TUNING Educational Structures in Europe

Report of the ENGINEERING Synergy Group

May 2002

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1. Introduction

1.1 Background

The European labour market is developing fast. At the same time the Bologna process is promoting fundamental changes in the Higher Education (HE) sector. The meeting of European education ministers in May 2001 in Prague has confirmed the intention of gradually arriving at a fair degree of convergence between the different educational systems in Europe by 2010 [1]. This implies the necessity of adapting curricula in terms of structures, contents, learning attributes, learning tools, assessment methods. The project "Tuning Educational Structures in Europe" (from now on Tuning for short) aims at "pooling together and capitalising on available experience and recent developments in several of the Member-states.....particularly from previous and on-going European co-operation in the context of the Socrates programme."[2]

The Tuning project aimed initially at enabling European universities to conduct a joint debate on these issues in five areas: Mathematics, Geology, Business, History, and Educational Sciences. Many other synergy areas were soon identified on the basis of previously done and/or on-going work in the context of the ERASMUS Thematic Networks (TN) action, in particular when concerning the European Credit Transfer System (ECTS), quality assurance, definition of core curricula. Selected areas include Chemistry, Physics, Languages, Law, Medical Sciences and Engineering.

The Engineering Synergy Group (SG) of the Tuning project includes:

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The Engineering SG has been formed with the declared goal of taking advantage of the experience being obtained within the Thematic Network (TN) "Enhancing Engineering Education in Europe" (E4) (and of the experience gained within previous TN's in the field of Engineering Education such as H3E (Higher Engineering Education for Europe, 1996-99) and EUCEET (European Civil Engineering Education and Training, 1998-2001). This has implied some differences in methodology with respect to other areas of Tuning for arriving at recommendations, in particular the Engineering SG decided not to use the questionnaire approach of other Groups of Tuning, but rather to rely on recently done surveys of similar characteristics. The needs to respect the time schedule of Tuning as well as that of producing a report as much in line as possible with those of other areas are very well recognised by this SG. Another difference immediately apparent is the relatively small number of members of the Engineering SG, which may cast doubts on how representative it is of the European Engineering Education world. However it must be pointed out that GA, GH, AH, BM and MP are Promoters of the five Activities of E4 and that FM is its co-ordinator, whereas JM is the General Secretary of EUCEET. It is through these links to Thematic Networks in the engineering field that the representativeness of the Engineering SG is ensured together with the active role that engineering education societies such as SEFI and CESAER, and professional organisations such as FEANI, play within E4.

The background work done within these organisations has been very helpful, informing the work of the Tuning Engineering Synergy Group. SEFI and CESAER, together with CLUSTER, have also made their views known in a joint letter to the Ministers of Education emphasizing the need to take into account the specific aspects of higher engineering education when implementing the objectives of the Bologna Declaration.

It is a pleasure to acknowledge here the support that the Engineering Synergy Group of Tuning has received and which has made it possible to produce this report. These acknowledgements go first to all the Institutions of the members of the group for having allowed to use some of the time of the colleagues members of the group, then to the Directorate General for Education and Culture of the EC for having suggested the need of such a group and having hosted some of its meeting at its premises, and, last but not

least, to the Thematic Network E4 (in the person of its President prof. Claudio Borri) for having strongly supported this “side” effort of the Promoters of its five Activity Working Groups and for having accepted to consider as part of the E4 mission to allow Ms. Bricola to act as secretary of the Engineering Synergy Group.

1.2 Objectives of the Bologna Declaration

The main objectives of the Bologna Declaration are:

- Adoption of a common framework of readable and comparable degrees, “also with the implementation of the Diploma Supplement”;
- Adoption of a system of higher education based on two cycles, undergraduate or first cycle studies, lasting a minimum of 3 years and a maximum of 4, and postgraduate or second cycle studies following successful completion of first cycle studies and leading to a master and/or doctorate degree;
- Implementation of the European Credit Transfer System (ECTS);
- Elimination of obstacles to free movement of students and teachers;
- Inclusion of a European dimension to quality assurance in higher education.

The objective to promote the adoption of a two-cycle system of higher education is the one that poses the greatest challenge. The European Universities in March 2001 in Salamanca, accepting this challenge, endorsed the move towards a compatible qualifications framework and pointed out that “There is broad agreement that first degrees should require 180 to 240 ECTS points but need to be diverse leading to employment or mainly preparing for further postgraduate studies. “ Arriving at a good level of convergence in higher education in engineering may well be easier than in other fields, because of the fact that Engineering Education (EE) institutions have always been keen to respond to the requests coming from the labour market, nevertheless the diverse scenarios still existing in different countries [6] suggest the necessity of a long phase of gradual modification.

This enhances the importance of initiatives like Tuning aiming at identifying the instruments, which can help in this delicate phase. However the EE world resents the fact that technical universities and faculties are not properly represented in the Bologna process, which has lead to the specific needs of EE not being taken sufficiently into account. Hence a question of particular importance for EE would be to reconcile some of the contradictions between the general needs of higher education, as developed in the Bologna process, and the specific needs of technical education.

1.3 Objectives of this report

The objectives of this report emerge quite clearly from its table of contents. After having summarised the European scenario in EE in chapter 2, some current important trends are surveyed in chapter 3, in chapter 4 the four lines of Tuning are considered as far as EE is concerned, chapter 5 presents briefly some consideration about the doctorate level in Europe. Chapter 6 is devoted to life-long learning issues. Based on this analysis a number of recommendations and tools for arriving at a certain degree of convergence within EE in Europe are presented in chapter 7.

2. Engineering Education (EE) in Europe

2.1 Models

A description of engineering education in the European Union at the end of the 20th Century can be found in Chapter 1 of the "State-of-the-art" Report of Working Group 2 of H3E [7]. A striking similarity between the national systems is portrayed: with only a little simplification, it can be said that EE in Continental Europe followed two basic "models", usually coexisting "in parallel" within each country.

The first model, to which we shall refer as "long cycle" engineering education, evolved in the 19th century from German and French schools. Its characteristics are, firstly, a strong theoretical base (which shows itself in the requirement for mathematical competence even at the entry stage) and, secondly, a strong research orientation (which shapes the syllabus and the form of teaching at the later stages: according to Von Humboldt, these links to research activity should be encouraged not only for innovation purposes, but also to let the universities be less influenced by political and industrial forces). This education takes place within an environment that is centred on the individual work of the student, rather than on highly structured classroom teaching. A consequence is that the duration of the course is often not well defined or regulated, and even the structure may be very flexible - leading to the time to graduation being up to as much as twice the nominal 5 or 6 years. It may well be that it is the learning or discovering for oneself which makes the graduate fitted for a professional career where high level judgements have to made independently.

As a result of the growing and changing needs of industry, in the early 1970's Germany, the Netherlands and some other countries developed "short-cycle" engineering diploma programs, of 3 to 4 years' duration, usually provided by separate Institutions, such as the German Fachhochschulen. In the short-cycle courses the emphasis in the content is more practical, the course of study is more rigidly controlled, and there is often a stronger emphasis on formal teaching. The result is that the study period is usually quite close to the nominal 3 or 4 years. In addition, there is usually a requirement for periods of practical experience that are quite well defined both in content and in duration. "Short cycle" engineering education has since spread, in different forms, to most European countries. It may be worth noting that in the early 1990's it was introduced in Italy too, with the notable peculiarity that "short cycle" courses (called "Diplomi Universitari") had to be provided by the same Institutions (the Universities) that provided "long cycle" education (these courses never really took off, and have been eliminated by the recent law introducing the so-called 3+2 system: see section 3.1).

Most current long-cycle degree courses are not merely short-cycle courses followed by a suitable length of additional study, as is very clear from the rules governing transfer from one type of courses to the other. In going from "short" to "long" there is usually a requirement not only for the time to be made up, but also for additional time to be spent in taking care of the (supposed) deficiencies in basic knowledge. Thus, as a matter of fact, short- and long-cycle engineering courses remain essentially in parallel, rather then forming a "two-tier" system, as envisaged in the Bologna Declaration, according to which the "short-cycle" courses should lead to a complete qualification "relevant for the job market", and be the entry point for "post graduate" courses leading to advanced degrees.

There is however some evidence that, in many countries, the systems are evolving (often with a lot of resistance from the higher level institutions) to make the short-cycle Degree equivalent to the first stage of a long-cycle degree, in formal accord with the Bologna Declaration (see section 3.1). Despite this, it is to be expected and in our view desirable, that a great variety of scopes and goals will remain between the "short-cycle" courses, some of them being more oriented towards being the first stage of a "long-cycle" degree course, others towards really providing a self-contained practically oriented technical formation (see sections 2.1 and 3.2)

The Bachelors and Masters degrees of the "Anglo-Saxon" countries (UK and Ireland) do not fit this pattern as well as might be expected from the nomenclature. The Bachelor degrees, although like a short-cycle degree in length, often have an underlying theoretical content closer in concept, even if not in quantity, to that of the continental European long-cycle degrees. However, the course of study is quite rigidly controlled, and most students graduate within the nominal study duration. The picture is confused by the fact that there are also many short-cycle degrees, with the title Bachelor, which are closer in content to practically oriented short-cycle Diplomas of other European countries. There are also quite wide differences between universities in the style of teaching and learning; at one extreme the emphasis is on a learning environment, like in the continental European long-cycle courses, whilst at the other the courses have a strong teaching focus.

2.2 Likely requirements for European employability

What makes a good engineer ? A general profile for a good engineer in the Learning Society of the new millennium is built on the ability and willingness to learn, on solid knowledge of the basic natural sciences and on good knowledge of some field of technology. Other skills include general human values and the communication and leadership capacities needed in modern working life.

As an example of a list of skills, the following is given here [9]:

Ability and willingness to learn
Solid basic knowledge of the natural sciences
Basic engineering skills
Good knowledge of one's major technical discipline

Commitment to quality
Internationalisation oriented skills
Ability to work in teams
Good communication skills
Ability to lead and manage resources
Professional and ethical responsibility
Ability to deal with uncertainty and ambiguity

There are other, very similar lists, for example those of BEST (the Board of European Students of Technology), ABET (Accreditation Board of Engineering and Technology), and Finnish Academies of Technology. All these lists seem to have in common the fact, that an engineering graduate at Master level has to be able to continuously learn new approaches, theories and methods. Thus, she/he has to be prepared for lifelong learning. She/he has, of course, the knowledge of technology, but also needs to have good communication and team work skills. Technology alone is not enough in the present world. These lists lead to lists of required competencies (cf. Section 4.1) and, although different weights should be given to each "attribute", they are basically valid for either short-cycle and long-cycle engineers.

It is widely agreed that industry requires (and will continue to do so) a large number of engineers of both types, in many countries more of the "applied" (i.e. short-cycle) kind than of the other. This fact can be attributed to the rapid development and wide range of new technologies in modern industry. This development has created the need for professionals with the skills and knowledge needed to take advantage of the new technologies, both for current use in the manufacturing process, as well as for the development of new products. The growth in importance of enterprises in the service sector has also contributed to change the overall picture, giving a greater importance to, for instance, formation in Information and Communication Technologies (ICT) in both "short" and "long" cycles of EE. Further reasons for stimulating an updating of curricula are the growing relevance of basic financial/economic formation and, last but not least, the internationalisation aspects of formation, mainly the need for foreign language skill, but also cross-cultural competences, crucial for working in a wider European environment.

To reach full professional qualifications in three years is not possible. Therefore the focus in university education must lie in basic sciences and the basics of the field of engineering in question, thus making the student able to either learn more in the working life or continue in the university towards a master degree, that gives her/him a full spectrum of engineering skills.

Since a certain level of simplification helps in grasping the full picture, we can schematise and distinguish only a "long cycle" of nominally 5 years (often becoming 6 or 7) and a "short cycle" of 3-4 years, but remembering that it is only a rough approximation of reality. FEANI distinguishes also, in its *FEANI Index* and in the requirements for the professional designation "Eur Ing", between a professional (*theoretical*) degree and professional (*applied*) degree.

2.3 Issues at entry level

In many European countries a number of factors have contributed reducing the enrolment of students in EE. The main ones are (besides the effect of reduction in birth rate):

- The low level of interest in science and mathematics of secondary school students;
- The perception that engineering studies are more difficult than equally (or more) lucrative choices (such as business, accountancy, law, etc.);
- The negative opinion coming from stereotypes of bad working environment and/or impact on the environment.

The consequences of the above are very serious, not only for the engineering schools, but also for industry and by and large for the European economy.

Another issue is the difference implicit in the existence or not of a selective entrance examination. In this respect European institutions differ substantially, hence implying a quite different interpretation of, say, dropout rates in different countries. It is unlikely that this major factor of difference will change at the entry level of the first degree (Bachelors), whereas the need of an entry selection system to the second level (Masters) must be stressed.

2.4 International agreements

The European Union has established a legal framework for the mutual recognition of professional qualifications. Directive 89/48/EEC of 21st December 1988 establishes a general system for the recognition of higher education diplomas awarded on completion of professional education and training of at least three years duration. This general system concerns all regulated professions that are not subject to a specific directive, including engineering. (Specific procedures have been established for certain professions, for example, the medical professions, architects, and lawyers.) The directive is limited by its focus on regulated professions: for the engineering professions it only apples in nine out of eighteen states [12].

Some international agreements relevant to the engineering profession have been signed in recent years and have to be taken into account. Among these the most important are the followings.

- The *Washington Accord* requires the 8 signatories (national professional or accrediting organizations from Australia, Canada, Hong Kong, Ireland, New Zealand, South Africa, UK, USA) to give the same professional recognition to holders of engineering degrees obtained in any one of these countries. Japan in June 2001 applied for "provisional status" in the accord.

- The "*Trilateral Accord*" (for short) has been signed by the professional organisations of Italy, France and UK. This agreement will apply to registered engineers (of both "cycles") with four years post-qualification professional experience, allowing them to work as professional engineers in the language of the receiving country. Ireland is now negotiating its admission.

- The *Engineers Mobility Forum Agreement* establishes an International Register of Professional Engineers signed in South Africa in June 2001 by the 8 countries of the Washington Accord plus Japan, Korea and Malaysia. Expected to become operational in 2002.

- The agreement to establish a common Register of Engineers for the Asia-Pacific Economic Community (APEC), should initially cover Australia, New Zealand, Canada, Hong Kong, Japan, Korea, Malaysia, and in the near future be enlarged to Indonesia and Philippines (with some accord also with the USA).

- The "*Paris Agreement*" (September 2000) established the European Standing Observatory for the Engineering Profession and Education (ESOEPE), aimed at exchanging information on accreditation and recognition procedures and facilitating mutual recognition agreements. New members are being added to the initial signatories (institutions from France, Germany, Italy, Portugal, UK along with European associations).

- The *FEANI Register* was set up by FEANI in 1987 to facilitate movement of practising engineers and to establish a framework of mutual recognition and qualifications. Engineers who satisfy the FEANI requirements can apply for registration and receive the designation "Eur Ing". The *FEANI Index* is an accompanying list of higher engineering institutions and programs, recognised by FEANI and its national members.

- The ECCE (European Council of Civil Engineers, an organisation created in 1985 and grouping professional civil engineering associations of 19 countries) decided in October 2000 to create and maintain a Register of European Civil Engineers. ECCE aims at ensuring that persons entered into this Register offer demonstrable level of academic achievement, professional skill, and continuing professional development.

Although these agreements are to be welcomed, because they facilitate the bottom-up internationalisation of the engineering formation and recognition, it can be noted they often overlap with each other. Therefore, care should be taken to see that too many "accords" do not result in "cacophony".

3. Current trends

3.1 Examples of existing initiatives [6]

In Germany, the existing EE programme structure is being complemented in many institutions, both at universities and fachhochschulen, by a “Bachelor”+”Master” structure. It is not yet decided if this structure will ever replace the old one.

In Italy, a rigid structure of degrees in series (the so called "3+2" structure) has been established by law for all university education: it is compulsory since academic year 2001-2002, but some engineering faculties (e.g. Politecnico di Milano) introduced it one or two years earlier. According to this law, which applies very formally the letter of the Bologna Declaration, all university students should obtain first a "Laurea" after a three-year course of study; only afterwards they may apply for two further years of study, leading to a "Laurea Specialistica". Only disciplines for which there exist special European Community Directives (i.e. Medicine and Architecture - and consequently Architectural Engineering) are not obliged to follow this pattern.

Even if the French Minister of Education at the time was one of the very first signing of the Bologna Declaration (indeed even the preceding Sorbonne Declaration), French EE does not seem to try to adapt its complicated system to the Bologna model. This is particularly true in the case of the Grandes Ecoles, for which the introduction of an intermediate degree at the Bac+3 level, would appear to be purely “cosmetic”, having little relevance to the European labour market as an appropriate level of professional qualification.

In the Netherlands, for the three Dutch technical universities (Delft, Eindhoven and Twente) the adoption of the 3+2 structure looks purely formal, with a Bachelor degree relevant to mobility, but again not to the labour market.

In the Czech Republic a two-tier system is being introduced with a 4+1.5 structure. It will be implemented starting with the academic year 2003-2004. The short-cycle 4-years programmes that used to exist in parallel with the long-cycle ones will cease to exist.

In Romania a two-tier system (4+2) seems acceptable to fields such as electrical, electronics, and automation engineering, but not to civil engineering faculties, still favouring the parallel offer of a long and a short cycle curriculum. This attitude appears to be widely spread in Europe and grounded on real differences perceived to exist between the civil engineering profession and the others.

A 3-year Bachelor degree without professional ambitions is being introduced as a facilitator of student’s mobility in many European schools. It must be emphasised, however, that this is not in line with the objectives of the Bologna Declaration.

3.2 Diversity within the two-tier systems

The Bologna Declaration recommends a two-tier structure of undergraduate and post-graduate studies as a common reference structure for the „European Area of Higher Education“, applicable to most of the disciplines and subject areas. The recommended sequenced structure challenges mainly those higher education systems in Europe, which are constituted by binary or other parallel structures, prevalent in most countries of continental Europe. They tend to offer programmes of study with different profiles and length of study, often delivered by different, also non-university institutions, but usually focused on only one type of degree after three, four, five, sometimes even six years of study. In other words, there was or is no second cycle or post-graduate education. Respective contents of an elsewhere post-graduate education are already integrated in a first-degree programme. Qualifications achieved, even at the level of the first and only degree, range from Bachelor to Master levels and often raise problems of comparability when related to the so-called Anglo-American system of higher education.

Strongly professionally oriented disciplines like engineering are characterized by a great diversity of profiles and degrees – even within a single country. In the parallel degree structures of continental Europe all these programmes and degrees in engineering claim to provide a professional education and award the title of engineer. Degree holders can thus work as professional engineers without any additional training or registration immediately after the first degree, at least in the country where the degree was obtained.

In the traditional two tier Bachelor/Master systems of the UK and Ireland employability is an aim also for engineering Bachelors after minimum 3 years of study, but to become a professional engineer with the respective title (Chartered Engineer or Incorporated Engineer) some years of Initial Professional Development (IPD) on top of a Bachelor or a Master degree are required before registration with one of the Engineering Institutions. In some contradiction to the two-tier reference structure of the Bologna Declaration the UK recently implemented integrated 4-years programmes in engineering leading directly to a Master of Engineering degree (MEng) with no Bachelor degree in between. This degree is now the compulsory minimum requirement and initial phase for the registration as a Chartered Engineer (CEng). The ordinary 3-year Bachelor degree is now a prerequisite for the registration as Incorporate Engineer (IEng). At the same time the USA continues to base its engineering education and professional licensing mainly on 4-year Bachelor degrees. The difference in course length arose in large part from differences in the secondary school systems.

For the creation of a European Area of Higher Engineering Education it is therefore a crucial question whether the existing diversity should be replaced by a common and strictly consecutive system of Bachelors and Masters degrees or whether another structure, e.g. a multi-level and multi-profile systems with a high degree of transparency, flexibility and mutual recognition would be more suitable. Whereas Italy already in all areas of higher education started to implement the two-tier 3+2 system, many other countries have started either to introduce Bachelor/Master programmes as complementary offers to the existing traditional degree programmes or to integrate additional degree levels into their existing systems and programmes. These strategies also include keeping existing long-cycle research-based university programmes leading directly to a Master degree as an option among others.

Tuning Higher Education in Engineering should therefore be more focused on defining adequate and comparable profiles and competence levels, on modularisation and a qualified system of transferable credit points, on output standards and assessment, than on the implementation of a rigid two-tier system. However, the advantages of a flexible system of undergraduate and post-graduate programmes have to be taken into account. With regard to the first cycle the central question will be what kind of undergraduate education will be needed to guarantee employability, professional standards and quality, a basis for post-graduate specialisation and life long learning, flexible profiling to satisfy different demands and students abilities and, last but not least, trans-national recognition and mobility.

3.3 Importance of learning to learn

As technology continues to develop at an increasing pace, certain "lifelong learning skills" are a prerequisite for every professional engineer. The must is to be fully effective "adult learners" able, fluently and without external direction, to:

- audit and assess what they already know and can do
- work out, at a level of detail that will differ from individual to individual, a career and a learning development plan
- integrate, into their learning, acknowledgement of their need for continuing *personal* development in the private as well as the professional realms
- understand the qualities of different kinds of knowing, of understanding, of skills, personality traits and attitudes; how these different aspects of competence inter-relate and reinforce each other
- reflect upon their experience, establishing links between different kinds of knowledge, and formulating relevant theoretical constructs to explain it
- conduct research into elements of professional practice and competence that lie within the context of their work, in pursuit of solutions to "problems of the day", personal professional development, and (more generally) the development of their profession.

In short, the adult learner knows *how to learn*. (A summary of some interesting theories about what is "learning" can be found in the Appendix.)

First-degree education should equip every graduating engineer with the foundations of these important life skills. It should be a goal of every professional's own lifelong learning to develop the full portfolio. By implication, it should be a goal of the engineering education system – including, in their various roles universities, trades unions, professional institutions, employers and government agencies – to teach the necessary skills and to facilitate individuals through the process, throughout their working lives. These same institutions should continue to support and encourage individuals to continue their learning in professional practice, though here the emphasis should primarily be on achieving learning from every opportunity that arises, rather than through attendance at formal courses.

3.4 Trans-national employability

Barriers to trans-national employability fall into two categories. On the one hand, the regulation of professions will demand that those practising the profession can demonstrate their competence, at least in a legal sense, by having the appropriate qualifications. The qualifications required usually include an academic degree, but may well include other certification. The legal framework varies quite widely throughout Europe, and also varies widely by industry. In general the Civil Engineering and Construction industries are the most strongly regulated, and Electronic Engineering the least. The European Union provides a general framework for trans-national recognition of professional qualifications. In principle a qualification gained in one country of the European Union (see also section 2.5) must be recognised in any other. Each country has a national authority the function of which is to manage and ensure this. An achievement of H3E, continued with the support of E4, was to promote the establishment of ESOEPE (the European Standing Observatory on the Engineering Profession and Education). Formally this body may not be needed, but it is already clear that far more exchange of information is required, both to make recognition easier within the current arrangements and to facilitate the evolution of new ways of expressing qualifications which will be more transparent.

Outside the legal framework the barriers to employability will be twofold. On the one hand, employers may have difficulty in recognising exactly what a particular qualification means, and in making an adequate comparison with those of their home country. On the other hand, there are many impediments to employees moving away form their home country.

It is possible that in the future the new two-tier education system recommended by the Bologna Declaration makes the difference between a Bachelor from a polytechnic and a Bachelor from an engineering university hard to understand in the labour market. Therefore the definition of goals of the education is extremely important.

The latter, the barriers from the point of view of the employees, are largely outside the scope of the educational system. What education can provide, through internationally oriented elements of the degree programmes are a stronger awareness of the opportunities abroad and a better capacity to adapt to living abroad, along with instilling the students with an open and flexible attitude to the world at large. Education can also (and usually does, apart from the English-speaking countries) give the linguistic capability for moving abroad.

On the employers side, there are, broadly, two categories of companies: firstly, those, which employ only one or two Professional Engineers, and a commensurate number of other technical staff, and, secondly, the rest. The rest here are usually large companies, where there is a Personnel Department. These larger companies appear to have little difficulty in recruiting staff with a plethora of qualifications; this is probably true even where new graduates are concerned, and much more true when considering applications from more experienced staff. The very small companies are thought to have more difficulty, but such companies are also less oriented to recruiting from a wide area. A further point concerns technicians and technician engineers. Here there seems to be less mobility and greater impediments. However, this aspect is outside the remit of this report.

4. The four lines of the Tuning project

4.1 Line 1: Learning outcomes

The demands on Engineering Education have seen remarkable changes during the past twenty years for a number of different reasons:

- The demand for more graduates in engineering resulted also in changing qualitative demands leading to a diversification of profiles because of different functions of engineers. Simplifying it can be said that first the demand for application oriented graduates increased, followed by a demand for engineers with an economical and management background.

- Technological development has led to a demand for competencies in new specialities like computer science, mechatronics, micro-technologies, bio-engineering as well as for system-oriented, often interdisciplinary, design abilities, taking ecological and ethical dimensions into account.
- Changes in organisation and work processes in manufacturing and services have lead to an increasing need for transferable skills in teamwork, communication and leadership.
- The rapid pace of technological and organisational change have resulted in the need for lifelong learning and self-management abilities enabling graduates to adapt flexibly to new requirements. The use of ICT's and open and distance learning for continuing education further emphasise these needs.
- Globalisation and internationalisation have created the need for abilities in intercultural communication and international project work,
- The expectations for an increased contribution of engineers to economic growth and welfare have raised the requirement on entrepreneurship abilities of graduates along with the promotion of scientific and engineering excellence.
- Finally, the need to attract more students of different background and abilities for engineering have raised the general demand for diverse and flexible programme profiles and learning arrangements allowing students to follow own interests and personal preferences in learning.

The diversity of these needs makes it difficult, if not impossible, to define a common requirement profile or general output standard for engineering graduates on a European level, and even more difficult to meet all the needs listed above. As national political, economical and cultural contexts still play a dominating role, the reaction to the changing needs has up to now lead to an increasing diversity of engineering education in Europe. However, as far as needs and not programmes deliveries and institutional backgrounds are concerned some general trends can be observed:

- an increasing need for transferable skills and competencies

- a stronger application orientation

- integrative approaches and system orientation in engineering design, with the inclusion of context dimensions e.g. economical, social, environmental, and ethical

- explicit and differentiated outcome orientation.

In order to influence engineering curriculum development and the teaching/learning practice the changing demands should not only be statements of various interest groups and stakeholders but must be part of a framework of regulations for programme design or accreditation. Most countries in Europe embody in law rules specifying what has to be fulfilled or achieved by the respective programmes mostly approved by government bodies. Accreditation as a procedure ensuring certain common standards of programmes, based on external assessment by an accreditation agency or by peers, is becoming common in ever more European countries. The procedures usually show a stronger influence of the engineering practice and profession in comparison to the role of academia and state government bodies.

Like the USA accreditation by ABET (Accreditation Board for Engineering and Technology) also in the UK the accreditation of engineering programmes is run by professional bodies, the Engineering Council and the Engineering Institutions. It is therefore more closely related to engineering practice than governmental approval procedures. In both countries accreditation is primarily concerned with the first-degree level (BEng or MEng, respectively). The recent new set of criteria and standards both in the US and in the UK indicate a trend switching from input to output orientation and require, besides a solid mathematics and engineering foundation, transferable skills and competencies.

The new German Accreditation Council and in particular the Accreditation Agency for Study Programmes in Engineering and Informatics (ASII), have been established to ensure a certain quality standard of the newly implemented Bachelors and Masters degree programmes. They explicitly address not only the first but also the second degree level and in addition the two different profiles at each level (practice and application orientation versus theory and research orientation). This approach with different profiles and types of graduates is new. The traditional German system has known only the two profiles of Fachhochschule Diploma Engineer (Dipl.-Ing) and University Diploma Engineer (Dipl.-Ing.) degrees, but each of the two types of institutions have offered only one level of (first) degrees. With the new sequential Bachelor/Master structure the question of levels has to be answered explicitly, and the relation between old and new degrees must be articulated. From the previous experiences in Germany it looks like the definition of the requirements on Masters level is less difficult than determining the first cycle degree level. From some experts point of view a Bachelors degree after three years of study in engineering does not satisfy professional demands; it should therefore be mainly a "pivot" leading into different Masters programmes or into a structured phase of Initial Professional Development rather than an exit level. In contrary to this opinion the German Frame Law requires all Bachelor degrees in general to focus on employability (Berufsfähigkeit) with access to Masters level programmes therefore limited and selective and not a necessary supplement to a Bachelors degree in order to achieve a basic level of employability. The same expectations seem to apply to the 3 years Laurea degree in the newly implemented system in Italy.

Since 1997 the UK has seen an attempt to define level descriptors in general, applicable to the whole education system including higher education. Besides sub-degree levels they determine the requirements not only for the three-years Bachelors degrees, but also for the four-years Bachelors with Honours and Masters levels. The general descriptors have been specified in subject-specific benchmarking documents, among many others also engineering. In a corresponding activity the Engineering Professors Council (EPC) is developing a list of Engineering Graduate Out-put Standards. This takes the form of a list of twenty-six "ability to" statements, which are expressed in generic non-discipline-specific terms. The standard is applied to a particular engineering discipline in two steps. The first step is of course to ask the providers to interpret the generic "ability to" statements in the context of the specific discipline. They then provide benchmark statements to describe the threshold level of attainment required for each ability. This outcome-oriented approach may well contribute to a more diversified solution for the European Area of Higher Education than a rigid 3 + 2 frame.

It is obvious that up to now significant differences concerning learning outcomes exist between sub-degree levels like the French IUT and the Greek TEI, now supposed to award bachelor level degree after some additions and changes, the new Italian Laurea degree after 3 years of study and the Fachhochschule type of degrees after 3,5 or 4 years of study. Some of the Fachhochschule degrees claim to be at MEng level rather than at Bachelor level and at the same time state that they represent a certain necessary standard for professional engineers. Regarding the learning outcomes it also has to be taken into consideration that the duration of studies is not a very valid indicator for learning outcomes as remarkable differences exist concerning selectivity and the entrance level to engineering programmes throughout Europe. This is another reason why qualified out-put standards and reliable learning outcome assessments are needed for a Bachelor at the end of the first cycle.

From a competitive global point of view competences and learning outcomes at the end of the first cycle for a professional engineer from Europe should not be lower than, but at least of comparable level to what is required for the USA ABET accredited Bachelors degrees. From a regional point of view and with regard to the idea of a flexible multi-level higher education system it may be also justified to continue with sub-degree levels or qualifications lower than this kind of professional Bachelor.

Accredited engineering programmes should therefore be *outcome oriented* and achieve the following qualification attributes or competencies*:

- an ability to apply knowledge of mathematics to engineering problems,
- an ability to design and conduct experiments, as well as to analyse and interpret data,
- an ability to identify, formulate and solve engineering problems,
- an ability to design a system, component or process to meet desired or customers needs,
- an ability to use the techniques, skills and modern engineering tools necessary for practice,
- an understanding of ethical and professional responsibility,
- an ability to communicate effectively,
- an ability to cooperate in multidisciplinary and international teams,
- a recognition of the need for and the ability to engage in life long learning,
- a broad education necessary to understand the impact of engineering solutions in a societal, economical and global context,
- a knowledge of contemporary issues.

Further considerations will have to fix the level of attainment up to which each of these competencies have to be achieved by the end of the first and of the second cycle.

* This list is similar to that of ABET.

4.2 Line 2: Knowledge - core curricula - content

There should be certain common standard on outcomes and qualification profiles, but the way a programme attempts to achieve these outcomes should be free and object of decisions of the higher education institution offering the programme. Therefore it can be questioned whether besides common outcome agreements also common core curricula and contents have to be defined. In some ways such attempts would be the continuation of traditional input-oriented approaches to curriculum design, accreditation and comparison, and would ignore the problem that with the rapid development of scientific and technological knowledge, it is difficult and risky to fix core contents in detail. It also limits the freedom for universities and faculty to decide how certain outcomes can best be achieved.

However, up to now it is still a widely used approach to start curriculum development with lists of subjects and contents and then to reflect on what kind of outcomes in terms of knowledge, understanding, skills and attitudes should be achieved in relation to these contents. It is also a widely shared opinion that there is or should be a certain common core of fundamentals in engineering, which should be a compulsory part of any engineering programme. It is argued that precise content lists facilitate mutual recognition and mobility of students. On the other hand they limit the flexibility and individualization of curricula and the profiling of programmes.

As pointed out the proposal put forward here starts from learning outcomes and core profiles from which the contents and appropriate teaching/learning arrangements are delivered. Nevertheless, it seems possible and helpful to complement the outcome oriented approach with input-oriented content decisions. This is even part of accreditation criteria particularly when it comes to subject area related specifications.

A less prescriptive approach is not to go into details of subjects and contents but to require certain shares of contact hours, credits or workload to groups of subjects. The German Accreditation Agency for Study Programmes in Engineering and Informatics, ASII, recommends that engineering curricula for Bachelors programmes should consist of at least:

20 % mathematics and natural sciences,
25 % engineering subject specific fundamentals,
15% specialisation in the chosen engineering branch,
10 % to 15% other than engineering subjects,

plus a minimum of 3 months for a final thesis and 3 months for practical training and internships.

ABET in its Criteria for Accrediting Engineering Programs at bachelor level specified the Criterion 4, which is addressing the Professional Component as follows:

“The professional component requirements specify subject areas appropriate to engineering but do not prescribe specific courses. The engineering faculty must assure that the program curriculum devotes adequate attention and time to each component, consistent with the objective of the program and institution. Students must be prepared for engineering practice through the curriculum culminating in a major design experience based on the knowledge and skills acquired in earlier course work and incorporating engineering standards and realistic constraints that include most of the following considerations: economic; environmental; sustainability; manufacturability; ethical; health and safety; social; and political. The professional component must include:

a) one year of a combination of college level mathematics and basic science (some with experimental experience) appropriate to the discipline
b) one and one-half year of engineering topics consisting of engineering sciences and engineering design appropriate to the student field of study
c) a general education component that complement the technical content of the curriculum and is consistent with the program and institution objectives.“

ABET does not specify in detail what is expected in each branch of engineering; for example for mechanical engineers it says:

> “The program must demonstrate that graduates have: knowledge of chemistry and calculus based physics with depth in at least one; the ability to apply advanced mathematics through multivariate calculus and differential equations; familiarity with statistics and linear algebra; the ability to work in

both thermal and mechanical systems areas including the design and realization of such systems."

These ABET determinations of compulsory core components and contents provide a flexible framework for a variety of different profiles, specialisations and modes of course delivery. So far many European approaches defining core components and contents tend to go much more into detail but they also often differentiate already during the first cycle between different profiles with a strongemphasis on mathematics and natural sciences in theoretically and research oriented programmes or with a stronger component of practical engineering in application oriented curricula. Most likely this diversity will continue to exist and will not be replaced by a common European Core for the first cycle, with diversity being offered only on Masters level or within other kinds of post-graduate degrees or qualifications.

4.3 Line 3: ECTS and beyond

Behind any credit transfer scheme is the idea that studycarried out in one (or even several) institution should be able to satisfy in part the requirements for an award at another institution. The development of the European Credit Transfer System is directed to satisfying a very clear need, as ever more students are spending part of their studies at other universities (and, in the vast majority of cases, in another country). A secondary use of a credit transfer system is as a means of comparing courses and, moreover, of comparing the quality of courses. Of course, the way that courses are built up, and marks awarded and combined to determine the final Diploma or Degree, are based in almost all institutions on a credit accumulation system, or on a system which is, in essence, a credit system, even though theword credit may not be used. It is only when transferability of credit is desired that all the implicit assumptions and compromises inherent in any academic system become apparent.

The basis of ECTS is that each course of study should be divided into a number of modules. The modules are at different levels, depending on where in the course they are normally taken. The most common pattern is for each level to correspond to a year of study, and for it to be necessary to have obtained credit in (that is, passed) a sufficient number of modules at a lower level before any modules at a higher level may be studied. Unfortunately, even at this point problems arise, caused by the fact that there exist quite different understandings and perceptions of what a module is. These range from a module being understood to consist of just a single normal lecture course or seminar to a module being a comprehensive learning arrangement embracing various teaching/learning and working activities, with their different course contents and targeted to a defined multi-dimensional learning outcome. A step forward, consistent with the thrust of much of the work in all Activities of the Engineering Thematic Network, E4, would be for the description of modules to be in terms of learning outcomes, rather than in terms of syllabus content. It may well happen that virtual university approaches and the development of world wide accessible learning software will contribute positively to an acceptable module and credit system.

The credit value of a module is a measure of the amount of study demanded. A crude measure is the number of hours of lectures or instruction given, perhaps expressed as the time spent in the classroom or the number of hours of contact with the teaching staff. A better measure, to be used within ECTS, is to focus on student learning and the overall workload for students, contact (teaching) hours then being only one factor in the estimate of workload. For lectures, for example, a 1-hour lecture might demand a further 4 hours of private study. A full year's study corresponds to 60 European Credits. Unfortunately, even with this measure of Credit (but there are yet other factors, to be discussed below), there are constraints to developing a generally accepted and satisfactory scheme of credit transfer and accumulation; such constraints are not engineering specific, but are of a more general nature.

1. The workload associated with 1 credit differs significantly throughout Europe: Some countries using ECTS tend to calculate 30 hours per credit, so 60 credits (a year's worth of study) corresponds to a total workload of 1800 hours, all examinations included. At the other extreme, in the UK, the total workload is only 1200 hours, calculated on the basis of 120 credits peryear, but only 10 hours of workload per credit. So, although 2 UK credits should be equivalent to 1 ECTS credit, this is clearly often not the case on a workload basis. Other countries like the Netherlands use to attribute 40 hours per credit equal to aone weeks workload. There is some consistency, in that the UK calculations also assume 40 hours work per week; however, in the UK the undergraduate academic is only 30 weeks long (the remaining 22 weeks are vacation, the greater part being in the summer). Moreover, in the UK the examinations are included within the 30 teaching weeks, whereas in some other countries the examinations are held outside the 30 teaching weeks.

Needless to add, the number of hours to be spent by the typical student in earning each credit is not scientifically determined, but is based on the estimate (guess?) of the lecturer giving the course.

2. The ECTS pilot project has tended to encourage a simple, mechanistic conversion between contact hours and credits by just using a specific factor - e.g. a factor 1.5 if 20 contact hours per week in a semester is to be worth 30 credits. Yet it is the experience of every academic that the demands made of a student vary widely between courses and between styles of teaching. The use of standard factors discourages serious reflection on these matters.

3. The award of Credits implies that the student has successfully finished a course or module, but that alone is rarely sufficient, even for the internal purposes of the institution, and certainly not for international transfer of credit. Further measures of the credit are needed, specifically (i) a measure of the quality of the pass, (ii) a measure of the place in the course, or the level, and (iii) a description of the course content.

Since there is already so much divergence on the matter of credit value, despite the fact that it is the measure which it would be expected would be most amenable to objective analysis and harmonisation, it might appear futile to discuss the other measures. Nevertheless, if a satisfactory transfer and accumulation scheme is to be devised, these other matters must also be resolved.

Even the level of study is not easy to define. Clearly any university will know at which stage (year) a particular module is usually given, but even this is rarely a sufficient specification, given the variations between countries, and even between institutions within a country, in the education preceding this stage. It is also sometimes the case that a module is taken by students at quite different levels - the outcomes may then be different, but in a certain sense all will be successful.

The measure of the success with which a student has completed a module is a further important factor in specifying the credit. We might refer to this as the "points value" or "mark" attributed to the credit, as opposed to its "amount" or "credit value". In a Grade Point Averaging scheme (the GPA used in the USA) the mark is obtained by multiplying the credit value by the points value, and aggregating the total; the average is then found by dividing the final total by the aggregate credit value. In ECTS the points value is defined by a letter (A is high, down to E, and F for failure to attend the examination) with the boundaries being expressed in terms of a supposed normal (Gaussian) distribution of marks. This appears to be objective, but transferability will only be practicable if the performance statistics of the class in the sending university are similar to those in the receiving university. Among the many problems are:

(i) In practice marks distributions are rarely normal, even in large classes,

(ii) Even in universities where there is tight control of the examination process, so that the mean marks for the different modules are consistent among themselves, the standard deviations tend to be much less well controlled,

(iii) The mechanism for calibrating one university against another hardly exists. Theoretically the system of external examiners in the UK, where each course in a university has in its panel of examiners teachers from other universities, ensures consistency, but there are few who believe that the worth of a Degree is independent of the University awarding it.

Despite the foregoing, it is relatively easy to perform the statistical calculations needed to generate ECTS points values. This is done in the Department of one of the authors (BM), where it can be shown that at least point (ii) above is satisfied.

However, because transfer both is wanted and already takes place, and because it must, therefore, be assumed that a form of ECTS will continue to be implemented more and more widely, some crucial questions should be studied and answered. First, should the requirements for first- and second-cycle degrees be expressed in terms of years of study or in credits? It may be that resolution of the problems of credit value will also provide the answer here, or it may be that there are other, more subtle factors to be considered. However, it should be noted that in some countries the discussion has already started on how to count intensified studies, with nearly no holidays, and whether to allow the accelerated collection of credits by individual students (as is quite normal in the USA, for instance). Second, should a first-cycle degree in engineering be specified as 180 ECTS credits, or should it really be more, Bologna notwithstanding? And, then, is a masters' degree achieved by an overall sum of 300 ECTS credits or can it be less? Another question is whether and how to recognise within ECTS credits gained by the accreditation of prior, informal and experimental learning, by open and distant learning, by continuing education or just credits by providers other than higher education institutions, even schools of the upper secondary level.

Up to now in engineering education not much open mindedness and trust can be observed. Change in this behaviour and in the administrative processes of student transfer will depend very much on whether the credit system can include not justa quantitative workload but also the additional dimensions.

4.4 Line 4: Methods of teaching and learning, assessment and performance

Methods of teaching and learning in engineering education are under pressure to adapt to new demands and learning resources. In due course the assessment methods are to be questioned and often need to be enhanced. Challenges and changes derive from:

- the general shift towards student learning, in other terms the shift from teacher centred delivery of content towards a learner centred process of achieving a wide variety of targeted learning outcomes;

- the increasing demand on engineering graduates raise better employability by acquiring more practical skills and particularly transferable key skills (or even competencies);

- the enrolment of students with a growing diversity in profiles and capabilities at entry level and with often quite different learning styles;

- the availability of an increasing range of e-learning facilities, requiring and encouraging flexible self directed student learning in different learning environments;

- finally, the modularisation of programmes with a focus on complex outcomes of modules in terms of abilities and/or key competencies.

Compared to other disciplines engineering education already in the past comprised quite a big diversity of teaching and learning situations. Besides lectures, labs and exercises usually practical work in internships in industry or in research projects and final thesis work belong to the methods employed. Reacting to the mentioned challenges the move towards "active learning" caused the implementation of problem based and project oriented learning, team work, international projects, communication and presentation activities, special forms of foreign language learning, collaboration with industry, web- and computer-based learning etc. The increasing variety of learning arrangements or situations reflect the fact that either different learning styles or, even more, the increased diversity of learning objectives require other and better matching approaches to learning and the achievement of diversified outcomes than just providing lectures and exercises.

How far certain learning objectives, in a European or national qualifications framework possibly fixed by output standards or benchmarks, are achieved by the enrichment of teaching and learning methods has to be proven by adequate assessment procedures. In a European framework of degree levels and credits it is an additional crucial question how assessment (and also grading procedures) must be designed to not only assign credits to workloads or programme levels to inputs but to provide comparable qualitative indicators of learning achievement.

For these purposes in engineering education an increased move towards outcome and performance related assessment concepts and methods is favoured in many higher education institutions as well as in national accreditation procedures and quality evaluations. This applies also for European Networks like the Socrates Thematic Network E4 but also ESOEPE and ENQUA. A satisfactory format applicable on a European scale does not exist yet but has seen some valuable contributions recently e.g. in the respective discussions in the UK, particularly with regard to qualification levels and output standards. However, output standards or accreditation criteria and standards may well express what kind of demands are explicitly taken into account and what kind of learning outcomes are expected.

Whether and to what extent these outcomes are achieved is an open question and has to be proved by different assessment systems and procedures. The first and most direct one is the examination and grading system, which has to be consistent with the intended outcomes on a certain level. In this area, there are significant differences across Europe, which cause quite some constraints for mutual recognition and mobility. Modularisation, common or at least comparable credit point systems, and the Diploma Supplement, which documents learning outcomes in detail, may partly overcome these differences.

A second approach of learning outcome assessment is incorporated in accreditation and external quality assurance evaluations on programme level. Recent developments with a big variety of outcome assessment methods in use prove that these external evaluations are quite effective with regard to programmes as a whole. But usually they take place only in regular intervals of 5 to 8 years.

A third approach is the assessment of individual capabilities and competencies, including the accreditation of prior and experiential learning. It extends normal higher education examination results in the direction of structured self-assessment and methods used in Assessment Centres, and culminates in learning outcome portfolios, individual qualification profiles or records of achievements.

Concerning the real learning outcomes of engineering education in Europe it is sometimes argued that despite all the diversity of traditions, institutional contexts and teaching/learning arrangements, the learning outcomes are already quite homogenous and comparable, at least at Masters level. This has not been proved in valid empirical studies, apart from some transnational comparisons of selected programmes in certain engineering subject areas, either organised as comparative surveys, e.g. in electrical engineering, or as part of a trans-national quality evaluation. Also some multinational companies employing engineers from many different countries provide anecdotal evidence confirming this assumption.

5. The doctorate level

The contents and organisation of doctoral studies falls beyond the scope of the Tuning project, but a few words about this aspect appear worth including. Doctoral students represents only a small fraction of the total number of students in Europe: less than a quarter of million compared with a total student population of over 14 million. Hence the justifiable fact that they occupy a small role within education programmes of the European Commission. On the other hand the question of doctoral programmes is of special interest for Higher Education in Europe because of its intermediate situation between education and research and because of the related issues coming from job market considerations. (See [5] for more information.)

Recently a project named TRENDS has been launched, jointly by the European Commission's Directorates General for Education and Culture (EAC) and for Research, aiming at exploring the situation of doctoral studies in five areas, corresponding to five existing Thematic Networks: Physics, Political Science, Women Studies, Humanitarian Studies, and Engineering. The DG EAC also supports a survey on national legislation and regulations of doctoral studies. The main issues to be addressed within TRENDS are: how to improve the quality and quantity of exchanges of students at doctoral level in Europe; how to improve the European dimension of doctoral studies; how to favour the development of doctoral studies in the context of the world-wide competition in higher education and research; how to improve the integration of doctoral students in the labour market, both national and European. The heterogeneity of national systems of doctoral studies and of the situation with respect to the job market in different European countries has been observed. A more complete picture will be achieved through an ad-hoc questionnaire survey, which will be circulated within existing Thematic Networks. First results are expected for the autumn of 2002.

6. Continuing education and lifelong learning

6.1 Continuing professional development

When formal education is complete the engineer embarks on professional life, in a majority of cases as an employee of a company. From this point onwards the individual's most important life-skill is commitment. This is truer now than ever before, as individuals must maintain their employability in an open mobile world that is changing rapidly around them as technology advances and as business practices evolve. Their primary source of new knowledge and new competences is no longer formal instruction by experts; professionals rather learn through their activity in and beyond the workplace.

In this context adult professionals learn and develop in response to the current and anticipated future demands of their work, their employer's and their own ambitions. This is an untidy world, which is neither formal nor coherent, but it is the environment in which a professional lifetime's learning must take place. An individual's continuing education cannot be based on formalized curricula – it must respond to change and, where possible, anticipate it. Working engineers need to be able to specify precisely the content of what they learn, and how they learn it, if they are to take the maximum advantage of the limited time available.

Continuing professional development is a matter of acquiring specific knowledge and skills as and when these are needed. There is no place here for the ideal prescriptions of a syllabus or a timetable, and there is little place for the formal teaching style. Adult, experienced professionals expect to participate, to learn by doing, researching and contributing, by applying knowledge, know-how, and skills.

It is difficult to envisage a wholly coherent approach to lifelong learning, or to education and training in the workplace, nor can this be considered desirable given the diversity of needs and the rapid pace of change. Any such attempts will fail, except in closely defined professional or corporate environments that are deliberately isolated from change.

Although learning at work is by far the most important component of professional development, because the focus of the Tuning project is on educational structures in Europe, we concentrate here on continuing education and professional development from a university perspective. For a more detailed discussion of lifelong learning in the corporate context, see the “Call to Action” report of the H3E project [3].

6.2 Professional competence

The educational deficit in European countries, at least as concerns economic performance, does not rest with the young who are still in schools and universities, but with those who have passed – or in some cases fallen – out of the educational system: the huge numbers of workers, professionals and managers in early and mid-career, and those who have never made it to the bottom rung of the ladder. The deficit is exacerbated by a failure to pursue structured professional development beyond the formal qualification stage.

Everyone is uncomfortably familiar with the increasing gap between the rate of learning and the rate of forgetting. We forget from the moment we leave the examination hall, but even faster is new knowledge accumulated within the research and industrial communities of the globe.

Knowledge forms only a part of the professional tool-kit. Universities have traditionally been good places to teach basic knowledge and understanding, but they have been much less good at teaching *professional skills* or *know-how*. These are best developed through practice, at work, and most effectively when there is in place a support system; where older, experienced people take a professional interest in the development of young professionals, and where mechanisms are in place to ensure that an individual continues to acquire the intellectual frameworks that are essential to understanding, in pace with the growth of their professional know-how and competence.

As professional competence and know-how develop, so an individual is ready for promotion and greater responsibility, which in turn requires an ever-increasing fund of knowledge and a broad range of understanding across discipline boundaries. Senior people operate in an interdisciplinary environment, where they make more use of the competences of critical thinking and creative response than of their basic technical knowledge.

At school or at university this broad context-related knowledge has little relevance to the individual’s life experience, and, even if taught, would be very imperfectly understood and remembered. It needs to be acquired stage by stage, as needed in the context of the individual’s own aspirations and in the relevant organizational context. Nevertheless the foundations for this broader range of educational and competence accomplishments need to be laid during formal education.

6.3 University-based continuing education

Universities currently have only a limited role in the post-degree development of professional engineers. For the health of the entire system, it is vital that universities should play their small part *fully*, rather than not at all.

If universities neglect to seek ways of engaging with the learning of professionals beyond graduation, they will by default be accepting a role that ends at a relatively early stage in the professional development system. They can expect, over time, to lose their pre-eminent status to other institutions that will come to be seen as having authority in the field of higher professional development.

In response to this observation, some universities have already begun to customize Master’s programmes to individual students’ requirements. Some provide extensive mentoring services for professionals in industry, helping them plan and reflect upon their learning. Others encourage practising professionals to register for part-time research degrees.

The role of the academic institutions in continuing education has increased, but possibly not so fast as other kinds of organization have in this area. If universities wish to be engaged at a strategic level with companies in professional education and the management of knowledge, they must put in place structures and processes to promote and manage their relationships with those companies.

Much research conducted by companies is directed towards specific development. University research is mostly in longer-term scientific subjects, but is often carried out in collaboration with companies. However, these distinctions are becoming less clear. Today knowledge-based competition is so intense that companies often outrun universities in the scope and pace of their technological and scientific advance. They may employ a greater number of high-calibre professionals and they often have greater resources at their disposal.

One of the main contributions that university research performs for society is therefore, and always has been, to work on complex and diverse subject matter, codifying and reducing it to patterns that are comprehensible, recognisable, and teachable. Research of this kind contributes as much to understanding as to new knowledge.

University teachers can communicate new knowledge and teach new skills, but more importantly they can also help professionals to learn from their own experience.

Professionals who are seeking to become fully-effective "adult-learners" need to become competent in these processes, to become researchers into the professional concerns of their day, and thus steer their own development, play a leading role in shaping their profession and drive forward the competitiveness of their organisations. The essential processes here are research, scholarship and reflection. These are precisely the techniques used by academics in their own work.

Helping professionals to learn from experience creates a new role for university teachers in continuing education: the *facilitation of learning*. This is different from teaching, but complementary to it. It is a different, peer-to-peer relationship that is entirely consistent with the interaction of expert academic with expert professional.

6.4 Standards and accreditation

In spite of the many differences in initial engineering education across Europe, the overall picture is still uniform when compared with learning after graduation. The universities of Europe educate engineers of comparable knowledge and qualification. In the informal and unstructured world of lifelong learning there are no standards, no systems, and little comparability. And yet, as we have seen, the knowledge and skills acquired in this fluid environment are likely to be the most valuable that individuals acquire during their professional lifetime.

What can be done to give prospective employers – and engineers themselves – some benchmarks for evaluating the learning achieved, post-experience? Two main suggestions have been repeatedly put forward: the accreditation of continuing education courses and providers, and the introduction of new qualifications. Both approaches have their difficulties.

Proponents of accreditation believe that a system would accelerate the adoption of shared standards, and guarantee consistent quality. Accreditation becomes appropriate when there is consensus on the nature of the system being accredited:

- the definition of learning objectives
- the provision of learning opportunities (e.g. courses)
- the assessment and quantification of learning outcomes
- the award of credit/qualification in recognition of learning achieved against the objectives.

This is the case in initial education, but in continuing education there is no consensus within Europe on a system to be adopted for these important elements. Although there are various initiatives for providing post-experience education and development in some countries, there are no comprehensive structures and systems for continuing education in professional practice that can compare with those for initial education and qualification.

Although the traditional "gatekeepers" of the profession (professional institutions or universities) have an important role to play, they are not the key players and should not be allowed to design and control any universal system of accreditation. The key players are the engineers themselves and their employers. The concerted voices of the engineers are rarely heard and companies can rarely be persuaded to speak in unison. Any attempts to establish an accreditation system without the considered support of these representatives of the industrial community will not be worthwhile, and could even lead to the evolution of unhelpful restrictive practices.

One further objection to any general system of accreditation is that such a system would suggest that “courses” are the key ingredient of continuing professional development. However, courses are only a very minor feature, dwarfed in importance by the potential of the many other forms of professional learning.

6.5 Qualification and credit in continuing education

Systems of qualification have been proposed as the means of measuring lifelong learning achievement. Supporters of this idea have suggested either modifying existing qualifications or creating completely new ones. But qualifications are not necessarily an indication of the amount of learning achieved or of its effectiveness. Universities have often assumed that the solution is simple: create an academic credit system, and encourage people to attend a large number of courses. However, this is not an approach that can provide good linkage and reinforcement between what is learned in class, and its application in practice. A further difficulty is that development needs are individual, and the solutions need to be tailored to these individual needs. One size does not fit all.

Diplomas and degrees symbolize the completion of a course, whereas continuing education is by definition never completed: it is lifelong learning, there is no end. As individuals acquire additional responsibility and as their professional compass expands, the learning agenda expands exponentially, while time itself becomes more precious. If there are to be qualifications for lifelong learning they should be printed using fading ink ink that becomes invisible after two years or so, requiring an individual to engage in a continuous process of updating and development to keep the ink fresh.

There is, however, a niche market of continuing education courses with objectives similar to that of traditional diplomas and degrees: preparing for a specific job, task or specialization within a profession. We argue for maintaining the flexibility of extent of these qualifications, but recognize the merit of articulating their scope and content within the general qualification framework. But as the Bologna Declaration only indirectly addresses lifelong learning there is a danger that qualifications-oriented continuing education on university level will be further marginalized.

We have suggested that a system of formal qualifications cannot provide the general infrastructure of common language and practice in lifelong learning across Europe. Nevertheless, a flexible system of recording learning, which can be interpreted quantitatively by institutions for the award of credit towards additional qualifications, has potential as a motivator.

Credit systems traditionally tend to measure educational inputs (volume and level of teaching), though an increasing number are sensitive to outputs (achievement against expected learning outcomes). Volume tends to be indicated in terms of hours of study. The ECTS, for example, encourages course providers to offer credit for course modules that can, in principle, be accumulated towards a qualification. To achieve this, the individual registers with a recognized institution, negotiates the acceptance of their existing credit towards the qualification, and then takes a variety of course modules to make up the deficit. It is notable that this facility, which is increasingly being applied by universities across Europe, has had little impact on continuing education practice.

An academic institution may allow exemption from part of the formal requirements for a programme, by giving the applicant credit for “prior learning”. The valuation of credit might be on acceptance of credits issued by other organizations (accreditation of prior learning, APL) or based on evidence of the learning achieved through experience (accreditation of prior experiential learning, APEL). The volume of APL credit accepted by an institution towards its qualifications depends very much on its assessment of the status of the institution(s) that awarded the credit.

The negotiation for incoming credit may take many possible forms, but normally good practice demands that the individual has to fit into one of the following categories:

- Curriculum-based qualifications: Credit is only given if the learning can be shown to be relevant to an established course curriculum.
- Individually tailored curriculum: The applicant may put forward his or her own learning plan as an alternative to any established course curriculum. The institution (university or other), considers whether the plan is of sufficient calibre, coherence and weight. If it is so persuaded, then it agrees to accept the personalized curriculum, and judges APL and APEL for credit against it. This kind of individually negotiated qualification is only available from a small number of universities, but the number is growing, and we welcome this trend.

In both of these categories of learning programme the key considerations are: content (learning outcomes), level of achievement, volume of learning, and assessment strategy (evidence of learning achieved). An institution considering an individually tailored proposal will also need to be convinced that it can offer appropriate support for the learner.

Credit has no absolute value. Just as the US dollar is accepted everywhere, whereas the Tanzanian shilling is accepted less universally and with less enthusiasm, credit from some institutions is more convertible than from others. Credit is “in the eye of the beholder”.

6.6 Recording professional achievement

We have looked at qualifications and credit, and concluded that neither can offer the necessary common system for communicating what a professional has learned. What are the features of a system that can attribute an agreed value to learning achieved? We suggest that to be acceptable and effective a system must be:

- flexible, as professional lives are subject to rapid unpredictable change;
- open-ended, with no suggestion that learning has been completed: any qualification must require continuous renewal;
- responsive to the real nature of professional learning that is largely achieved through experience in and through work;
- able to meet the needs of the various key stakeholders.

An international system must be relevant and useful to the individual. It must help with the planning and recording of learning. It must be relevant to the employer for recruitment, promotion, and managing staff development. It must add value to professional institutions for recognising increasing professional mastery. Finally it must be applicable to universities for the award of academic qualifications.

Differences between awarding institutions and between countries will continue to rule out a common credit system for continuing education until there is some accepted method for evaluating the learning outcomes: for describing learning and the means by which it has been acquired.

We may conclude that we need a system for recording learning, however achieved, in such a form that any of the key players could make use of the data for recognition within their own credit or qualification systems. We believe that this will be best achieved through a neutral medium such as a *Record of Achievement*. Such a tool can support the capturing and recording of learning, without trying to attribute any value or measure to it. It leaves users freedom to decide for themselves the important question of what form of assessment strategy to adopt in each different circumstance: if they want hard evidence for external purposes, then rigorous external validation and certification of their abilities will be relevant, whereas if the purpose is to self-monitor progress against a development plan, then self-assessment will be satisfactory.

Universities and other providers of continuing education can play a key role in offering and supporting such a tool for planning and recording professional learning. They can, for example, offer support for developing learning plans, or provide mentoring support for reflecting on and capturing the learning achieved.

7. Some recommendations for tuning tools

7.1 General aspects

This Report has put in evidence that a great variety of routes to the formation of engineers exists in Europe, not only from country to country, but also within the same country. In the last few years, two phenomena in apparent contrast have been noted:

- on the one hand, an increased de-regulation and the need for more engineering graduates tends to lead to an increase in the variety of the educational offer;
- on the other hand, the creation of the “European Higher Education Space”, strongly supported by the policies and efforts of the European Commission and the “Declarations” of the Education Ministers (Sorbonne, Bologna, Prague), favour an increased “harmonization” of the European educational structures, in engineering as in other disciplines.

To pursue this “harmonization” while avoiding to turn it into a “cage”, the means to follow are not strict rules for educational programmes, but rather appropriate procedures for quality assurance and accreditation of courses: in this way, engineering education will be improved, academic degrees and professional qualifications granted in one country will be easily recognized in other countries, and the transnational mobility of engineers will be ensured.

In working towards the creation of a European Higher Education Area, it is crucial to recognise that specific characteristics of engineering education, which reflect, on one hand, the needs of European industry, and on the other hand, the special nature of scientific and technological studies.

Providing highly qualified engineers able to contribute to the technological progress through their leadership in research and development activities is vital for the economic competitiveness of Europe. The education of these engineers needs to be based on a scientific oriented curriculum. The first degree qualifying for this kind of professional activity should correspond to the second-cycle (Masters) level. The economy also demands graduates from practically oriented engineering studies lasting for three to four years with a first-cycle (Bachelors) degree, the specific qualities of which must be appropriately recognised.

Many thinks that within the two-tier structure envisaged in the Bologna Declaration, we should maintain the option of 5-year integrated programmes (exceptionally 4-year) spanning the first and second cycles and leading straight to a Master Degree in Engineering. This should be possible without the mandatory award of an intermediate professional degree. The creation of new Masters programmes of between one and two years duration should also be encouraged: Universities should be fully allowed to set their admission criteria for entry into the second cycle.

To achieve this, all parts of the educational system need to be moving in the same direction. Thus it is very important to ensure the greatest dissemination possible for Tuning results/documents. As far as engineering is concerned, this can be obtained through the existing Thematic Networks (EUCEET, E4, and others) as well as through the associations involved (SEFI, CESAER, BEST, FEANI, CLAIU). Given the role that Promoters of E4 Activities have played in producing this report, and as a first step in its dissemination, this document is also downloadable from the E4 web site, www.ing.unifi.it/tne4.

7.2 Attributes and Qualification Profiles

It is essential that each “type” (i.e. "short-" and "long-cycle") and “branch” of engineering qualification can be easily recognised, including its appropriate differences. This requirement is not satisfied by most existing national systems nor by the FEANI Register, which set only minimum standards.

To further this goal, the emphasis in the programme requirements need to be shifted from the way in which the programme is structured and delivered, i.e. from prescriptions concerning the curriculum, to requirements on its “final product”, i.e. on the “competencies” acquired by its graduates. This shift will also turn the great diversity of educational systems throughout Europe into an asset of, instead of being an obstacle to, mutual recognition.

The maximum *transparency* of course objectives and contents is a prerequisite for pursuing this objective: each educational institution must provide complete information about itself and its degree programmes. In other words, the type qualification profile produced by each engineering degree programme must be articulated. Each engineering education provider will have to demonstrate which qualification profiles of engineers they have defined and which they produce.

Both academic and professional recognition will benefit from this increased transparency, covering not only structures and input data but also concentrating outcomes and qualification profiles achieved through initial and continuing education as well as professional experience.

Making this information available and easily understandable is a problem in itself: a “common language” is needed to describe educational outcomes or qualification profiles in engineering. It could also be a basis for internal or external assessments employed to ensure adequate recognition as well as quality maintenance and improvement [8].

The tools to pursue this aims might be differentiated lists of “qualification attributes” for engineering education and professional practice, including a categorisation of “types” and "branches" (specialisations) and specifications of levels at which certain attributes must be achieved. These lists should be based on descriptions of aims and objectives of the various programmes and profiles of engineering education, performance records, outcome-oriented criteria and standards of accreditation procedures and competence-oriented assessment approaches. These lists should form a *two-dimensional grid* of Engineering

Qualifications, taking into account both academic (and non-academic) *education* (and where relevant, including *continuing education*) and professional *experience and training*. The columns of the grid should correspond to different "*types*" of qualifications, and lines to the different *branches* of engineering.

It worth noting that, in order to be accepted by a British Chartered Institution, i.e. before full professional qualification, a period of acceptable engineering experience after the achievement of the academic requirements is necessary. Although this requirement appears logical (some experience "on the field" is normally required for the legal, medical and other professions, before the licence to practice a profession in full autonomy is granted), for engineers this seems to happen only in the British system and for the FEANI Eur Ing Register: even ABET accredits only educational programmes and completely neglects external training and professional experience. Also in the examinations required by some European countries for granting professional qualification, field experience does not appear to play any significant role. A study and a definite proposal on this point might be another appropriate "tuning" tool. Finally we should distinguish general employability from professional employability. The Bachelors level needs not necessarily qualify for professional employability.

7.3 Quality assessment and recognition

A pre-requisite for mutual recognition of engineering degrees across Europe is undoubtedly the "accreditation" of the courses of study. It is, however, unrealistic to suggest any form of overall European accreditation system, at least for the time being. The best way forward is a bottom-up approach to promote and facilitate increasing contacts and agreements between national bodies, in order to build up gradually a consensus, perhaps starting with mutual recognition of accreditation bodies, and agreements between countries of similar systems and cultural background. In the end, the system might look more like a European "Washington Accord" than a "European ABET".

A step in this direction has been the establishment of the "European Standing Observatory for the Engineering Education and Profession" (ESOEPE), which *"is intended to build confidence in systems of accreditation of engineering degree programmes within Europe"* and not *"to harmonise engineering programmes nor accreditation procedures, but simply to assist national agencies and other bodies in planning and developing such systems"* and to *"facilitate systematic exchange of know-how in accreditation and permanent monitoring of the educational requirements in engineering formation".* An effort to enlarge ESOEPE to all European countries is suggested as a significant "Tuning" tool.

It should be underlined that accreditation is useless, even counterproductive, if based only on formal requirements and not strictly connected with a process of quality assessment and quality assurance. In many European countries this is ensured by a quality assurance procedure, allowing higher education institutions to validate the learning opportunities they offer; and supported by a quality assessment body, managed either by the competent government body, by professional associations, or by both.

In Italy, a Pilot Project to assess and "accredit" University courses (including, but not limited to, engineering "Lauree") has been started. A significant "Tuning" tool would be to introduce similar accreditation structures in the few remaining countries that do not yet have such systems.

Whatever the future steps in this matter, the engineering leadership organisations of Europe, both educational and professional, should play a formal role in the development of accreditation, quality assurance and recognition at a European level.

7.4 Credits and quality level

If the system ECTS should become a system ECAS (for European Credit Accumulation System) then there are two essential additional descriptors which are needed. One should introduce a label to describe the "level" of the course unit, such as: B for basic or introductory course (e.g. Fundamental of Computers or Calculus), A for advanced or intermediate course (such as Electrical Network Theory or Automatic Control), S for specialised course (such as Software Engineering). The other label should describe the "type" of relation of the course unit to the discipline itself, for instance: C for core or major course unit (i.e. belonging to the discipline), R for (closely) related course unit (e.g. some fundamental mathematics course for engineering), M for minor/optional. With these additional descriptors a course such as Automatic Control offered for students in Electronic Engineering would be labelled having perhaps 7AC credits, meaning that it is advanced and belonging to the core of the curriculum.

Another element to add is the measure of the success with which the student has satisfied the requirements of the examination procedure. Without repeating in detail what already illustrated in section 4.3, a system similar to the GAP adopted in many U.S. Universities could be considered satisfactory. A more sophisticated way to measure learning results would obviously welcome, and in some occasions considered necessary, however it appears difficult to arrive at this result without augmenting substantially the cumbersomeness of the procedure. This is not meant to discourage from using, say, something similar to the Diploma Supplement in order to provide further information. It only suggests that its use will probably be limited to those cases where deeper analysis is mandatory.

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Appendix: what is learning ?

Traditionally, many educators have considered learning to be an individual responsibility with students accepting the burden of acquiring knowledge and expertise. Recently, the notion of collaborative learning has been strengthened, from a number of sources. These include communicating with other students and tutors across a network in the domain of distance learning. Digital communications networks such as the Internet or the use of e-mail facilities have become the new medium in which group learning is anticipated to take place, and many large businesses have already built internal group learning systems using Internet.

The reader probably knows what learning means. It is, nevertheless, still worth defining it in the present context. Surprisingly little is known about how people actually learn, though there are a number of theories; so it is perhaps easiest to define learning "after the event" by asking how you know whether or not learning has, in fact, taken place. You know that learning has taken place, when you know something which you did not know before and can show it and/or you are able to do something which you were not able to do before. You will notice that in both cases you are required to offer proof. Thinking that you know something or can do something is not enough; you must be able to show that you know it or are able to do it.

In the same way, it is not sufficient to know the theory; you have to be able to prove that you know it by your actions. This ties in directly with Action Learning, where you are required to apply theory and concept to real situations.

There are several schools of thought and theoretical models of how people learn. One of the most useful for adult learning has proved to be that initially developed by David Kolb [10]. In it learning is presented as a cycle.

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Although, hypothetically, a learner would consciously move through every stage in the cycle in every learning situation, practical experience and research show that not all learners are equally at home at all stages of the cycle. Many show marked preferences for one or more of the stages and sometimes positive dislike of one of the others. And there is no evidence to show that such preferences make them better or worse than one another.

Honey and Mumford [11] have identified four different preferences, or ways in which people prefer to learn, each related to a different stage of the learning cycle. These preferred "learning styles" they call Activist, Reflector, Theorist and Pragmatist. Some people are happiest operating in just one mode, others in two or even three. Perhaps not surprisingly, people's learning style tends to reflect their work style... or vice versa.

Activists
Activists involve themselves fully and without bias in new experiences. They enjoy the here and now and are happy to be dominated by immediate experiences. They are open-ended not sceptical and this tends to make them enthusiastic about anything new. Their philosophy is "I will try anything once". Their days are filled with activity. They tackle problems by brainstorming. As soon as the excitement from one activity has died down, they are busy looking for the next. They tend to thrive on the challenge of new experiences but are bored with implementation and longer-term consolidation. They are gregarious people, constantly involving themselves with others but in doing so; they seek to make themselves the centre of all activities.

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Reflectors
Reflectors like to stand back to ponder experiences and observe them from many different perspectives. They collect data, both first-hand and from others, and prefer to analyse them thoroughly and think about them from every possible angle before coming to any definite conclusions. These they postpone as long as possible. Their philosophy is to be cautious. They enjoy watching other people in action and prefer to take a back seat in meetings and discussions. They think before they speak. They tend to adopt a low profile and have a slightly distant, tolerant, unruffled air about them. When they act, it is part of a wide picture, which includes the past as well as the present and others' observations as well as their own.

Theorists
Theorists like to analyse and synthesise. They assimilate and convert disparate facts and observations into coherent, logical theories. Their philosophy prizes rationality and logic above all. They think problems through in a vertical, step-by-step, logical way. They tend to be perfectionists who will not rest easy until things are tidy and fit into a rational scheme. They are keen on basic assumptions, principles, theories, models and systems thinking. They tend to be detached, analytical and dedicated to rational objectivity. They feel uncomfortable with subjective judgements, ambiguity, lateral thinking and anything flippant. Theorists learn best when they are offered a system, model, concept or theory, even when the application is not clear and the ideas may be distant from current reality. They like to work in structured situations with a clear purpose, and be allowed to explore associations and interrelationships, to question assumptions and logic and to analyse reasons and generalise. They like to be intellectually stretched.

Pragmatists
Pragmatists are keen on trying out ideas, theories and techniques to see if they work in practice. They positively search out new ideas and take the first opportunity to experiment with applications. They are the sorts of people who return from management courses bursting with new ideas, which they want to try out in

practice. They like to get on with things, and act quickly and confidently on ideas that attract them. They tend to be impatient with ruminating and open-ended discussions. They are essentially practical, down-to-earth people, who like making practical decisions and solving problems. They respond to problems and opportunities "as a challenge". Pragmatists learn best when there is an obvious link between the subject matter and their current job. They like being exposed to techniques or processes which are clearly practical, have immediate relevance and which they are likelyto have the opportunity to implement.

Engineers fall into these last two categories, they like to analyse and synthesise. They assimilate facts and observations into coherent, logical theories and they are also pragmatists since they always are keen on trying out theories and techniques to see if they work in practice since the main objective of an engineer is to make things work efficiently.