*Laurea*" programmes ; they had different educational objectives, focused on short time technical and industrial problems, and their organization was also centralized ; it corresponded to about 2,100 hours student's work and the students could afterwards continue their studies as "*Laurea*" ; but it never took off : only some 15 % of students stopped at the "*Diploma*" level and, on the average, the length of their studies was significantly longer than 3 years.

After the Bologna declaration in May 1999 and a ministerial decree in November of the same year, the 3 + 2 model (3-year "*Laurea*" with 180 ECTS + 2-year "*Specialistica*" with 120 ECTS) was introduced in Italy for the 2001-2002 academic year, with educational objectives more coherent with the needs of the job market, more didactic autonomy of universities and more effectiveness of university education ; it was a political decision, though the Conference of the Deans of Italian Engineering Faculties were not in favour of it ; there were some constraints, different classes and qualifying educational objectives.

It was a true revolution, which had huge consequences, particularly for the 2nd cycle ; the 1st cycle programmes were more practice-oriented than theory-oriented, but not as much as the job market required ; but it was difficult to reconnect the 1st practice-oriented level with the 2nd theory-oriented level, as it implied a change in the study approach and students had a lack in basic education ; nevertheless, 83 % of "*Laurea*" graduates went on to "*Specialistica*". Furthermore, it appeared that the programmes were not well adapted to the needs of industry and that it would have been necessary to introduce strict admission criteria ; globally, there was a decrease in academic level and, as a result, the CNI asked the government to reintroduce the ancient 5-year "*Laurea*" programme.

So, there was a new ministerial decree, that distinguished between "*Laurea Magistrale*" (instead of "*Specialistica*") programmes based on a strong mastering of scientific knowledge and methods, and "*Laurea*" programmes for the acquisition of professional competences for the job market. Furthermore, there was a clearer separation between both cycles, with the possibility to introduce admission criteria for the 2nd cycle ; such a reform of the reform was introduced in the 2008-2009 academic year, but full information and results were not yet available at the time of the 2010 conference in Brussels.

This is why **Fabrizio VESTRONI**, one year later in Rome, came back on the subject and, referring to Alfredo SQUARZONI's presentation, first summarized for the participants what had been said in Brussels. He then gave some information about the results of the "reform of the reform". It has been ascertained that, 10 years after the introduction of the Bologna process, the number of graduates has increased, the duration of studies has decreased (students graduate younger) and the relationship with the outside world was enhanced through students having experience abroad.

One noticed a strongly monitored situation and an increase in the regularity of studies, particularly for "*Laurea Magistrale*" students, where the percentage of drop-outs is moderate (but that percentage remains too high for "*Laurea*" students). Nevertheless, an important concern is the decrease in student understanding of fundamental matters such as mathematics and physics, and more "bridging" studies are needed. It seems that many students cannot, in 2 years, make the necessary leap from "*Laurea*" to "*Laurea Magistrale*", and this is why some universities suggest that there were really two different paths. There is also the possibility that other modifications could be induced by the needs of industry. A more in-depth analysis has to be done in the next few years.

Introduction of the Bologna process in Spain

Manuel ACERO, in Brussels (2010), explained why the implementation of the Bologna process for Engineering Education in Spain has been complex and difficult and how, finally, a solution has been adopted, leading to its implementation upon a sufficiently defined, although sketchy, basis.

One has to know that, before implementing the Bologna process, engineering studies in Spain had consisted of two levels, not only with their corresponding professions and degrees – a "low" level, Technical Engineering, a three-year degree corresponding to the short cycle, and a "high" level, Engineering, a five-year degree corresponding to the long cycle – but also with their own educational institutions, completely independent from each other and making some times incompatible propositions. Added to that were changes in governmental coalitions and a lack of initiatives on their part. Therefore it is easy to understand why the search for a solution gave rise to drawn out discussions that prolonged the process more than was reasonably expected.

Since the beginning of the process, the ministerial position was that the Bachelor degree in Spain would have a four-year duration, while, in parallel, a single additional year was planned for the Master degree, a position that granted the Bachelor degree full recognition and the Master degree an exclusive value of specialization, without any added official and formal recognition.

In light of that, Engineering made its position clear from the very beginning, estimating that the Master degree should have a higher level of recognition than the Bachelor degree ; and, in light of what exists in many other European countries, they demanded a 3 + 2 model, insisting on the point that the two additional years for the Master degree could not be waived if one wanted to provide it with the due quality and scope ; therefore, a 4 + 1 model was judged unacceptable.

As a result, after a while, the process was renewed, with at first the establishment of a Ministerial Commission composed of three Senior Ministry Officials, six prominent Rectors of Spanish Universities, four representatives of the different Technical Engineering branches and four representatives, as well, of different Engineering branches. This commission began its work in September 2007.

But, in December 2007, it became apparent that it was highly improbable that the two cycles would reach an agreement and the Ministry proposed that the University – that is the six rectors forming part of the commission – set down the definitive position ; this was accepted by all parties. Nevertheless, the proposed position was finally rejected by Technical Engineering and the Ministry did not exercise its decision-making authority.

At that time, political elections were just around the corner and the process was put on hold. Following the elections, there was no party change, but there were changes regarding the representatives of the Ministry ; the dialogue became more open and receptive, a new proposal was drawn up by the Ministry and the University, and this was accepted by all interested parties.

In December 2008, two Agreements emerged from the Council of Ministers, each of them identifying the regulated professions – nine in Technical Engineering and eight in Engineering – and establishing regulations for the naming of the engineering degree and including a specific paragraph to that effect in the Agreement for Technical Engineering.

The durations of both degree programmes were set down in the Agreements : for the Bachelor degree, 240 ECTS credits (that is to say 4 years) was specified, while, for the Master degree, a range was established between a minimum of 300 ECTS plus a final project, and 360 ECTS including the final project. It must be noted that this leaves the possibility for Universities to develop two-year Master programmes, a solution that seems to have been adopted by the most prestigious Engineering Schools. In the Order of February 2009, there is an article that is basically an Integrated Master degree proposal and it is stipulated that Bachelor degree graduates whose areas of knowledge do not sufficiently cover the Master requirement are requested to make up the necessary ECTS credits corresponding to a second year of the Master degree programme.

This is how the Bologna process has been introduced in Spain, even if some erroneous interpretations and approaches remain to be corrected.

In 2012, in Madrid, **Jesús FÉLEZ** also said a few words about that, before tackling the subject of doctoral studies in Spain : the present system replaces the previous 3-year and 5-year degrees, with a Bachelor degree of 4 academic years and 240 ECTS, which can be followed by a Master degree of 1 or 2 academic year(s) and 60 or 120 ECTS, plus a thesis worth between 6 and 30 ECTS.

Engineering Education in Belgium

Marc DEMOLDER, in Rome (2011), explained the structure of Engineering Education in Belgium. First, the approximately 140,000 Belgian engineers have always been divided into "Civil Engineers", graduated from universities after 5-year studies, and "Industrial Engineers", graduated from Engineering Schools (Hautes Ecoles / Hogescholen) after – initially – 3-year studies. Second, Belgium has evolved, in its history, from a unitary country to a federal country, with 3 Regions (Brussels, Flanders & Wallonia) and 3 Communities : a Dutch-speaking Community (DsC), a French-speaking Community (FsC) and a smaller German-speaking Community (GsC). With the Federal Government, that makes 7 governments, each having different competencies.

So, there are in Belgium 4 Engineers' Associations, whether their members are Civil Engineers or Industrial Engineers, and are within the purview of the DsC or the FsC (for Engineering Associations, German-speaking engineers are grouped together with the FsC). Nevertheless, for the past few years, a joint consultation organization, CIBIC (Belgian Engineering Committee), has represented Belgian engineers within FEANI.

In the DsC, engineering education in the HE space can lead to 3 degrees : Bachelor, Master and Doctor. Bachelors are either "professionally oriented" or "academically oriented". Engineering Schools are allowed to organize "academically oriented" education only within an association having at least one university member. Programme accreditation is conferred by an organization operating in Flanders and the Netherlands, NVAO, which is not yet authorized by ENAEE to award the EUR-ACE label to its accredited programmes. So, there are currently two channels : 1° the Master of Science in Engineering Sciences (3-year Bachelor + 2-year Master) in the study areas of civil engineers, and 2° the Master of Science in Industrial Sciences and Technology (3-year Bachelor + 1 year Master) in the study areas of industrial engineers. Further integration is forecast for the academic year 2013-2014.

In the FsC, a decree brought the formation of industrial engineers to 5 years (3-year Bachelor + 2-year Master) and associations like those existing in the DsC do not exist, the collaboration between universities and engineering schools being organized by "Academic Poles". It is the Ministry of Education of the FsC who is responsible for programme accreditation |[3]|.

Both communities had to adapt to the Bologna process, but it did not have much influence on the global structure of studies : only some procedures and teaching concepts changed to a certain extent, though differently in one and the other communities. And the system is still currently evolving.

Setting up an Engineering Master degree in Switzerland

Setting up an Engineering MSc programme in Switzerland was quite a feat, explained **Sylvie VILLA** in Rome (2011), because, Switzerland being a confederation of 26 fairly autonomous states called "cantons", which are autonomous in many fields, including education, we had to start from scratch in a loose network of schools. As the Swiss government exerts some leverage through legislation and partial financing of the cantonal High Schools, they took the introduction of the Bologna reform as a pretext to induce the cantons to streamline, optimize and even merge their High Schools.

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[3] At the time of this report, some programme accreditation is carried on by the CTI (France)

In Western Switzerland, a University of Applied Sciences (HES-SO) was therefore created through joining its 5 existing cantonal High Schools, covering 6 French speaking cantons – Geneva, Vaud, Neuchâtel, Jura, Fribourg and Valais, plus a part of the Bern canton – into a network operating with some degree of cooperation. Original solutions had to be found in order to meet some real challenges, as keeping within the budget boundaries, attracting a sufficient number of Master students, making sure to respond to the needs of companies, using the proper selection criteria for both the candidates and the professors, sharing the load between the cantonal High Schools, getting the required space and equipment, …

The first challenge was : how to stay within the budget boundaries with a relatively low number of students having a broad spectre of Bachelor's graduations and a teaching staff whose number could not be increased ? The solution was to have the students choose quite freely among a set of modules and actually teach only those having obtained the highest levels of preference, while limiting their number to what was allowed by the budget. Of course, students needed some help – provided by an advisor for each student – to choose a well-balanced set of modules. Individual curricula required much more complex planning and managing than a few standards curricula, and a time-table had to be built for optimizing the fulfilment of the students' wishes.

Another difficulty arose from the fact that Bachelor graduates were fully employable as design engineers and needed some incentives – such as better wages and better employment opportunities – in order to pursue a Master degree. So, HES-SO had to carry out a survey among local companies in order to define the competence profiles, the proportion of part-time students, and adequate time-tables for allowing them to get the required 60 ECTS.

Some 18 months of intense planning were necessary before starting an MSc in Engineering in September 2009, with two specialization areas : industrial and information technologies. Over 160 students were admitted. Common sense and some brainstorming had been sufficient in finding appropriate solutions, which could be applied elsewhere with little difficulty.

There are however two hurdles on the way : the first one is the need to have a specific and efficient information system, with very good time-table optimization software ; the second – and biggest – one is the barrier arising from the many fears among professors and school managers.

Engineering formation in the UK : a professional competence approach

Richard SHEARMAN, in Rome (2011), explained that there are in the UK three registration levels, Engineering Technician (EngTech), Incorporated Engineer (IEng) and Chartered Engineer (CEng). These titles are owned and regulated by the Engineering Council. Originally based on the principle " *Registration = Accredited Education + Approved Training + Approved Experience* ", registration is now based on demonstration of the required professional competences and commitment.

These three categories form a continuum : progression between them is possible and individuals within each category will perform a wide variety of things. Professional competence can be acquired both formally and informally, and is generally demonstrated by degree, diploma or other certification. The IEng is an accredited Bachelor degree, while the CEng corresponds either to an accredited Bachelor degree plus an accredited Master degree (MSc) or to an accredited integrated Master degree (MEng).

There are other ways of demonstrating knowledge and understanding, for instance through the submission of technical reports and reflective statements, or of a portfolio of substantial evidence. But, besides knowledge and understanding, there are some competencies that can only be developed in employment, hence the importance of approved graduate training schemes. The Engineering Council is also working on integrating aspects of formation, as education and professional development do not have to be separate and sequential.

The formation of the Chartered Engineer in Ireland

William GRIMSON, in Rome (2011), set out the standards for the formation of a Chartered Engineer in Ireland in terms of both the education to be undertaken and the experience to be gained. In other words, the main and twin features of the criteria by which a judgement is made as to whether an applicant can be considered to be a Chartered Engineer are : 1° the achievement of programme outcomes by graduating with an accredited degree – and 2° the competences attained through working in an engineering environment.

The educational formation phase is specified by Engineers Ireland in terms of programme outcomes, which apply to Master degree engineering programmes and which are achieved through the learning outcomes of all modules in all years of the Master degree programme and any preceding Bachelor degree programmes, involving nominally five years of study and attracting a minimum of 300 ECTS credits. What the programme should enable graduates to demonstrate was then formulated in some details by the speaker, as well as the six Programme Areas which determine the academic standard to be achieved.

Concerning the application process for the Chartered Engineer title, the applicant has to write a report, the purpose of which is to provide a clear and comprehensive account of his career, and each application has to be validated by two supporters of the applicant, who are themselves Chartered Engineers familiar with all or part of the career being examined.

The speaker concluded his presentation by a short comment on the negative results of a certain lack of emphasis, in Engineering Education, on ethical and societal aspects of engineering, as opposed to the accreditation criteria of Engineers Ireland.

The situation in Australia

Robin KING, in Brussels (2010), explained that engineering has always been critical throughout Australia's economic and social development. The responsibility to supply an adequate number of well-qualified graduates to enter practice as professional engineers and engineering technologists falls essentially to the university engineering schools, whose work is supported collectively by the Australian Council of Engineering Deans (ACED) and the professional body, *Engineers Australia*, the national signatory of the Washington Accord.

Australia is characterized by a high diversity of pathways ; such flexibility is strongly endorsed by industry who, with government, are strong advocates of workplace integrated learning to increase graduates' employability. In addition to the two-year Vocational education and training and the two-year Engineering Associate degree, there are Bachelor degrees that can be 3 or 4 years long, and Master degrees that require at least 2 years study beyond the three-year Bachelor degree. But an increasing number of Australian universities are operating integrated and articulated five-year programmes of study leading to Master of Engineering (MEng) degrees that are intended to meet the accreditation requirements set by *Engineers Australia*.

Since 1989, the 38 Australian public universities have been autonomous 'self-accrediting' institutions that operate within a "National Unified System" of protocols and frameworks. The Australian Government contracts with each university as regards their financial support, which varies by discipline and is driven by student demand and quantitative performance indicators.

Student demand patterns have resulted in engineering being taken by about 6 % of Australian university students, too small a number to meet industry needs (actually, Australia needs at least 20,000 more engineers) ; about 25 % of them take 5-year programmes. Doubling the proportion of women students in engineering from the current figure of 16 % is along term goal. It needs also to be mentioned that the number of international students – who pay full tuition costs – enrolling in Australian engineering schools has more than doubled since 1996, to now total more than one third of commencing enrolments.

Current directions for Higher Engineering Education in Australia include an increased participation goal, a better "articulation" between the HE and VET sectors, national benchmarked outcome educational standards, an increase of student mobility and more workplace-based learning.

Besides the established five-year MEng pathways (double degrees, BEng with industry practice, integrated/advanced MEng and articulated BEngTech-MEng) and emerging MEng degrees (generic three-year Bachelor's degrees with two-year professional Master degrees, and stand-alone two-year Masters), the University of Sydney has commenced the development of a two-year Master of Professional Engineering (MPE) with three alternative pathways.

Quality Assurance and Programme Accreditation

A Tuning – The AHELO Project

As explained by **Robert WAGENAAR** in Brussels (2010), AHELO – acronym for "Assessment of Higher Education Learning Outcomes" – is a ground-breaking OECD initiative to assess Learning Outcomes (LO's) on an international scale by creating measures that would be valid for all cultures and languages. There are four strands : 1° Generic skills or transferable competences – 2° Economics – 3° Engineering and 4° Value-added measurement.

The role of tuning is to develop a conceptual framework of desired or expected LO's in the fields of Economics and Engineering and to demonstrate that agreements on domain definition can be reached in two contrasted fields and, as such, provide a preliminary output of the AHELO feasibility output.

Ten steps were defined, the first ones being setting the time-line, identifying and selecting the experts, selecting the set of key documents for defining the framework, … There were 9 European and 4 non-European experts, plus representatives of some organizations (FEANI, ENAEE, ASEE, IFEES). For defining the LO's statements, the main issues were : 1° Grouping them – 2° Defining them – and 3° Defining level descriptors and their indicators. Some examples were given in the presentation. The main structure of the framework report was also an important issue ; it comprised the typical degrees offered in the subject area of engineering, the typical occupations of engineers (both cycles), prior work, qualification frameworks, structure and length of engineering studies, level indicators and overlap of specializations. Then, an Experts Meeting took place in Brussels to define the main topics.

In conclusion, a conceptual framework of expected/desired LO's in Engineering was produced, based on the tuning approach ; they were, in some way, an improved combination of the EUR-ACE framework standards and the ABET criteria for Accrediting Engineering Programs. The full report is available through the link ***www.oecd.org/dataoecd/46/33/43160495.pdf*** ; its purpose is to provide a framework that will serve as input (reference material) for the call for tender for the design and development of (an) instrument(s) to measure/assess the performance of students who are close to obtaining their first cycle or bachelor's degree.

Quality Assurance and EUR-ACE Programme Accreditation

The question of Quality Assurance and of the Accreditation of Engineering Programmes has been tackled by both **Ian FREESTON** in Brussels (2010) and **Giuliano AUGUSTI** in Rome (2011).

Everybody would agree, said **Giuliano AUGUSTI**, that Quality Assurance and Accreditation have become widespread practices in Higher Education throughout the world, but, in "accrediting" Engineering Education, several approaches are possible, that may involve the very definition and significance of the word. So, he first discussed both "programme" and "institutional" accreditation, explaining that they do not oppose each other, but on the contrary complement each other well.

Briefly speaking, he said that institutional accreditation is essential to guarantee the "quality" of the educational process, since only well-structured Higher Education institutions can provide reliable education, while programme accreditation is essential to assure "relevance for the job" besides "academic quality" of educational programmes, particularly for all "professional" disciplines that – like engineering – involve public health and safety and require a license, in many countries, before being allowed to practice.

The EUR-ACE Framework Standards (EFS) are administered by the European Network for Accreditation of Engineering Education (ENAEE), a non-for-profit organization formed in February 2006 by 13 interested associations and agencies, and can be considered as a synthesis between existing national standards ; they specify the Programmes Outcomes to be satisfied. Valid for all branches and profiles of engineering, and distinguishing between, not only 1st and 2nd cycle programmes, but also integrated programmes, they describe the abilities that graduates must achieve, but not how they should be taught.

The EUR-ACE Label is a registered trademark ; it is quoted by the European Commission as an example of good practice in Quality Assurance. Though having no "legal" or "official" value, its significance and weight are rapidly growing.

A national – or regional – Agency is authorized to award the EUR-ACE quality label only if that Agency itself satisfies appropriate quality requirements and if the accredited programmes satisfy the EUR-ACE Framework Standards. At the time of the conferences, seven agencies had been assessed as meeting the standards specified in EFS, and therefore authorized to award the EUR-ACE Label to accredited programmes : ASIIN (Germany), CTI (France), the Engineering Council (UK), Engineers Ireland, MÜDEK (Turkey), Ordem dos Engenheros (Portugal) and RAEE (Russia) ; over 400 programmes |[4]| accredited by these agencies have been so far awarded the EUR-ACE Label. There is a project to extend such an authorization to agencies in Italy, Lithuania, Romania and Switzerland.

One has also to take into account the fact that the title of engineer may be legally regulated in some countries – as Italy and Spain for instance – and not in other countries (In Rome, **Richard SHEARMAN** recalled that, in the UK, there is no general restriction on the right to work as an engineer or to call oneself an engineer).

Ian FREESTON described the main features of EFS, the main purpose of which is to provide a system for pan-European recognition of the accreditation of engineering education, with the underlying motive of promoting and supporting the mobility of professional engineers. It has been designed to be consistent with the requirements of the Bologna process.

The process for accrediting engineering education programmes should contain four basic elements : 1° a specification of the content of the programme – 2° a specification of the level of the programme – 3° an assessment of the resources to deliver the programme – and 4° a procedure for evaluating and deciding on the previous three elements. In developing EFS it was important to ensure that it was consistent with existing and parallel developments in the European Higher Education Area, and also with some existing international agreements on engineering standards, as for instance the Washington Accord.

The use of Programme Outcomes (PO's) in EFS is important, as it ensures that the Framework respects existing different traditions and methods of engineering education, is applicable to new and emerging branches of engineering, can accommodate the development of new and innovative teaching methods, and can promote the sharing of good practice. The PO's for both First and Second Cycles are listed under six headings (1° Knowledge & understanding – 2° Engineering analysis – 3° Engineering design – 4° Investigations – 5° Engineering practice – 6° Transferable skills) : 21 PO's concern the First Cycle degrees, and 19 the Second Cycle degrees.

EFS has been designed so that a graduate of a labelled First Cycle programme can progress to a labelled Second Cycle degree ; students entering a labelled Second Cycle degree without a labelled First Cycle qualification would need an opportunity to demonstrate that they have satisfied the First Cycle PO's.

Defining how the level of the PO's in EFS is to be specified is a difficulty that is also met elsewhere in the quality assurance of education programmes. There seem to be essentially two different methods of evaluating level – or a combination of both – whether we develop an agreed statement of rules for determining if an accreditation agency is correctly specifying the level, or we do not specify the criteria for determining level, but ask the accrediting agencies seeking authorization to award the EUR-ACE Label what criteria they use for qualifying the level and what method they use to assess if this level is achieved by the graduates.

The process of Professional Engineer licensing in the United States

All the 50 States in the Union, plus the Federal District of Columbia and four US territories, said **Christopher STONE** in Rome (2011), have registration laws governing the practice of engineering. These laws also prohibit people who are not licensed Professional Engineers (PE's) from offering their services directly to the public. Although the various states and territories strive

[4] Some 1200 accredited programmes in December 2012 (editor's note)

for consistency in their licensure laws (e.g. the "Model Law" of 1941), uniformity does not exist and an engineer has to apply for licensure in any state in which he wants to offer direct public service. At the time of the conference, there were some 1.7 million graduate engineers in the US, of which 465,000 (27 %) are PE's. Licensure as a PE in the United States is a five-step process.

The **first step** requires an ABET-accredited four-year university engineering degree. In 1997, ABET adopted "Engineering Criteria 2000", in order to enable innovation in engineering programmes. Accredited engineering degree programmes also have to be re-evaluated every six years to retain accreditation. Currently, ABET accredits over 3,100 programmes at more than 600 colleges and universities worldwide. ABET also accredits a small number of programmes at Master level. There are special procedures for engineering graduates whose degree was not accredited by ABET.

The **second step** requires engineering graduates to successfully complete the standard Fundamentals of Engineering (FE) written examination (180 multiple-choice questions), which tests applicants on their breadth of understanding of engineering principles, and optionally some elements of an engineering speciality. Completion of the first two steps typically qualifies for certification in the US as an Engineer-In-Training (EIT), sometimes also called an Engineer Intern (EI) ; roughly some 78 % of graduates annually earn that certification. There are also some agreements with foreign entities.

The **third step** consists of accumulating a certain amount of qualifying experience. In most states, the requirement is four years completed under the supervision of a PE, and that acceptable experience must involve increasing levels of responsibility. However, in some states the requirement is less. Further, many states will also accept a Master degree in engineering in lieu of one year of experience. Most states have broad language in order to help their licensure boards evaluate qualifying experience. Some non-qualifying experience is also required by some states.

The **fourth step** is to successfully complete a written Principles and Practice in Engineering (PE) examination, testing the applicant's knowledge and skills in a chosen engineering discipline (civil, electrical, mechanical, etc.). Upon passing the PE exam and meeting other eligibility requirements, for instance about education and experience, imposed by the individual state in which he seeks a license, an engineer is eligible to be licensed in that state.

The **fifth – and final – step** is to apply for licensure in each individual state in which the engineer desires to practice engineering directly for public service. The application process for each of the 50 jurisdictions is unique. In many cases, the applicant must provide documentation of having participated in continuing engineering education during each renewal period – typically every two years – to maintain an active PE license in good standing ; some state boards require that continuing education providers be pre-approved.

Dual and Joint Degree Programmes (Brussels – 2010)

Ramon WYSS presented a survey of the CLUSTER University Engineering Education network, which was founded in France in 1990 with the aim of boosting Research and Education in Europe by favouring transparency and mobility (both horizontal and vertical) of students across Europe and preparing future leaders in Technological Innovation through very competitive Dual and Joint Educational Degree programmes. It is composed of 12 European Universities |[5]| and 6 non-European Universities |[6]|.

The added value for students derives from the possibility of exchange, mutual recognition, double degree programmes and dual Master degrees. It is an institutional cooperation, supported by the Erasmus Socrates exchange programme of the European Commission, and different successive

[5] "Universitat Politècnica de Catalunya" in Barcelona (Spain), "Technische Universität Darmstadt" and "Technische Institut Karlsruhe" (Germany), "Technische Universiteit Eindhoven" (the Netherlands), "Institut Polytechnique de Grenoble" (France), "Aalto Yliopisto (University of Science & Technology)" in Helsinki (Finland), "Ecole Polytechnique Fédérale de Lausanne (EPFL)" (Switzerland), "Katholieke Universiteit Leuven (KUL) & Université Catholique de Louvain (UCL)" (Belgium), "Instituto Superior Técnico de Lisboa" (Portugal), "Kungliga Tekniska Högskolan (KTH)" in Stockholm (Sweden), "Trinity College Dublin" (Ireland) and "Politécnico di Torino" (Italy)

[6] "Georgia Institute of Technology" in Atlanta (USA), "Universidade de São Paulo" (Brazil), "Tsinghua University" in Beijing (China), "Ecole Polytechnique de Montréal" (Canada), "Томский Политехнический Университет" (Russia) and "Technion" in Haifa (Israel)

statements have been issued. The network favours industry cooperation and maintains strong links with the EIT (European Institute of Innovation and Technology). An example of cooperation is the MS in Nanotechnologies for ICT's, between Grenoble, Lausanne and Torino.

Paul CROWTHER presented a survey carried out by the T.I.M.E. Association. This association was founded in 1989 by "Ecole Centrale Paris", with the aim of offering to students Double Degrees in Engineering and mutual recognition, through some 250 bilateral agreements (there is no single model) between Technical Universities and/or Faculties and Schools of Engineering |[7]|. Actually, it offers either Double/Dual Degrees (that is two degrees), or – when possible – Joint Degrees (that is one degree) that are accredited jointly in both countries ; there is no standard study track and no double counting (360 ECTS).

It is a decentralized network which, through commitment to international cooperation and strong links with employers, brings many benefits to all parties : students (source of enrichment), institutions and employers.

There are also some "collateral" products, as TESS (joint summer programmes), TEMP (joint management programmes) and joint PhD studies and degrees.

As explained by **Yvan BAUDOIN,** STARS – acronym of "Sensory Technology and Robotic Systems" – is a USA-Europe Atlantis project between the members of a consortium composed of the Royal Military Academy (Belgium), the Budapest University of Technology and Economics (Hungary) and the Florida Institute of Technology (USA). Each of these three institutions must have an international office and have signed bilateral agreements. They must also offer a description of the curriculum and the guarantee of deliverance of accredited degrees to successful students.

Actually, it is a special double degree concept that provides students with "two degrees for the price of one". The academic content has been carefully designed, based on a previous Complementary Activity Report. It offers to students the possibility of getting expertise in at least two languages spoken in Europe, favours mobility (minimum one year abroad), comprises student and faculty grants and pays for some travelling costs (on the basis of 1 US$ = 1 €). The curriculum deals, not only with "hard skills", but also with a number of "soft skills".

Different approaches to designing the curriculum

Engineering Education : theoretical versus *applied approaches*

Sebastião FEYO de AZEVEDO, in Rome (2011), began his presentation by setting the stage in which engineering education has to develop now, as we are in a world of "coopetition" – that is, where cooperation and competition have to coexist. This requires new approaches, including a political will to address the existing political issues ; a world, also, which needs trust between the various stakeholders, trust that can be expressed in terms of mobility, cooperation and accreditation. He then described the different models that have been discussed during the past few years, ending with the recognition of two main levels and of two possible profiles as entry routes.

He underlined the fact that qualification frameworks, completed by sectoral descriptors and branch level descriptors, on the one hand, and the directive for the recognition of professional qualification on the other hand, show a remarkable convergence that has been translated into our accreditation system.

He then described the different levels of qualification and the two main profiles, which can be either more theory-oriented or more application-oriented. Engineering education, he said, develops in three dimensions : 1° knowledge, understanding and application to increasing levels of complexity – 2° judgments and learning skills – and 3° communication and interpersonal skills. He also described the two different routes for different qualification levels : route T (for Theory) and route A (for Application), with different forks and interconnections.

[7] Some 55 members in 2009, mostly European, but also some members from Asia and Latin America

Programme Outcomes must therefore be evaluated in relation to those levels and routes, in dimensional terms of scope, depth and breadth. Qualification requires a minimum of 300 ECTS, which is not reached everywhere, but has it to be achieved through long cycle degrees or through accumulated two-cycles studies ? The main issue is to get more flexible paths, more differentiation in competencies, a more attractive offer to the market, and the promotion of a true offer for Lifelong Learning.

The development of quality assurance in engineering, with its objectives, standards and "field specificities", lead to the Qualification Framework and to the EUR-ACE Accreditation System (already described elsewhere). The speaker also gave a detailed comparison of the different frameworks (Bologna, EQH and EUR-ACE).

In conclusion, he stated that the effort has still to go on, with the aim of guaranteeing quality and increasing transparency, so as to increase academic and professional mobility, promote academic cooperation (e.g. joint degrees) and throw down barriers impeding recognition.

In Rome also, **Marc DEMOLDER**, speaking about the situation in Belgium, stated that, now in the FsC and soon in the DsC, both industrial and civil engineers will have to complete 5-year programmes. Nevertheless, the distinction between them seems relevant, not only to keep some versatility and to offer better employability to engineers, but also because the formation of the civil engineer is more focused on theoretical aspects, abstract and deductive methods, while the formation of industrial engineers is more focused on practical aspects, concrete and inductive methods. The distinction is therefore rather a question of orientation than of level. And, apparently, industry is happy with that situation, as companies want to find both profiles on the market.

In Brussels (2010), **Marc GOOSSENS** tackled that subject, stating that one cannot form application-oriented engineers first, and afterwards transform some of them into theory-oriented engineers |[8]|. They actually, in his opinion, need different educational paths. One year later, in Rome, basing his argument on the development of cognitive sciences and quoting David PYE (" *In a designer's drawing, all joints fit perfectly* "), he explained that theory-oriented engineers tend to live more in a world of cognitive models more or less disconnected from reality, while application-oriented engineers are more directly geared to reality. This gives rise to two dangers : a first one is cutting off theory-oriented engineers from reality and making them more easily influenced by opinions (as in other professions also), and a second danger is having too many application-oriented engineers turning away from theory.

The competence approach

Although there was no presentation specifically dedicated to engineering competence in the three Annual Conferences of CLAIU-EU under review, most speakers used that word at least once and some of them went so far as giving a definition of what competence is or should be.

Competence, said **Richard SHEARMAN**, is defined by the UK Standard for Professional Engineering Competence as : " *A quality that integrates knowledge, understanding, skills and values, and that goes beyond the ability to perform specific tasks* ". It has a number of dimensions :

- *Cognitive competence (theory and concepts)*
- *Functional competence (skills and know-how)*
- *Personal competence (knowing how to behave)*
- *Ethical competence (having and acting on personal and professional values)*
- *Meta-competence (learning and reflecting, dealing with uncertainty).*

Furthermore, he said, there is a common framework for all three types of professional engineers recognized in the UK, and it covers all areas of engineering.

For **William GRIMSON**, the expected standard of competences of a Chartered Engineer in Ireland is articulated in a set of five competences that the engineer should have developed and will be obliged to maintain and extend in his future professional life :

[8] That is actually what he meant as, at the time of the conference, he opposed Bachelor's and Master's degrees, which is not the same thing (*editor's note*).

- *Use a combination of general and specialist engineering knowledge and understanding to optimise the application of existing and emerging technology*
- *Apply appropriate theoretical and practical methods to the analysis and solution of engineering problems*
- *Provide technical, commercial and managerial leadership*
- *Use effective communication and interpersonal skills*
- *Make a personal commitment to abide by the appropriate code of professional conduct, recognizing obligations society, the profession and the environment.*

The EQF-LLL standards distinguish between knowledge, skills and competences, while the EUR-ACE Accreditation Framework defines six areas of competences :

- *Knowledge and understanding*
- *Engineering analysis*
- *Engineering design*
- *Investigations*
- *Engineering practice*
- *Transferable skills*

For **Marc GOOSSENS**, competence can be defined in four stages :

- *First, there is knowledge and understanding*
- *Knowing how to properly apply knowledge provides you with know-how*
- *Adding enough motivation and will to know-how enables you to perform the adequate action*
- *And when you can perform the adequate action with a high enough level of quality, it means you have reached the expected competence.*

Research excellence in Master degree programmes

At first sight, said **Erik de GRAAFF** in Rome (2011), the statement " *Research excellence provides enhancement of a high academic standard in Master degree programmes* " seems obvious and highly compelling. And we can go home, satisfied with our agreement on that point. Yet, he said, an agreement on the face value of a statement does not constitute a proof of its validity and even less on its implications and consequent actions. So, he challenged that statement, breaking it down into the various elements on which it is built and analysing the implications of different visions of the respective elements.

But first, he recalled that there are, roughly speaking and with different names depending on the countries, two types of Higher Engineering Education institutions in Europe, "Research Universities" on the one hand, and "High Schools" on the other hand ; and that the aforementioned statement could not very well apply for application-oriented Master programmes.

What is excellence ? True excellence, he stated, has to be exceptional : it is lonely at the top. Such a label should only apply to research leading to totally new ways of understanding, leading to ground breaking innovations. What is a standard ? There are nine different meanings for that word : let us say that it is something established by authority, custom of general consent as a model or an example. Therefore, with these definitions, can excellence enhance academic standard ? Maybe, but this involves several drawbacks which have to be discussed.

First, there are not many people who fulfil the criterion of being excellent. This means that the standard is not available as an example in most of our institutions. Second, the distance between the level of excellence and the Master programme is simply too large to allow for any significant influence. Third – and this is the more fundamental issue – what do we want to achieve by using a standard of research excellence ? Impress people with something that is out of their reach, or provide them with something they can use to calibrate their own performance ? And fourth, if it aims at facilitating a close connection between research and teaching, a close look into the curricula actually shows that there is seldom any specific training in research methodology.

Consequently, the standard of excellence will be out of reach all too often. And therefore, though we may feel that acquiring a critical scientific attitude should be part of an engineer's education, we need to agree on a much more practical definition of research excellence than the one described above. Excellence should come within reach, so to say.

The Engineering Doctorate : principles & policies (Madrid – 2012)

Doctoral Education : the EUA Salzburg II recommendations

Thomas Ekman JØRGENSEN set out the point of view of the European Universities Association (EUA), and particularly of its Council for Doctoral Education (CDE), about the development of Doctoral Education in Europe. He placed that point of view in a historical perspective – inclusion in the Bologna process (2003), Salzburg I principles (2005) and successive Trends (2005, 2007, 2010) – and in the context of a progressive reform of the curriculum. This ranges from " *doctoral schools = doctoral programmes* " (interdisciplinarity, transferable skills, taught courses, ECTS as incentives) towards " *doctoral schools = strategic units at institutional level* " (common rules and guidelines, monitoring, quality management, problem solving and strategic planning).

The Salzburg II recommendations, developed by the CDE, strengthen and prolong the Salzburg I recommendations, after 5 years of their rapid implementation and feedback. They can be summarized in three main points : research-based, individual development and autonomy.

The Doctorate is and must remain research-based, because it has a specific nature that makes it different from the types of education in the 1st and 2nd cycles and that training through research creates a certain mindset for many sectors and careers, cultivated by having done original research. However, it must be carried on in an inclusive research environment, where critical mass can be attained in many ways (pooling, international networks, …).

Doctoral education gains much of its value from the unique and individual paths that doctoral candidates take, where they meet unforeseen problems and obstacles and learn how to tackle them. Having to work in different environments helps them to create awareness and to build trust between sectors, with inter-sectoral mobility as a by-product.

Institutions must have full autonomy to choose both mission and strategy and to set up the appropriate structures, since they have demonstrated their capacity and their experience in how to develop doctoral education, and because autonomy will secure the critical diversity needed to sustain a vibrant European environment for doctoral education. However, this requires a large degree of accountability for the institutions.

Although these recommendations are very generic and should work for all disciplines, we see more discipline-based networks making their own standards. Furthermore, implementation in different discipline-cultures and traditions could indeed be difficult, and we do not always know how big is the common ground and how important are the differences (humanities versus STEM, regulated professions, teams versus 'lonely scholars').

Aris AVDELAS, in his presentation, also tackled the same subject, starting from the Dublin Descriptors (2004), with the description of the following qualifications : 1° Knowledge and understanding – 2° Applying knowledge and understanding – 3° Making judgments – 4° Communication – and 5° Learning skills. He also mentioned that the Dublin Descriptors have been adopted by the European Qualifications Framework (EQF – 2008), level 8 of which corresponds to the descriptor for the Doctorate. He then briefly described the 10 Salzburg I recommendations (2005) :

a. *The core component of doctoral training is the advancement of knowledge through original research*
b. *Its embedding in institutional strategies and policies*
c. *The importance of diversity*
d. *Doctoral candidates considered as early stage researchers*
e. *The crucial role of supervision and assessment*
f. *The necessity of achieving a critical mass (through various solutions)*
g. *The duration of doctoral programmes : 3-4 years full time*
h. *The promotion of innovative structures (interdisciplinary training / transferable skills)*
i. *Increasing mobility (inter-sectoral / international)*
j. *Ensuring appropriate funding*

And finally, in the framework of that subject, he recalled the main lines of the Salzburg II Recommendations, with a few comments about the limited use of the credit system in doctoral education.

Engineering Doctorates in the ERA and Innovation Union

Stefaan HERMANS began his presentation with a diagram showing that, for developed countries, investment in R&D in 2010 was roughly proportional to the growth of the GDP (Gross Domestic Product) and forms therefore part of the solution to exit from the economic crises. He then brought forward some figures illustrating the fact that, in Europe, as compared with the US and Japan, there are too few researchers, whether it is per unit of the labour force or of those working in the private sector.

This is why the DG Research and Innovation of the European Commission has defined seven Principles for Innovative Doctoral Training :

1. *Research Excellence*
2. *Attractive Institutional Environment*
3. *Interdisciplinary Research Options*
4. *Exposure to industry and other relevant employment sectors*
5. *International networking*
6. *Transferable skills training*
7. *Quality Assurance*

And this with special emphasis on the " Triple i " : International, Interdisciplinary, Inter-sectoral.

CESAER's policies on the engineering doctorate

During the last years, explained **Peter SCHARFF**, the doctorate was often subject to basic discussions concerning its relevance, for instance within the Bologna process : length, orientation, programmes, qualification, ... Depending on the culture in various scientific branches, a broad variety of opinions exists and different routes to doctoral degrees are evolving.

Concerning the engineering doctorate, CESAER started a discussion process in 2006, which finally led to the document " *Corner Stones for a Doctorate in Engineering* ", endorsed by the General Assembly in Budapest on 17th November 2007. It describes CESAER's view on the requirements of a research oriented qualification phase for engineers. The essence of a doctorate, it is said, is the development of the ability to conduct original research and extend the boundaries of knowledge and, in order to reach such an ability, a PhD candidate should have the following generic skills :

- *Ability to communicate in an international academic, scientific and industrial environment*
- *Ability to acquire information and synthesize knowledge*
- *Multidisciplinary and cross-cultural experiences*
- *Ability to deal with uncertainty, handle conflicts, solve problems and manage failure*
- *Leadership and teamwork*
- *Ability to manage research*
- *Creativity and ethics*

Admission to a doctorate should be based on the individual assessment of qualifications, experience and intellectual potential, without any discrimination deriving from gender, ethnicity, social or cultural background, and others. Apart from any legal considerations, PhD candidates must be considered as – early stage – researchers. They must be exposed to a rich scientific – preferably international – environment and supervised by an academic of recognized standing within the scientific community. Appropriate resources must be provided to carry out the research.

One of the main outcomes of the doctorate has to be a defended individual thesis, accepted by the scientific community as a substantial contribution to the field of research. The examination process should be transparent and involve independent external experts. The thesis should meet the following requirements :

- *Well defined engineering/scientific problem or hypothesis*
- *Originality of the (proposed) solution*
- *Validation of the results*
- *Quality indicators (such as publication in a peer-reviewed journal or conferences)*
- *Indication of deep expertise in the particular engineering/scientific field*
- *Clear exposition in the thesis*

The right to award a doctoral degree must be restricted to higher education institutions offering both advanced education and advanced research.

With these cornerstones, CESAER defines a standard that should be accepted for any engineering doctorate in order to meet the requirements of industrial and academic research. That position was also recalled by **Aris AVDELAS** in his presentation.

SEFI position on the Doctorate in Engineering

In the second part of his presentation, **Jörg STEINBACH** summarized the position of SEFI (European Society for Engineering Education) on the Engineering Doctorate (a position that was also mentioned by **Aris AVDELAS**) :

1. *A doctorate in engineering must be the result of individual research work (even if it is embedded in teams and clusters)*
2. *The doctorate is regarded as the third cycle of qualification within the Bologna process (rather an individual learning process than curriculum-based education)*
3. *Diversity in doctoral careers must remain possible (different paths, partners and funding)*
4. *Quality of mentoring must be enhanced (impact on the quality of the thesis)*
5. *Clear entrance qualifications must be defined*
6. *The doctoral degree programme should not take the form of a curriculum*

Introducing Quality Indicators in Doctoral Education

After having said some words about the Dublin descriptors, the European Qualifications Framework, the Salzburg I and Salzburg II Recommendations, CESAER's cornerstones for a Doctorate in Engineering and the SEFI position on the Doctorate in Engineering (see the previous chapters), **Aris AVDELAS** presented the main results of the EUGENE (**EU**ropean and **G**lobal **EN**gineering **E**ducation) Network, which began its work on the 1st October 2009 and is due to end on the 30th September 2012. With 78 partners from 32 European countries and six associate partners from four other countries, EUGENE is coordinated by the University of Florence (Faculty of Applied Sciences) and develops its activities following five "Activity Lines" and three "Transversal Activities".

Line A focuses on two objectives :

- Action A1, coordinated by Professor **Jean BERLAMONT** (K.U. Leuven), tries to identify institutions where doctoral schools with structured PhD programmes have been introduced, and to establish their influence on the level, quality and employability of PhD graduates.
- Action A2, coordinated by Professor **Aris AVDELAS**, tries to identify a number of indicators for measuring quality in doctoral engineering education.

After having summarized the provisional outcomes of Action A1, **Aris AVDELAS** explained that the objective of Action A2 precisely corresponds to one of the Salzburg II Recommendations : " *In order to be accountable for the quality of doctoral programmes, institutions should develop indicators based on institutional priorities* ". He then described the method that was used, with a questionnaire addressed to participating institutions and bearing on the following themes : 1° Organizational models – 2° Entrance qualifications – 3° Supervision, mentoring and performance – 4° Monitoring the outcomes-career development – 5° Internationalization – and 6° Financing.

It could be seen that the majority of the questions were within the Salzburg II Principles, a small number of them going nevertheless a little further. Respondents did not only have to answer the questions, but were asked to give a weight to each of them : questions that are considered as most important for quality got an IMI = 1, the ones considered least important an IMI = 5.

By this questionnaire, Action A2 tries to identify indicators by which different models of PhD education will be compared. Each question is a specific indicator related to one or more quality actions, which either most institutions (for their global application) or only a few of them (as examples of good practice) apply. This is why we shall group these indicators in three categories : Common Indicators, Key Indicators and Good Practice Indicators. In this way, we hope to have a strong tool to be used as a first step in measuring the quality of doctoral engineering education.

The Engineering Doctorate : case studies (Madrid – 2012)

Development of the Engineering Doctorate in Spain

Jesús FÉLEZ first recalled briefly what had been the central subject of Manuel ACERO's presentation three years earlier in Brussels, namely the adaptation of engineering studies in Spain to the Bologna process, thus allowing the country to enter into the European Higher Education Area and facilitating university student mobility. For the first two cycles, it led to a Bachelor degree of 4 years and 240 ECTS, followed by a Master degree of one or two year(s) and 60 to 120 ECTS, plus a thesis worth between 6 and 30 credits. So, the combination of the Bachelor degree followed by its corresponding Master degree replaced the former long cycle – 5 years – degree in engineering.

Concerning doctoral studies, the situation before 2005 and the progressive entrance of Spain into EHEA was as follow : there was first a two-year training stage, worth 32 "Spanish" credits, leading to a Diploma of Advanced Studies, after which the student could begin his doctoral thesis without any time limit.

After two provisional regulations in 2005 and 2007, the Spanish Government, in 2008, launched the Strategy University 2015 programme, intended to develop a modern Spanish University system. It led to a new regulation on Doctoral Studies (2011), the main characteristics of which are :

- The assertion of the fundamental role of a research-based doctorate in the transfer of knowledge for the well-being of society.
- The creation of Doctoral Schools, defined as units set up by one or more universities, developing a coherent individual strategy and working under the supervision of a Steering Committee.
- The organization of doctoral studies through programmes, namely a set of activities leading to the acquisition of the required competencies and skills, most of which are specifically listed.
- A duration of doctoral studies limited to three full-time years.
- The importance of supervising and monitoring the doctoral student (with a written and signed commitment).
- Some obligations for the members of the Thesis Board.

The new legislation laid down a series of deadlines for compliance, divided into several phases. The last deadline was set at the start of the 2013-14 academic year.

Finally, the speaker gave some global data about the doctorate in Spain : number of doctoral theses, number of students enrolled on doctoral programmes, gender and age groups, distribution by branch of learning, and distribution of theses read by foreigners.

Interdisciplinarity : a modern approach to Engineering Education in Italy

Massimo GUARASCIO began his presentation with an almost philosophical approach to the mission, the role and the social function of engineers in society. Quoting Galileo GALILEI and Judea PEARL, he wondered " *Which levels of knowledge, skills and competencies are required to provide the modern society with the necessary contribution of engineers to increase its well-being* ". " *There are*, he said, *many possible answers to that question, depending on what level they are formulated : EU Institutions, European Engineers Community, single country (Italy), single university (La Sapienza of Rome), or individual engineer* ".

For the first answers, he mainly referred to what had been presented one year earlier in Rome about the 'raison d'être' of different qualification levels, their descriptors, and the necessity of a good balance and communication between theory-oriented and application-oriented engineers. However, engineering education in the European Higher Education Area is faced with increasing mobility of students and graduates and with rapidly transforming employment conditions. This requires an enhanced harmonization of the education processes, where Programme Accreditation and Quality Assurance are essential for professional disciplines, such as engineering, which involve public safety and require a license for public practice. Nevertheless, such a harmonization is not progressing at the same pace. This is most unfortunate, as Europe needs high quality educational programmes, at all levels, to prepare talented engineers for actual and future challenges facing our society.

In Italy, the National University Council (CUN |[9]|) has recently recognized the urgent need for strategic initiatives for the transformation of the Doctoral degree, which should no longer be considered a mere preparation path to academic or research careers, but also – or rather – the highest qualification level in the framework, not only of Public Administration, but also of Italian and foreign companies. Furthermore, the Doctoral degree is considered to be of strategic importance, particularly when considering the present economic transformation. So, they created the National Agency for Evaluation of Universities and Research Institutes (ANVUR |[10]|) in order to work for the development of methodologies and indicators about Engineering Education Programmes, including the doctoral level.

The EU principles on Innovative Doctoral Training, including above all the Triple "I" concept |[11]|, have been retained for the implementation of new modern educational strategies in the Doctoral Schools that have been created in most Italian universities. In Rome, at the Engineering Faculty of the "Università la Sapienza", some doctoral training programmes, focusing on "interdisciplinarity", are in progress. Interdisciplinarity is neither just a mere addition of different disciplines within a sector, nor a set of independent multidisciplinary actions, but the search for an optimal synergy of the disciplines themselves, taking into account the constraints of the market.

The speaker illustrated such an approach through some examples of challenges, not only which are to be met presently in Italy, but also which were met in the past by the "engineers" working in the Roman Empire. Our hope, he said, is that the new open educational environment is better suited for the identification and growth of young talented graduates, corresponding to the expectations of modern society. Perhaps our era, with huge challenges lying in front of us and requiring "titanic" efforts, is just the era when having "*Prometheus Unbound*" would be highly necessary !

The Engineering Doctorate in Germany

In the first part of his presentation, **Jörg STEINBACH** gave some information about the Doctorate in Germany. He recalled that it was the Austrian Professor Alois RIEDLER, after he had been appointed principal of the TH Berlin, who succeeded in convincing the Emperor WILHELM II to grant Prussian technical universities the right to award doctorates.

The traditional German doctorate is awarded for producing a substantial, independent research thesis under the supervision of a university professor. This means that the student, after having selected his own research topic, has to draw up a research portfolio with which he looks for a personal supervisor at the university ; the supervisor will help, monitor and support the student during his research. As a traditional doctoral candidate, the student can work as a research assistant at an engineering department collaborating with industry, or in one of the affiliated institutes. Emphasis is placed on practical, applied research commissioned by industry and public institutions. During that time, the students also perform teaching, organizational and management tasks.

Another traditional option is laboratory-based research, mainly conducted in the laboratory of the technology centre or in the workstation of the institute. The research topic is either set by the supervisor, or mutually agreed between the student and the supervisor. The student has to perform certain tasks not directly related to his PhD project (teaching, maintenance, …).

The TU9 Universities also offer the student the opportunity to complete his doctorate in research training groups, graduate schools or university doctoral programmes. They are called structured programmes and have a high degree of funding, support and additional training, which explains why they are considered as the last and highest level of university education in Germany.

Engineering Doctorates in Australia

Australia, **Robin KING** said, has a mature doctoral education system. All 38 public universities that operate accredited professional engineering degrees also provide doctoral programmes, the overwhelming majority of which are research-based PhD programmes, corresponding to level 10 of

[9] Consiglio Universitario Nazionale

[10] Agencia Nazionale di Valutazione del sistema Universitario e della Ricerca

[11] See the summary of Stefaan Hermans' presentation

the Australian Qualifications Table. They require a minimum of three years of research training – this is why universities must have defined research capability – and are examined on a substantial thesis that describes original research work ; the many criteria used tend to appraise knowledge, skills and application capacity.

A small number of universities also offer professional doctorates in engineering, which have been introduced to focus advanced work on engineering practice. They are usually linked to an industry sector – mainly the defence systems – and enrolments are quite small ; they are most often undertaken on a part-time basis, with the direct support of employers. They include advanced coursework (one year equivalent) and must also contain substantial research on a topic in advanced engineering practice. The thesis bears on systematic problem definition, solution formulation and coordination.

Over the past fifteen years, aggregated across all Australian universities, PhD commencing enrolments in engineering have increased by nearly 150 % (from some 600 in 1996 to some 1450 in 2010), largely due to a strong recruitment of international students (from about 25 % in 1996 to about 55 % in 2010). Most PhD students complete their programmes successfully : it is estimated that 730 of the 800 commencers in 2004 graduated not later than 2008. It must be noted that about 20 to 25 % of enrolments are women, in contrast with only 15 % for bachelor degrees.

Nevertheless, although Australian universities produce more domestic engineering PhD graduates per population than the USA (21 per million, compared with 13 per million), it must be noted that domestic enrolments are not increasing (around 600 every year) and that domestic graduations are even slightly decreasing (from 520 in 2007 to 475 in 2010) ; as most international graduates are likely to return home, the question is : is Australia producing sufficient PhD graduates for national needs, including for replacing retiring academic staff ?

It must be noted that the environment of university engineering research and research training is changing : for instance, 62.5 % of all engineering graduates come from only ten universities and 25.6 % from six former Institutes of Technology. One notices some erosion of the "supervisor-apprentice" model of training, towards more corporately regulated and accountable forms, a growth of research concentration in "centres" and "institutes", and the growth of post-doctoral positions.

The speaker also considered the career paths for Australian engineering PhD graduates. A survey showed that, globally, 78.6 % of PhDs who graduated in 2010 were in full-time employment, mostly in large organizations. Some 80 % of them judged that their research degree is "at least important" for their employment. Some salary advantage on appointment is apparent, but would not compensate for years of study. Some engineering employers "*will not employ PhD graduates*", because of perceptions that they have : narrow focus (on detail and in their area of expertise), poor generic skills and lack of ability "to get the job done". And some engineering academics do not consider that Australia operates at world best practice.

Concerning generic skills, short courses in innovation and project leadership are provided by many universities, but most systematically by some of them.

The speaker concluded with a commentary on the government's current initiatives to increase the quality of doctoral programmes that support Australian innovation. It seems that the Australian engineering doctoral system can be improved, that generic skills development, advanced coursework and international experience would be highly desirable (but funding and regulation are inadequate at present), that an increase in the number of graduates is unlikely in the current economy, that new incentives are necessary to encourage "the best" and that models for research training that include multidisciplinary thinking may be needed to address emerging problems.

Development of professional Engineering Doctorates

The development of the professional Engineering Doctorate, focused on the needs of industry, was dealt with by both **Patrick GODFREY** for the United-Kingdom (where it is called **EngD**) and **Kees Van HEE** for the Netherlands (where it is called **PDEng**). In this summary, we shall call it **EngPD**.

Both speakers, of course, placed the development of EngPD in a historical perspective. <u>In the UK</u>, the starting point was the Parnaby Report in 1990, which recommended that " *EngPD should be distinct from, and complementary to, the traditional existing PhD, which has been criticised for its* *lack of industrial relevance, as most companies with research activities view the PhD as both too narrow and academic for the industry's needs, and that its standard is therefore declining* ". So, it suggested that a broader range of training be established, to respond to the needs of industry and of doctoral candidates, with additional taught coursework in both technical and non technical areas, and that the doctoral student's work should bear on a significant, challenging and engineering problem, or set of problems, chosen in partnership with industry and academia.

In the Netherlands, the trend finds its origin in the two successive changes in the length of BSc and MSc studies that took place in 1986 and 1997, but the title of EngPD is used since 2004 only ; up to now, 3000 such graduations have been delivered. Actually, it was understood that there are many differences between research and design :

- A researcher asks himself " *Why ?* ", starts from empirical data, thinks in terms of invariants, and uses an abstract approach that aims to create new knowledge and, eventually, a new theory.
- A designer asks himself " *What ?* ", starts from some requirements, thinks in terms of variants or choices, and uses a concrete approach that aims to create new value and, often, an artefact |[12]|.

In the UK, it is stipulated that the intellectual challenge of the EngPD should be at least equivalent to that of the PhD. In other words, the quality standards for the thesis are the same : the difference is in why, what and how it is achieved. Usually, a research project has to be found at the interface between the university and an industrial sponsor, taking also into account the wishes of the candidate and the point of view of the supervisors. The project must be a real industrial problem, with significant challenging and innovative engineering content. More globally, it must respond to industry needs : recruiting and retaining talented people, stimulating innovation, developing leadership skills and bringing value for money. Presently, there are in the UK 27 Industrial Doctorate Centres, some 270 sponsoring companies and about 1000 innovation projects in progress.

In the Netherlands, the EngPD programme unfolds in two years. The 1st year consists of training courses bearing on personal skills, entrepreneurship, generic design methods and advanced domain specific design techniques. The 2nd year is devoted to carrying out a design project in industry, under the supervision of university staff (the project will have been chosen in cooperation between all stakeholders). Such a formula presents a triple value proposition :

- For companies, as design projects, carefully selected, really make a difference to the company.
- For students, who are offered a better industrial career.
- For universities |[13]|, as a source of income (companies pay for it) and of inspiration.

At the end of the two years, the quality of both the design result and the design process are evaluated by a committee, using different criteria. These criteria, which were at first too complex, have been reduced to five : functionality (satisfaction, ease of use, reusability), construction (structure, creativity, convincingness), feasibility (technical and economical), impact (social, risks) and presentation (correctness, completeness) ; they are appraised from both the academic viewpoint (problem description, state-of-the-art, evidence of scientific engagement, detailed description of the outcome, theoretical or empirical verification) and the industrial viewpoint (description of industrial context, analysis of the project impact, description of embedding in context, evidence of innovative outcome, demonstration that the outcome is fit for purpose).

Of course, such EngPD programmes are in need of a European label through some accreditation process by a well-established organization.

Engineering Education and the Needs of Industry

Marc GOOSSENS tackled the question of the appropriateness of Engineering Education to the needs and expectations of industry – as it stands nowadays – on two occasion : in Brussels in 2010, when he approached that question from a general point of view, and in Madrid in 2012, when he focused on the Engineering Doctorate.

[12] An artefact is a product, process or system, either tangible or intangible, which forms the 'solution' to a 'problem' and should be designed by using scientific methods.

[13] There are in the Netherlands three universities offering EngPD programmes (each in different disciplines) : Eindhoven, Delft and Twente

It must be noted that some other speakers also briefly tackled the subject. In Brussels, for instance, **Jörg STEINBACH** insisted on the characteristics of an "excellent" engineer and on the qualifications needed by industry, in which the so-called "soft" – or "transversal" – skills occupy an important place : this is why, he said, the TU Berlin includes them in its curricula.

Marc GOOSSENS began his presentation in Brussels with a quotation of Heiko MELL, a HR consultant, published in 2004 in a newsletter of VDI (Verein der Deutsche Ingenieure) : « *An engineer simply doesn't mean the same thing to a university and to a company. The former defines engineers purely in terms of expertise and ability in their field, while the latter adds over twenty individual characteristics and abilities, from 'adaptable' and 'team-oriented' to 'reliable'* ».

So, besides scientific and technological skills, which usually do not pose any problem if the engineer has the right profile for the job, and managerial skills, which usually do pose a problem for engineers, but can be easily taught in the many managerial schools, there are the so-called "soft", or "transferable", or "generic" skills. These pose a real problem to companies, not only because many engineers lack them, but also because they cannot be taught like other skills, as they lie in an unconscious mode of the brain : they can only by revealed and improved through practice.

It is the evolution of the world – globalization and decentralization, increasing complexity, more demanding customers, things going faster –, he said, that made them so important now. He then briefly reviewed most of them. He also very much insisted on the difference between a leader – "*you are born a leader*" – and a manager – "*you are taught to become a manager*" – for Europe is sorely lacking in leaders.

He then presented the results of a survey, led by INSEAD for the 2009 European Business Summit, bearing on the evaluation of a three-storeyed skills pyramid and showed that the situation of Europe is not good at all, as compared with its main competitors : USA, Japan, South-Korea and Singapore. This is particularly true in respect of the third storey of the pyramid, the "Global-Knowledge-Economy" skills, that is those skills that make the difference for engineers and managers.

In Madrid, **Marc GOOSSENS** first recalled that presently most engineering doctorates are research-based doctorates, awarded in recognition of academic research, while in other professions, as Doctors in Laws and Doctors in Medicine, they are professional doctorates, more closely aligned with the practice of a particular profession. He also showed, from figures published in the 2011 OECD Science, Technology and Industry Scoreboard, that the European Union has globally more PhD graduates in Science and Technology than most of its competitors, particularly the USA.

How come, he then wondered and supported with some evidence, that most PhD graduates in engineering cannot find a position corresponding to their qualifications, even if some other evidence claims that Europe needs more researchers, particularly in engineering ? Actually, he said, there is a gap between a desirable situation, guaranteeing Europe's competitiveness, and the reality on the ground. And, in order to better define the nature and origin of such a gap, he successively looked at it from different perspectives.

There is the <u>perspective of PhD students</u>. What is exactly their motivation and do they even know what is motivating them ? Do they know precisely enough what is expected of them afterwards ? Do they possess a high enough level of soft skills, which are now so highly valued by industry ?

There is the <u>perspective of universities</u>. Does their appraisal of PhD graduates' abilities correspond to the proven abilities, required by the job ? Is carrying out an individual research project work the best way to prepare these graduates for a job in industry, where R&D is usually the result of teamwork ? Is claiming that universities should "produce" more PhD graduates an impartial view, when one knows how interesting it is for universities to have as many PhD students as possible ?

And then, there is the <u>perspective of industry</u>. Of course, their policy about the recruitment of PhD graduates is linked to their volume of R&D and they are reluctant to take on one of them for a position for which he is overqualified, not to mention the fact that he will have to move towards a more managerial position. But, when coupling the figures of the aforementioned OECD report about the number of PhD graduations with the figures of the 2011 Innovation Union Competitiveness Report about investment and performance in R&D, it appears that the Achilles' heel of Europe in that field is not the number of PhD graduations, but not enough investment by European industrial companies in R&D. Therefore, increasing the number of PhD graduations is useless.

And, before concluding, the speaker ventured into some possible explanations of such a situation.

Photo Gallery

Brussels – Royal Military Academy - 2010

From left to right :

Robin KING, Ramon WYSS, David TIMONEY (chairman of the 1st session), Paul CROWTHER, Marc GOOSSENS, Jörg STEINBACH, Alfredo SQUARZONI, Robert WAGENAAR, Denis Mc GRATH (President of CLAIU-EU at that time), Yvan BAUDOIN, Ian FREESTON and Luc STERCKX (chairman of the 2nd session)

Rome – Università La Sapienza - 2011

First session – From left to right : Marc GOOSSENS, Marc DEMOLDER, Richard SHEARMAN, Giovanni ROLANDO (Chairman) and Christopher M. STONE

Second session – From left to right : Giuliano AUGUSTI, Fabrizio VESTRONI, Sylvie VILLA, Massimo GUARASCIO (Chairman) and Erik de GRAAFF

General view of the audience (during the second session)

Partial view of the audience (before a coffee break)

From left to right : Giuliano AUGUSTI, Bill GRIMSON, Sergio POLESE, Massimo GUARASCIO, Giovanni ROLANDO, Sylvie VILLA, Marc GOOSSENS, Fabrizio VESTRONI, Marc DEMOLDER, Richard SHEARMAN and Erik de GRAAFF

From left to right : Sergio POLESE (President of CLAIU-EU) and Denis Mc GRATH (Past President of CLAIU-EU)

During the lunch buffet in the cloister

During a coffee break

Two of the tables at the gala dinner

Madrid – Instituto de la Ingeniería de España - 2012

First session – From left to right : Thomas Ekman JØRGENSEN, Marc GOOSSENS, Peter SCHARFF and Alejandro MARIN (Chairman)

Second session – From left to right : Robin KING, José VIEIRA (Chairman), Massimo GUARASCIO and Jesús FÉLEZ

From left to right : Ann VAN EYCKEN (Secretary General of CLAIU-EU) & Dirk BOCHAR (Secretary General of FEANI)

Sergio POLESE, President of CLAIU-EU

Partial views of the audience

From left to right : Alejandro MARIN, Marc GOOSSENS, Aris AVDELAS, Jörg STEINBACH, Peter SCHARFF, Thomas EKMAN-JØRGENSEN, Stefaan HERMANS and Sergio POLESE

From left to right : (1st row) Robin KING, Jörg STEINBACH and Alejandro MARIN – (2nd row) Aris AVDELAS, Massimo GUARASCIO, Sergio POLESE and Marc GOOSSENS – (3rd row) Thomas Ekman JØRGENSEN, Patrick GODFREY, José VIEIRA, Jesús FÉLEZ and Peter SCHARFF

During the lunch buffet

During a coffee break

Some of the tables at the gala dinner in the restaurant " La Favorita "

Synthesis, conclusions and reflections

In summarizing the summaries of what has been presented during those three annual conferences of CLAIU-EU and drawing from it some conclusions, I am going to use the first person singular, because what I shall write in this section, although not being at variance with the points of view and objectives of CLAIU-EU |[14]|, represents nevertheless both a personal interpretation and a personal point of view.

In summarizing each presentation, I was faced with some difficulty, in some cases because of the scarcity of the information – when I had only some slides and no text at my disposal and had to rely on my notes and memory – and in most cases because I had to make a choice between what to say in the summary and what to leave aside. I have tried to be fair and objective, but it is impossible to part with all subjectivity. So, if any of the speakers should tell me that my summary of his presentation does not give a good enough representation of what he said, I could only but agree with him … and apologize !

A large part of the conferences was devoted to **the harmonization** – not the standardization ! – **of Engineering Education in the European Higher Education Area**, with the objective of facilitating, not only the mobility of students and graduates throughout Europe, but also the development of common policies at European level, that aim at improving educational outcomes. The first step consisted of harmonizing the engineering programme structure, something usually referred to as the **Bologna process** or implementation of the two-tier structure |[15]|. We have seen that this process was more difficult to implement in some countries than in others such as Italy and Spain, where the engineering profession is regulated : this required long discussions with successive governments. There were also some special situations, as the one prevailing in Switzerland. And we were given the opportunity to compare our situation with the evolution of engineering education in Australia.

A second step consisted of developing a form of Quality Assurance through the **Accreditation of European Engineering Education programmes**, an essential tool for guaranteeing a full mobility of graduates throughout Europe. Various labels were proposed, but it seems that the EUR-ACE label, developed by ENAEE (European Network for the Accreditation of Engineering Education), is gaining favour in a growing number of European countries, and even arousing interest outside Europe. It is a long process, as the institutions that are to award the EUR-ACE label must first be authorized to do so by ENAEE. It must be noted that the accreditation process is not linked with the Bologna process, as the accreditation bears on the learning outcomes, not on the way students are being taught. This is why we were told about AHELO, a ground-breaking OECD initiative to assess learning outcomes on an international scale. In that accreditation perspective, we were also given the opportunity to learn about the licensure process of professional engineers in the US.

In a similar perspective of favouring mobility, but of students rather than of graduates, we heard about the existence and the working of some university networks, as CLUSTER and T.I.M.E.S in Europe and STARS between Europe and the US, offering **dual and joint degrees programmes**.

Another important part of the conferences, concentrated in the third one, was devoted to **the engineering doctorate**, which is not directly – at least up to now – concerned by the Bologna process and the accreditation frameworks. We heard about the point of view of the European Commission on the necessary skills that have to be gained during doctoral studies, and about various **positions, policies and recommendations** : EUA's, SEFI's and CESAER's. Thrse are all more or less consistent with each other, particularly in emphasizing that the engineering doctorate must be the outcome of an individual research-based activity, without any significant curriculum attached. We also heard about a survey, carried on within the EUGENE Academic Network, which aims at introducing **quality indicators in doctoral education**, the first step – maybe – of a future accreditation system.

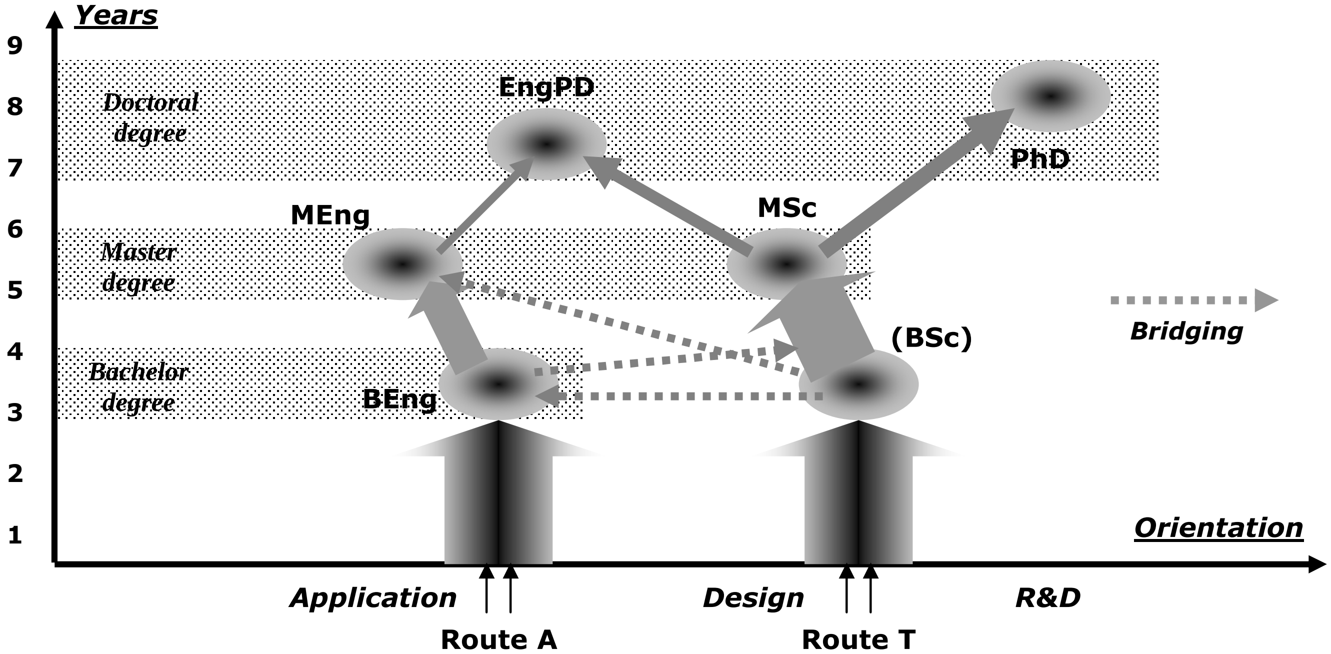
[14] Otherwise, it wouldn't appear here !

[15] As opposed to integrated structure.

For my part, in this third conference, I submitted some evidence of the fact that many PhD graduates – that is students that have been awarded a research-based doctoral degree in engineering - **cannot find a position corresponding to their qualifications**, and I tried to identify the origin of the problem. If it seems that there is an obvious mismatch between the expectations of industry and the skills – mainly, but not only, transferable skills |[16]| – gained by the students during their doctoral studies, it appears also that European industrial companies do not invest enough in R&D, as compared with their main competitors.

Then, some case studies were presented, first about the development of the **engineering doctorate** in Spain, in Italy and in Australia, continuing what was said during the first two conferences about the development of Bachelor and Master degree programmes in the same countries. The second series of case studies concerned the development of **professional engineering doctorates** in the United-Kingdom and in the Netherlands, in contradiction, in some way, with the aforementioned positions, policies and recommendations.

The third important part of the conferences, which was mainly dealt with in the second conference in Rome |[17]|, is the opposition – or, better, the differentiation and complementarities – between a more theoretical approach and a more applied approach to engineering education. It seems that, after a great deal of beating about the bush at the beginning of the implementation of the Bologna process, the necessity to distinguish between two entry routes (T & A), corresponding to the two aforementioned approaches, is generally recognized ; it corresponds to the position I had already defended in Brussels in 2010. Adding to that the possibility of proposing professional engineering doctorates (EngPD) as in the United-Kingdom and in the Netherlands (and also in Australia), we could have something like this :



In this diagram, the starting points of the two routes (A & T) are the same along the y-axis, as entering students have the same level, but different along the x-axis, as they have obviously different aptitudes, being more inclined to deal with either practical or theoretical problems. Thanks to the bridging possibilities, all end qualifications are accessible from both entry routes, though of course some trajectories are less probable than others. And, not least, it shows that application-oriented and theory-oriented engineers are on the same level, the difference between them lying in the approach they use for solving problems and developing solutions.

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16 I emphasized, in the 2010 conference, the necessity of developing a high enough standard of transferable – or soft – skills, as far as a career in industry is considered. I won't come back on that, as everybody agrees about such a necessity, though there is some discussion about whether they can be effectively taught and correctly appraised.

17 I put that subject in the third place, because I can then include doctoral studies in the discussion. Furthermore, it opens the door for deeper reflections on the role and place of engineers in society.

This brings me to the sensible analysis of **Erik de GRAAFF** about the inappropriateness of using research excellence as a standard for educating engineers at Master level, and to a more general reflection about engineers, their key competencies and the evolution of their role in society.

" ***What is an engineer ?*** ". When I was – much – younger, I used to say, out of bravado : " *I am an engineer, I can do anything !* ". But, was it really bravado ? I believe that most engineers have the "intellectual capacity" to become say, a lawyer, a doctor in medicine, a financier, or an economist, even if, by "nature", they would not have been inclined to take up such a profession. I am not sure that stating the reverse would be equally true.

But, defining an engineer in terms of intellectual capacity only would be a reductive approach. We could try to answer that question by explaining what they do : " *Engineers create what has never been* ", said **Massimo GUARASCIO**. Perfectly true, but maybe not enough. In her book « *Engineers' Glory* |[18]| », Hélène VÉRIN wrote that engineers are the best candidates for a leading position because « *by nature they have at their disposal the ability to generate, that inborn power of mind which, by its own virtue, drives them to find what is unknown* ».

We can still go deeper : the main difference between the engineer's view and that of other professionals like the ones I mentioned above lies in the way the actual work and the concomitant thinking are related, on a time scale, to their object itself, which we'll call the « ***generating fact*** ». Let me explain it with some examples.

Let's first consider the case of an engineer who has to work on constructing a bridge or a complex machine. Here, the generating fact is the construction itself and almost all the engineer's work will take place **upstream**, towards the generating fact : studies, calculations, plans, etc. … The engineer has therefore a direct action on the carrying-out of the generating fact. He is involved in a **proactive** process, he builds the future.

On the other hand, let's consider the case of a lawyer who has to minimize the consequences of an offence ; or the case of a doctor who has to treat a patient ; or the case of an accountant who has to draw up the balance sheet of a company. The generating fact is the committal of the offence for the first one, the occurrence of a disease for the second one, the accounting situation of the company for the third one. For the most part, their work will take place **downstream**, from the generating fact. They have therefore no influence on that generating fact, which presents for them a **random** characteristic. They have a **reactive** approach, they analyze and correct the outcomes of the past.

How come, then, that engineers, in so many cases and particularly in large companies, have handed over the reins to economists and financiers and are just "employed" as technical executives or managers ? Is it just an episodic fluctuation in the course of history, or is there a more continuous trend ? I favour the second explanation, the trend being the progressive wearing away of realism, since the end of the Middle-Ages, for the benefit of nominalism |[19]| :

- In realism, the **object** (from the Latin "*objectum*", meaning what is placed in front of you, what you are aiming at) is given first, it determines the "what to do", it requires a proactive action.
- In nominalism, the **subject** (from the Latin "*subjectum*", meaning what is placed under you, your underlying motivation) is given first, it determines the "why to do so" |[20]|, it implies a reactive action.

Nominalism prepared the way for dialectics, which is the art of presenting things to make them acceptable, and, through the French Revolution, to our present form of democracy. It also prepared the way for the industrial revolution, because such words as wealth creation, yield, capital, output, productivity, progress, etc. are typical of nominalism, as they do not design objects, but cover concepts that need long explanatory sentences to be understood, and can also be disputed. And the industrial revolution introduced the systematic reference to employment, which is a modern, though alleviated form of slavery.

[18] " La Gloire des Ingénieurs ", Albin Michel, 1993

[19] See Arnaud-Aaron Upinsky, « *La tête coupée, ou la parole aussi* » (Having your head cut off, or your power of speech too), O.E.I.L., Paris, 1991

[20] This "why", linked with our personal and often not very clear motivations, must not be confused with the "why" of the scientific method (for instance when Newton wondered why an apple is falling from the tree), which helps us to understand the surrounding world and better carry out the "what" ; it is such a confusion that the Church made when they condemned Galileo Galilei.

In ancient times, when a slave was not satisfying the needs of his master anymore, or simply could not find a master, he was sent into the arena : " *Ave, Cæsar, morituri te salutant* ". Nowadays, when an employee is not satisfying the needs of his employer anymore, or simply cannot find a job, he is sent into the marginal community of people living on social security. And now, with the socio-economic system we have built in Europe, the question of employment has become a crucial, almost insoluble problem as, according to the principle of communicating vessels, what one gives to one side has to be taken from the other side. Therefore, as costs cannot be reduced to -∞, the only option is to increase production through innovation.

I shall come back to that point later, after a short detour, a very fast time travel in the history of mankind.

A long time ago, our forefathers the mammoth hunters were slaughtering their preys in a rash way, by pushing whole herds towards precipices at the bottom of which they were crashing, not imagining that one day mammoths would become extinct. In the year 474 AD – two years before the last Roman Emperor's elimination by the Germanic invaders – Sidonius APOLLINARIS, Gallo-Roman writer, bishop and politician, wrote that he hoped his son would become consul of Rome. He was unable to imagine that the Roman Empire could disappear one day, even though all the signs of its impending disappearance were available.

And, in the last century, the British historian Arnold TOYNBEE, in his monumental Study of History, analyzed the origin and fate of 23 civilizations, among which 22 died by suicide, due to the progressive transition from the Promethean vision of their founders – as he expresses it – to the congenital blindness of their last representatives. The 23rd civilization is our Western Civilization : why should it be an exception to the rule ?

Our world, where one billion people lack drinking water and electricity, is now confronted with many serious problems such as poverty, disease, violence, fundamentalism... The most important of them is not climate change – we are not even sure that it is due to human activities – but energy. During the last 12,000 years – since the time just before the establishment of agriculture and breeding – the mean energy used per inhabitant of the Earth has multiplied by nearly 80 (namely, in round figures, from 1 GJ/year in 10000 BC to 80 GJ/year in 2000 AD). During the same period, the world population has multiplied by 1,500 (more or less from 4 million to 6 billion individuals). Therefore, the total yearly consumption of energy has passed from 4.10^{15} to 480.10^{18} J/year : that is a multiplicative factor of 120,000 ! In terms of power, our present capacity corresponds to 13 TW. In comparison with this, the total geothermal power of the Earth is 16 TW and the power of the tides due to the moon and the sun is 3.5 TW.

In this overall picture, Europe's position is far from comfortable, not because Europeans are less intelligent, but because Europe's structures and ways of working are mainly old-fashioned and many of us are struggling and losing energy trying to preserve our advantageous position, instead of contributing to our common interest. This is a particularly serious handicap, as Europe has few natural resources and has to rely on its human capacities.

Therefore, coming back to the question of employment and to the justified questioning linked to it in our socio-economic system, the historical detour I just presented explains why employability should not be such an important criterion for developing our curricula, both in secondary schools and in higher education. What does employability mean ? Appropriateness of the learning outcomes to the jobs being offered, I would say. But what is the use of working out a fantastic employability if the number of jobs being offered is decreasing due to the lack of competitiveness of European industry ?

Focusing on employability for developing curricula has a perverse effect, namely the danger of reducing education to a series of recipes for being able to get a job, instead of a well balanced set of knowledge and competences that aim at facilitating innovation and leadership ; or the danger, taking up again Arnold TOYNBEE's expression, of favouring congenital blindness instead of a Promethean vision. And who, better than engineers, could have such a vision ? But they need for that more than a series of short-term and narrow-minded recipes, they need to be able to take in the whole landscape at a glance and need more culture outside their respective specialisation.

This is the message I wanted to leave at the end of this report.

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Appendices

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Belgium :	31	South Korea :	6	Australia :	2
Spain :	26	the Netherlands :	5	Austria :	1
Ireland :	24	United Kingdom :	4	Turkey :	1
Portugal :	9	Finland :	4	Russia :	1
Germany :	6	Romania :	3	USA :	1
France :	6	Sweden :	3	Taiwan :	1

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