A TUNING-AHELO CONCEPTUAL FRAMEWORK OF EXPECTED/DESIRED LEARNING OUTCOMES IN ENGINEERING

Introduction

The OECD has taken the initiative for a feasibility study for assessing student Learning Outcomes for Higher Education. According to the OECD this "Assessment of Higher Education Learning Outcomes (AHELO) is a ground-breaking initiative to assess Learning Outcomes on an international scale by creating measures that would be valid for all cultures and languages". The initiative should be understood against the background that more students than ever participate in Higher Education degree programmes. At the same time society in general and the employability field undergo rapid change. While many traditional jobs disappear or change in content and form, new jobs come into being. Both require new knowledge and skills. As an effect these developments require changes in the way education is offered and perceived. Higher Education institutions all over the world are expected to respond to these demands. The HE sector is well aware of the fact that it has a responsibility to prepare their graduates for citizenship as well as for a dynamic job market. The HE graduates are expected to be flexible, internationally oriented and willing to keep up-to-date in a Life Long Learning context.

The AHELO feasibility study contains four complementary strands for assessment: generic skills or transferable competences, discipline-related competences, contextual related factors (input, process and outcome) and value-added elements. This report is related to the second strand. To test the possibilities and practicality of the approach two subject areas have been identified by the OECD-AHELO team for the project: Engineering and Economics[1].

***

At present Higher Education institutions, encompassing research universities, universities of applied sciences (polytechnic schools) as well as colleges, are undergoing a transformation process. The traditional 'staff-centered' and 'knowledge-oriented' approach is slowly giving way to degree programmes which take the student as the centre of the teaching and learning process. In practice this implies that, besides knowledge acquisition, more attention is given to the application of subject-specific skills as well as to general academic skills. The aim is to make students as competent as is feasible in a given timeframe for their future role in society, by differentiating the educational offer and by making optimum use of the interests and capabilities of the students. In these programmes the focus is on competence development and the achievement of so-called intended, expected or desired Learning Outcomes of the learning process.

Since 2001 a methodology has been developed – originally in the framework of the European Bologna Process[2] – by a large group of universities and their departments united in the initiative *Tuning Educational Structures in Europe*[3], to the challenges indicated above. From its launch, Tuning has been strongly supported – financially and morally – by the European Commission.

Tuning is a university driven initiative, which was originally set up to offer a concrete approach to implement the European Bologna Process at the level of higher education institutions and subject areas. The name *Tuning* was chosen to reflect the idea that universities do not look for uniformity in their degree programmes or any sort of unified, prescriptive or definitive curricula but simply for points of reference, convergence and common understanding. Tuning avoids using the expression of subject area 'standards' due to its connotation in many higher educational settings of a straitjacket although it acknowledges that in other countries the expression is understood differently. Anyhow, the protection of the rich diversity of higher education is paramount in Tuning. In no way does it seek to restrict the independence of academic and subject specialists, or undermine local and national academic authority.

The Tuning approach consists of a methodology to (re-) design, develop, implement and evaluate study programmes for each of the Bologna cycles, which are the bachelor, master and doctorate. It can be considered valid worldwide now, since it has been tested in several continents and found fruitful. In 2007 the Tuning approach was validated both as a methodology and as an application at subject area level by groups of high level peers for a range of disciplines. It is applied now in more than 30 subject areas, in a large number of institutions spread over nearly all European and Latin American countries as well as some countries in Asia. In other regions of the world, awareness has been raised about the Tuning approach. At present, the Tuning methodology is tested in three US states[4].

Furthermore, Tuning has served and is serving as a platform for developing reference points at subject area level. These are relevant for making programmes of studies comparable, compatible and transparent. Reference points are expressed in terms of Learning Outcomes and competences. Learning Outcomes are *statements of what a learner is expected to know, understand and /or be able to demonstrate after completion of a process of learning.* According to Tuning, Learning Outcomes are expressed in terms of the *level of competence* to be obtained by the learner. Competences represent a dynamic combination of cognitive and meta-cognitive skills, knowledge and understanding, interpersonal, intellectual and practical skills, and ethical values. This definition is in line with the international ISO 9000 norm which defines competences as "demonstrated ability to apply knowledge and skills".Fostering these competences is the object of all educational programmes, which build on the patrimony *of knowledge and understanding* developed over a period of many centuries. Competences are developed in all course units and assessed at different stages of a programme. Some competences are subject-area related (specific to a field of study); others are generic (common to any degree course). It is normally the case that competence development proceeds in an integrated and cyclical manner throughout a programme. Tuning has organized several consultation processes including employers, graduates and academic staff / faculty and students in different parts of the world to identify the most important competences that should be formed or developed in a degree programme. The outcome of these consultation processes is reflected in sets of reference points – generic and subject specific competences – identified by each subject area.

According to Tuning, the use of the Learning Outcomes and competences approach implies changes regarding the teaching, learning and assessment methods which are used in a programme. Tuning has identified approaches and best practices to form specific generic and subject specific competences. It has also raised awareness about the feasibility of Learning Outcomes by relating the Learning Outcomes approach to student work load. In this respect, Tuning has played a major role in transforming the European Credit Transfer System, in the *European Credit Transfer and Accumulation System (ECTS)* a system based on these two elements.[5]

Finally, Tuning has drawn attention to the role of quality in the process of designing or re-designing, developing and implementing study programmes. It has developed an approach for quality enhancement, which involves all elements of the learning chain. It has also developed a number of tools and has identified examples of good practice, which can help institutions to boost the quality of their study programmes.

The assignment given to the Tuning Association by the OECD-AHELO project has been to define a conceptual framework of expected/desired Learning Outcomes in Engineering and Economics following the Tuning approach. This document offers the framework for **Engineering**.

This framework is intended to be used as a basis for the design and development of (an) instrument(s) to measure / to assess the performance of students which are close to obtaining their first (cycle) or bachelor degree. This assessment should provide high-quality data which can be used for enhancing the quality of higher education programmes throughout the world. The report, in which this framework is presented and explained, is based on the following structure:

1. The field of Engineering and Engineering education explained
2. Overview of typical degrees offered in the subject area of Engineering: orientation and application and main sub-fields or specializations

3. Overview of typical occupations of engineers, with a first-cycle (or bachelor) degree and a second-cycle (or master) degree
4. Learning Outcomes, (cycle) level descriptors and Qualifications Frameworks
5. Overview of prior work on the Learning Outcomes approach in the field of Engineering
6. Clarification of the approach used and an introduction to the defined set of Learning Outcomes statements
7. Overview of agreed Learning Outcomes statements
8. Learning Outcomes for a selected number of branches of Engineering
9. Required new approaches regarding learning, teaching and assessment in the field of Engineering
10. Concluding remarks
11. References
12. Membership of the expert group Engineering

Defining this conceptual framework has been the responsibility of a group of experts. This group was composed with great care. Beforehand, it was agreed that the group should cover a range of continents and some thirteen countries, as well as different specializations and branches of engineering. These experts should have a good overview of the field as well as the issue at stake. A distinction was made between full members and corresponding members. The difference between the two is that the full members actually met in Brussels on the 4th and 5th of May 2009 to discuss the report. Both full members and corresponding members have received all documents and were invited to reflect and advice on all materials and drafts.

To establish the experts' group for Engineering contact was sought with representative organizations, that is for Europe FEANI (Fédération Européenne d'Associations Nationales d'Ingénieurs / European Federation of National Engineering Associations / Föderation Europäischer Nationaler and Ingenieurverbände) and ENAEE (European Network for the Accreditation of Engineering Education), for the United States the American Society for Engineering Education (ASEE) and worldwide the International Federation of Engineering Education Societies (IFEES). As part of the process to compose the group, discussions took place with in particular the president of ENAEE, Prof. Giuliano Augusti and with Dr. Hans Hoyer, Secretary General of the International Federation of Engineering Education Societies and Director of International Programmes and Strategy of the American Society for Engineering Education. Both Augusti and Hoyer gave very useful advice regarding the composition of the Engineering experts' group. Furthermore, the GNE-members were instrumental in assisting Tuning to identify a number of the experts.

The preparation of the actual text of this report has been the work of James Melsa, who was appointed chair of the group of experts and of Iring Wasser, who acted as its rapporteur, as well as the Tuning project coordinator for engineering, Robert Wagenaar. They have made use of the excellent contributions of the other members. The final result is collaborative work of all members involved.

---

[1] OECD (2008), Roadmap for the OECD Assessment of Higher Education Learning Outcomes (AHELO) Feasibility Study, *July*, http://www.oecd.org/dataoecd/50/50/41061421.pdf

[2] Bologna Process Web site; www.ond.vlaanderen.be/hogeronderwijs/bologna/

[3] Tuning Europe Web site http://tuning.unideusto.org/tuningeu/

[4] Tuning América Latina Web site http://tuning.unideusto.org/tuningal/;
Tuning USA Web site: http://www.luminafoundation.org/newsroom/news_releases/2009-04-08.html and http://www.luminafoundation.org/our_work/tuning/

[5] Wagenaar, R. (2003), "Educational Structures, Learning Outcomes, workload and the calculation of ECTS credits", in: J. González and R. Wagenaar (eds.), *Tuning Educational Structures in Europe. Final Report. Pilot Project - Phase 1* Deusto-Groningen, pp. 223-247. See alsoWeb site Tuning Europe: http://tuning.unideusto.org/tuningeu/
Wagenaar, R. (2006) "An Introduction to the European Credit Transfer and Accumulation System (ECTS)", in EUA, *Bologna Handbook. Making Bologna Work.* European University Association, Berlin. See also: Web site EUA http://www.eua.be/publications/bolognahandbook/
ECTS Users' Guide, edition 2009: http://ec.europa.eu/education/lifelong-learning-policy/doc/ects/guide_en.pdf

1. The field of Engineering and Engineering Education explained

The concept of engineering has existed since early man first devised fundamental inventions such as the pulley, lever, and wheel. Each of these inventions is consistent with the modern definition of engineering, exploiting basic mechanical and scientific principles to develop useful tools, objects, solutions to problems.

The original formal utilization of the term *engineer* applied to the constructor of military engines[6] such as catapults. Later, as the design of civilian structures such as bridges and buildings matured as a technical discipline, the term *civil engineering* entered the lexicon as a way to distinguish between those specializing in the construction of such non-military projects and those involved in the older discipline of military engineering. As technology advanced, other specialty fields such as *mechanical*, *electrical*, and *chemical engineering* arose.

Engineering has classically be defined as the profession that deals with the application of technical, scientific, and mathematical knowledge in order to utilize natural laws and physical resources to help design and implement materials, structures, machines, devices, systems and processes that safely realize a desired objective. As such, engineering is at the interface between scientific and mathematical knowledge and human society. The primary activity of engineers is to conceive, design, implement, and operate[7] innovative solutions – apparatus, process, and systems – to improve the quality of life, address social needs or problems, and improve the competitiveness and commercial success of society.

"Professional engineering is not just a job – it is a mindset and sometimes a way of life. Engineers use their judgment and experience to solve problems when the limits of scientific knowledge or mathematics are evident. Their constant intent is to limit or eliminate risk. Their most successful creations recognize human fallibility. Complexity is a constant companion.[8]"

"Engineering is a profoundly creative process. A most elegant description is that engineering is about design under constraints. The engineer designs devices, components, subsystems, and systems and to create a successful design, in the sense that it leads directly or indirectly to an improvement in our quality of life, must work within constraints provided by technical, economic, business, political, social, and ethical issues.[9]"

"The idea of design – of making something that has not existed before – is central to engineering.[10]" While scientists attempt to explain what is, engineers create what has never been. While scientists ask "why," engineers ask "why not."

As the focus of the world has shifted from past technological inventions such as electrification, telephony, the computer, radio and television, and the automobile[11] to the more complex and challenging modern societal problems such as food, health, energy, water, and the environment,[12] the definition of engineering has similarly taken on a new flavour so that it now has the following form. "No profession unleashes the spirit of innovation like engineering. From research to real-word applications, engineers constantly discover how to improve our lives by creating bold new solutions that connect science to life in unexpected, forward-thinking ways[13]"

As noted above the engineering field has been divided into a number of different branches such as civil, electrical, mechanical, and chemical engineering In recent years, branches such as biological engineering, food engineering, environmental engineering, and even financial engineering have been added to the list of specialties. Interestingly, even as these new branches were being created, the complex future challenges are demanding more interdisciplinary knowledge of all engineers hence breaking down the barriers between different areas of engineering.

Because of the challenging expectations of engineers including the ability to address complex societal problems, the education of engineers must be carefully planned and executed in order to provide the student with the necessary skills and competencies to serve successfully as a professional engineer. This education must certainly include a strong grounding in mathematics and science, both natural and life. The education must contain training in the engineering sciences related to the area of specialty. Since design is a critically important skill of the engineer, students must be challenged with increasingly complex problems as they proceed through the educational process. The complexity of the modern challenges facing engineers also requires that the education include sound grounding in topics such as economics, communications, team skills, and the current global geo-political environment.

The members of the engineering profession are expected to exhibit the highest standards of honesty and integrity. Engineering has a direct and vital impact on the quality of life for all people. Accordingly, the services provided by engineers require honesty, impartiality, fairness and equity, and must be dedicated to the protection of public health, safety and welfare. Engineers must perform under a standard of professional behaviour, which requires adherence to the highest principles of ethical conduct

New technologies always pose interesting ethical challenges for engineers. The things that engineers create often have consequences, positive and negative, sometimes unintended, often widespread, and occasionally irreversible. Unfortunately, the consequences are often not obvious at the time of invention.

---

[6] The word *engine* itself is of even older origin, ultimately deriving from the Latin word *ingenium* meaning innate quality, especially mental power, hence a clever invention.

[7] See Web site www.cdio.org

[8] UK Standard for Professional Engineering Competence (2008); Web site Engineering Council UK; www.engc.org.uk

[9] National Academy of Engineering (2004), *The Engineer of 2020: Visions of Engineering in the New Century,*, The National Academies Press, Washington, DC

[10] Petroski, H. (1985) *To Engineer is Human; The Role of Failure in Successful Design* , St. Martin's Press, New York

[11] Constable, G. and B. Somerville (2001) *A Century Of Innovation: Twenty Engineering Achievements That Transformed Our Lives*, Joseph Henry Press, Washington, DC

[12] National Academy of Engineering (2008), *Grand Challenges for Engineering*, National Academies Press, Washington, DC

[13] National Academy of Engineering (2008), *Changing The Conversation*, National Academies Press, Washington, DC

2. Overview of Typical Degrees Offered in the Subject Area of Engineering: Orientation and Application and Main Sub-Fields or Specialization

As noted earlier, the earliest disciplines of engineering were military and civil engineering which addressed the applications of engineering skills to solve military and civilian (e.g. roads and bridges) problems respectively. The disciplines of chemical, electrical and mechanical were then added. In recent years there has been an expanding of discipline specialization; there now exists over thirty named degree programmes with new programmes being added regularly. See annex 1 for an indicative overview of degree programmes reflecting the different branches in the subject area of engineering.

The first cycle (Bachelors) degree in engineering is typically referred to as the Bachelor of Science in a specialty branch such as civil. The degree may be labeled as *Bachelor of Civil Engineering, Bachelor of Science in Civil Engineering, and Bachelor of Engineering with a major in Civil,* or *Bachelor of Science in Engineering with a major in Civil.* Other variations may also occur.

In reference to the Bologna[14] process, first cycle graduates are expected to be both employable and qualified to enter a second cycle programme. Graduation from a first cycle programme, however, does not necessarily signify that the graduate is prepared to enter the practising profession.

Depending on the country, first cycle degrees may be either three or four years in duration. There continues to be discussion regarding the equivalence of three-year first cycle degree and the traditional four-year bachelors degree programmes offered in many Asian countries, Australia, and the United States. In France the first cycle of engineering education (Diplôme universitaire de technologie) is a two-year degree which does not allow entrance into the engineering practice.

Some would suggest that the traditional bachelors degree sits in between the European three-year first cycle and second cycle degrees. In Australia, although Engineers Australia has provisionally accredited the Master of Engineering degree at a couple of universities (European style five-year degree structure), their engineering competency level is seen to be the same as that of the conventional four-year bachelors degree. A meaningful measurement of the Learning Outcomes as defined in this report should add some much needed information to this discussion.

In some countries, there are two tracks for first-cycle degrees. One[15] (Applied BSc) is designed to prepare students for more applied careers; these students may not be adequately prepared to enter advanced (second cycle) educational programmes in engineering without additional preparation. The other track[16] (BEng) is more focused on theoretical and abstract thinking and creative analysis in solving of problems and prepares for the continuation of education for advanced degrees in engineering.

Second Cycle (Masters) follow a similar pattern of specialty branches. However, because students at this level are now focusing more on one technical area, there may be even further specialization of the degree offerings. Some institutions or countries offer integrated first and second cycle programmes.[17] In some cases these integrated programmes are a simple combination of a first and second cycle programme. In other cases (e.g. the UK MEng degree), the programmes are more fully integrated.

There exist some educational institutions which offer five year degrees leading to the historical "Diplom Engr" or similarly entitled degree. These degrees are not discussed in this report.

---

[14] Bologna Process Web site; www.ond.vlaanderen.be/hogeronderwijs/bologna/

[15] In the United States, the BS in Engineering Technology programmes are a version of this type of degree programme. In the UK, this route prepares for qualification as *Incorporated Engineer*.

[16] E.g., in the UK this route prepares for qualification as *Chartered Engineer*.

[17] These may be four or five years in duration.

3. Overview of Typical Occupations of Engineers with a First Cycle (Bachelors) Degree and a Second Cycle (Masters) Degree

Graduates with a first cycle degree in one of the fields of engineering enter a wide variety of positions with many different types of organizations. There are many graduates of engineering programmes who use their engineering education as an entry to other professions such as law or medicine. Engineering graduates also choose to enter fields such as financial services, sales, or non-engineering management where their engineering skills may be very helpful to their success. Some engineers enter public service in policy-making or political roles where their engineering education is instrumental in their ability to solve important societal problems. This report does not directly address the preparation for such students although there is much anecdotal evidence that the students' engineering education is a valuable preparation for these career choices.

In most cases, first cycle graduates will go directly to work for organizations which design, produce, and/or sell products, sub-systems, systems, and/or services. In most such employment, the graduate will begin to work under the supervision of a more senior engineer. The graduates are involved with a variety of duties ranging through the full life cycle of these products and services. Such roles might include limited basic research, design of the organization's products or services, the production of the product or service, selling of the product or services to other technical or non-technical organizations, or the operation, servicing and/or maintenance of the product or service in field applications.

In some countries[18], graduates with only a first cycle degree may be limited in the type of work they may enter. There is a movement by some professional organizations in some countries[19] to require a second cycle degree or its equivalent to become registered or to practice. Other professional organizations have gone on record opposing such a requirement and believe that a first cycle degree is sufficient to enter those professions.

In some cases, graduates choose to form new companies or to go into their own private consulting practice. While their technical preparation may be valuable in this case, the graduates' skills in other professional areas may be equally important.

The legality of a graduate to practice independently, i.e. without direct supervision by an experienced engineer, varies considerably from country to country. In order to become a licensed/registered engineer, graduates may be required to complete a period of supervised work experience and, in some cases, pass one or more examinations.

Many[20] first cycle graduates will pursue additional education often leading to second cycle degrees. In some cases, the students will pursue this additional education while being employed as a practicing engineer.

Graduates with second cycle degrees obtain employment in most of the same types of positions as first cycle graduates. However, these graduates are less likely to enter positions which are primarily focused on narrow application of engineering methods or positions such as sales engineering and applications engineering. On the other hand graduates of second cycle programmes are more likely to enter position with higher levels of engineering specialization, research focus, more loosely defined problems, and management responsibility.

---

[18] E.g. France.

[19] E.g., In the United States, the American Society for Civil Engineering (ASCE) has gone on record supporting such a position through its definition of the required Body of Knowledge; www.asce.org/professional/educ/

[20] E.g. In Romania, it is expected that up to 50% of the graduates of first cycle degree programmes will enroll in the master degree programmes.

4. Learning Outcomes, (Cycle) Level Descriptors and Qualifications Frameworks

The Learning Outcomes Concept is a comparatively new notion in educational policies. Starting in the 1990s, it has gained momentum and today can be considered to be a prime agent of change in Higher Education. Driving forces and sources of inspiration have been, among others, in particular the Quality Assurance Agency (QAA) for the United Kingdom and Tuning for Europe and beyond.

In the framework of the Bologna process, the importance of Learning Outcomes has risen more and more to the forefront of the political agenda. Whereas in the original 1999 Bologna Declaration and the Prague Communiqué of 2001[21] there was no reference of Learning Outcomes, in all ensuing ministerial Communiqués they figured prominently in their discourse.

At the Berlin Bologna follow-up conference which took place in September 2003, degree programmes were identified as having a central role in the process. The conceptual framework on which the Berlin Communiqué is based, shows - on purpose - complete coherence with the Tuning approach. This is made evident by the language used, where the Ministers indicate that degrees should be described in terms of workload, level, Learning Outcomes, competences and profile.

As a sequel to the Berlin conference, the Bologna follow-up group took the initiative of developing an overarching *Framework for Qualifications of the European Higher Education Area* (QF of the EHEA) which, in concept and language, is again in full agreement with the Tuning approach. This framework has been adopted at the Bergen Bologna follow-up conference of May 2005. The QF of the EHEA has made use of the outcomes both of the Joint Quality Initiative (JQI) and of Tuning. The JQI, an informal group of higher education experts, produced a set of criteria to distinguish between the different cycles in a broad and general manner. These criteria are commonly known as the "*Dublin descriptors*". From the beginning, the JQI and Tuning have been considered complementary. The JQI focuses on the comparability of cycles in general terms, whereas Tuning seeks to describe cycle degree programmes at the level of subject areas. An important aim of all three initiatives (QF of the EHEA, JQI and Tuning) is to make European higher education more transparent. In this respect, the concept of Qualifications Frameworks is a major step forward because it gives guidance for the construction of national qualifications frameworks based on Learning Outcomes and competences as well as on credits. We may also observe that there is a parallel between the QF of the EHEA and Tuning with regard to the importance of initiating and maintaining a dialogue between higher education and society and the value of consultation -- in the case of the QF of the EHEA with respect to higher education in general; in that of Tuning with respect to degree profiles.

In the summer of 2006 the European Commission launched a European Qualifications Framework for Life Long Learning (EQF for LLL). Its objective is to encompass all types of learning in one overall framework. This framework is the outcome of the so-called Copenhagen Process, which focuses on the Vocational Educational and Training sector. The EQF for LLL distinguishes 8 competence levels. National Qualification Frameworks are presently being mapped to the QF for the EHEA and/or the EQF for LLL.

Although the concepts on which the QF of the European Higher Education Area and the EQF for LLL are based differ, both are fully coherent with the Tuning approach. Like the other two, the LLL variant is based on the development of level of knowledge, skills and (wider) competences. From the Tuning perspective both initiatives have their value and their roles to play in the further development of a consistent European Education Area.

It is important to note that this Tuning-AHELO experts' group has concentrated exclusively on the first cycle or Bachelor level -that is, Competence level 6 of the European Qualifications Framework for LLL.

In the London Communiqué of 2007 the education ministers of 46 European countries confirmed the line taken at the Berlin and Bergen Bologna follow-up conferences:

"We underline the importance of curricula reform leading to qualifications better suited both to the needs of the labour market and to further study. Efforts should concentrate in future on removing barriers to access and progression between cycles and on proper implementation of ECTS, based on *Learning Outcomes* and student workload."... "Qualifications frameworks are important instruments in achieving comparability and transparency within the EHEA and facilitating the movement of learners within, as well as between higher education systems. They should also help HEIs to develop modules and study programmes based on *Learning Outcomes* and credits and improve the recognition of qualifications as well as all forms of prior learning." Finally: "We urge institutions to further develop partnerships and cooperation with employers in the ongoing process of curriculum innovation based on *Learning Outcomes*.... "With a view to the development of more student-centred, outcome-based learning, the next (stocktaking) exercise should also address in an integrated way national qualifications frameworks, *Learning Outcomes* and credits, lifelong learning and the recognition of prior learning." [22]

Today it is no exaggeration to note, that the Bologna process has fostered the transition of HE focus on knowledge possession to understanding performances, from a teaching- to a student-centered approach via Learning Outcomes. As Stephen Adam puts it:

> "It is arguable that the main end product of the Bologna reforms is better qualifications based on Learning Outcomes and certainly not just new educational structures. For this sort of bottom-up reform it is recognised that there is a need for fundamental changes at the institutional level where academics are responsible for creating and maintaining qualifications". [23]

In spite of this common political agenda, the existing Learning Outcomes for European Bachelor (and Master) programmes, which have been agreed on by the 46 members of the European Higher Education Area and which are referred to as so-called "Dublin Descriptors" (see above) have been very difficult to operationalize. This is mainly due to the fact that they are generic in nature and do not address different Learning Outcomes at the disciplinary level. Given the considerable diversity of the education systems in the member states of EHEA, this departure might be understandable. For some years now, however, there has been a growing demand for developing sectoral qualification profiles and Learning Outcomes by academics and employers alike. Also on the political level, the ministers of education in their recent Leuven/Louvain-la-Neuve Communité Communiqué have for the first time stressed the eminence of Learning Outcomes on the disciplinary level:

> "We reassert the importance of the teaching mission of higher education institutions and the necessity for ongoing curricular reform geared toward the development of Learning Outcomes... Academics in close cooperation with student and employer representatives, will continue to develop Learning Outcomes and international reference points for a growing number of subject areas... This should be a priority in the futher implementation of the European Standards and Guidelines for quality assurance". [24]

***

In the introduction of this report the *Tuning definition* of Learning Outcomes was given. It is worth repeating it here:

"*Learning Outcomes are statements of what a learner is expected to know, understand and /or be able to demonstrate after completion of a process of learning.*"[25]

There are many definitions of Learning Outcomes[26], but this one has obtained wide acceptance.

The UNESCO definition identifies both outcomes and student Learning Outcomes, the concept of the latter being linked to the assessment question: "LO, together with assessment criteria specify the minimum requirements for the award of credit."

It is also worthwhile noting, that one has to differentiate between

- intended Learning Outcomes, ILO – written statements in a course/programme syllabus
- achieved Learning Outcomes, ALO – those results that students actually have achieved

A Quality Education can be assumed when a student has acquired knowledge, skills and wider competences as described through the Learning Outcomes. Learning Outcomes are commonly further divided into different categories. The most common sub-division is between subject specific and generic (sometimes referred to as transferable or transversal) outcomes. If designed properly, Learning Outcomes will promote communication between teachers and students, information on courses and programmes, study guidance, study planning, assessment of learning as well as teaching methods, feedback mechanisms as students, employers and other stakeholder will assess the quality of the education at hand in relation to Learning Outcomes. In all the discussions there is however an underlying caveat that Learning Outcomes should not be used as a tool for standardization of curricular content on the national/European/OECD level but rather as one of the most important tools for academic and professional mobility, a view which has been unanimously shared by the members of the AHELO experts group.

As has been shown above, the concept of Learning Outcomes has been and is being used in a multitude of different settings: it has been instrumental in the development of qualifications frameworks, in the LLL discussion, in developing the European Credit Transfer and Accumulation System, for curricular reform, in the area of quality assurance and most importantly, as the primary vehicle for the recognition of qualifications and the corresponding academic and professional mobility.

In the field of engineering, the usefulness of the Learning Outcomes approach was identified early and has paved the way for similar developments in other areas, as will be shown in the following.

---

[21] http://www.bologna-bergen2005.no/Docs/00-Main_doc/010519PRAGUE_COMMUNIQUE.PDF
[22] London Communiqué: Web site http://www.dcsf.gov.uk/londonbologna
[23] Adam, S. (2008): "Learning Outcomes based higher education: the Scottish experiences", paper presented to the Bologna Seminar, Edinburgh, February.
[24] Communiqué of the Conference of European Ministers Responsible for Higher Education, Leuven and Louvain-la-Neuve, 28-29. April 2009: "The Bologna Process 2020 – the European Higher Education Area in the new decade", pp. 3-4.
See also the conclusions of the official Bologna Seminar (2008) "Development of a Common Understanding of Learning Outcomes and ECTS", Porto, June
http://portobologna.up.pt/documents/BS_P_Report_20080915_FINAL.pdf
[25] González J. and R. Wagenaar (eds.),(2008), *Tuning Educational Structures in Europe. Universities' contribution to the Bologna Process. An Introduction. 2nd. Ed,.* Bilbao-Groningen, p. 16.
See also European Commission (2009), *ECTS Users' Guide*
Web site European Commission; http://ec.europa.eu/education/lifelong-learning-policy/doc/ects/guide_en.pdf
[26] Harvey, L., (2004-9), Analytic Quality Glossary, Quality Research International, Web site; http://www.qualityresearchintrnational.com/glossary

5. Overview of prior work on the Learning Outcomes approach in the field of Engineering

In the field of engineering the concept of Learning Outcomes was introduced prior to the above mentioned developments; in fact engineers have proven to be pioneers in many ways. In the 1990 and early 2000s, a considerable number of methodologies has been elaborated, some of the most influential of which are briefly described in the following:

The Swedish System of Qualifications and Engineering Design Degrees

In Sweden, the Swedish Higher Education Ordinance, which lists the national requirements for Swedish engineering degrees was issued as early as 1993 with amendments in 2006[27]. It lists higher education qualifications that may be taken at first, second, and third level and the requirements that must be fulfilled for each qualification. In the amendments one can find the first level professional qualifications as a Swedish engineer, whereby a distinction is made between knowledge and understanding, skills and abilities, judgement and approach and others.

The EC 2000 Criteria of ABET

In the United States one of the most important developments was the introducation of the so called Engineering Criteria (EC) 2000 for the Accreditation of Engineering Education by the Accrediation Board of Engineering and Technology (ABET). For most of the 20th century, ABET's accreditation criteria dictated all major elements of an accredited programme, including programme curricula, faculty, and facilites. In the mid-1990s, however, the engineering community collectively began to question the validity of such rigid quality assurance requirements largely based on inputs rather than outcomes. As a consequence the EC 2000 criteria were elaborated. The core demand of ABET vis-à-vis the HE engineering programmes in terms of EC 2000 was that they were expected to be guided by a coherent quality scheme, starting with the mission of the institution, Learning Outcomes for the individual engineering programmes, operationalization of performance indicators, and a quality assurance system geared towards guaranteeing that the LO were actually being met. Next to programme-specific Learning Outcomes, ABET had formulated 11 generic outcomes to be reached by every engineering programmes (criteria 3 a-k) on the Bachelor level. The ABET approach became one of the role models for the development of similar trends in other parts of the world.

Tuning Educational Structures in Europe – the work of the Engineering Thematic Networks

From the start of the Tuning Project in 2001 many Erasmus Thematic Network Programmes (TNPs) linked up with the project as so-called synergy groups. One of these TNPs was Engineering. This TNP built on the expercience obtained within the Thematic Network H3E (Higher Engnineering Education for Europe 1996-99). The Thematic Network E4 "Enhancing Engineering Education in Europe" (E4) identified eleven competences and Learning Outcomes to be achieved by (accredited) engineering programmes, while at the time demanding that those Learning Outcomes at the end of the first cycle for a professional engineering from Europe should be at least of comparable level to the above mentioned ABET criteria.

Recently, the TNP for Electronical and Information Engineering in Europe (EIE) tested the Tuning approach for their particular branch. It organised a broad consultation of their stakeholders (academic staff, employers, graduates and students) following the Tuning model. This resulted in an extremely useful and interesting report.[28]

Learning Outcomes in the Area of Civil Engineering –the EUCEET Tuning Task Force

In a report of the EUCEET-Tuning Task Force (European Civil Engineering Education and Training) altogether 18 Learning Outcomes were being presented to academics and employers in the field of civil engineering. Interestingly enough none of the items showed a significant heterogeneity among the countries involved[29].

ESOEPE, ENAEE and the European Accredited Engineering System

Starting in September 2000, the European Standing Observatory was founded, which later developed in the European Network for the Accreditation of Engineering Education (ENAEE). In the course of a number of so-called European Accredited Engineer (EUR-ACE) Projects ("EUR-ACE"-, "EUR-ACE"-Implementation and "EUR-ACE"-Spread) five groups of Learning Outcomes were jointly elaborated and agreed on as minimum requirements for the entry route into the profession: Basic and Engineering Sciences, Engineering Analyses and Investigations, Engineering Design, Engineering Practice and Generic Skills. Today these groups of Learning Outcomes are used in seven countries[30] in Europe as guidelines for curricular development and accreditation practice, for recognition of engineering qualifications by FEANI and the European Engineering indices and and in the long run also as basis for the mutual recognition of accreditation decisions.

Washington Accord

The Washington Accord was devised in 2004, adopted in 2005 and is adhered to by 12 countries. The Accord is a mutual recognition agreement between accreditation agencies in a dozen countries, including Australia, Canada, Chinese Taipei, Hong Kong China, Ireland, Japan, Korea, New Zealand, Singapore, South Africa, United Kingdom and United States. In 2005, the WA adopted a set of Learning Outcomes with which those of all signatories must be compatible. The EC2000 criteria of ABET is an example of a compatible system[31].

The Dutch Criteria for Bachelor's and Master's Engineering Curricula

In a joint publication by the Dutch Technical Universities of Delft, Eindhoven and Twente, these universities have formulated criteria for Bachelor´s and Master´s Curricula at Technical Universities.

Standards for Professional Engineers in the United Kingdom

In the United Kingdom with the development of a mass Higher Education system and the associated need for transparency and the assurance of quality, a number of initiatives have led to attempts to provide a transparent, understandable description of the abilities that should be apparent in graduate engineers in the UK. The Quality Assurance Agency (QAA) sponsored the development of a Subject Benchmark Statement to cover all Engineering branches and the Higher Education Funding Council for England sponsored the development of a corresponding Qualifications Framework. At the same time, the Engineering Council (ECUK) developed its own Graduate Outcomes standards. Subsequently the situation between the QAA Engineering Subject Benchmark and UK-SPEC was rationalised by QAA adopting the UK-SPEC learning outcomes in a revised Engineering Subject Benchmark.

Under the ECUK Standard for Professional Engineering Competence (UK-SPEC) the decision on whether a programme is accredited is made on the basis of the programme delivering the Learning Outcomes which the professional institution has specified. The introduction of UK-SPEC and accreditation based on output standards has produced several issues, in particular how to identify evidence that Learning Outcomes are being met and at what level.

Criteria for Engineer's degrees in France

In France the CTI (Commission des Titres d' Ingenieur) is assigned to accredit the engineering programmes. In their Self –Evaluation Guide for Engineering Education Programmes expected outcomes have been designed (Part D2), alhtough these outcomes are expected for integrated five years programmes leading directly to a master's degree.[32]

Comparative Summary of engineering LO in five national/continental systems

In annex 2 a comparative summary of some of the most influential Learning Outcomes frameworks in the engineering field is included. What is striking, and what probably differentiates engineering from many other disciplines is the fact, that all across the world, there is pretty much a common understanding of what an engineer is supposed to know and be able to do.

[27] Ministry of Education and Research of Sweden (2008), Higher Education Ordinance, pp. 51-52, 73-74. Web site: http://www.regeringen.se/sb/d/574/a/21541
[28] EIE Surveyor Project (2009), *Final Report for Task on: The alignment of generic, specific and language skills within the Electrical and Information Engineering discipline, Application of the TUNING approach.*
[29] Manoliu, I. (2006)"Report of the EUCEET- Tuning Task Force on the Cooperation as a Synergy Group of the Thematic Network EUCEET" in I. Manoliu (ed.), *Inquiries into European Higher Education in Civil Engineering*, fifth EUCEET volume, Independent Film, Bucharest.
[30] The "EUR-ACE" criteria are used in Germany by the German Accreditation Agency for Study Programmes in Engineering, Informatics, Natural Sciences and Mathematics, in France by the Commission des Titres dÍngenieurs, in Great Britain by the Engineering Council UK, in Ireland by Engineers Ireland, in Portugal by the Ordem dos Engenhieros, in Russia by the Russian Association for the Accreditation of Engineering Education, and in Turkey by MÜDEK. In the framework of EUR-ACE spread initiatives are under way to spread the use of EUR-ACE Learning Outcomes to many other countries in Europe.
[31] Information about the Washington Accord can be found at the Web site www.washingtonaccord.org
[32] CTI Web site http://www.cti-commission.fr

6. Clarification of the approach used and an introduction to the conceptual framework: philosophy and selected order/construction of LO statements

When the Tuning-AHELO experts group for the engineering field was confronted with the challenge to agree on what set of commonly agreed Learning Outcomes to use as the basis for this AHELO feasibility study, a unanimous consensus was quickly reached to synthesize two of the above listed sets of Learning Outcomes: the LO used by the European Network for the Accreditation of Engineering Education and the LO developed and implemented by the American Accreditation Board of Engineering and Technology. The reason for this deliberate choice was manifold:

1) Both sets of criteria, the EC 2000 Criteria of ABET and the EUR-ACE Learning Outcomes for First Cycle Bachelor Degrees of ENAEE have been widely recognized on an international scale. EUR-ACE Learning Outcomes and corresponding criteria have meanwhile been integrated in national Learning Outcomes and accreditation requirements of altogether seven European countries: France, Germany, Great Britain, Ireland, Portugal, Russia and Turkey (Adam, 2008).

1) The ABET EC 2000 standards have equally been influential for the development of Learning Outcomes/accreditation standards in many other countries and regions, not least by accreditation activities of ABET outside the United States.

2) With EC 2000 and "EUR-ACE"-Learning Outcomes, two (pan-) continental networks, encompassing the most important engineering countries, are directly or indirectly covered. The "EUR-ACE" Learning Outcomes are the basis for a European mutual recognition agreement, currently developed under the framework of the European Network for the Accreditation of Engineering Education ENAEE. It is also important to note that the FEANI, the European Federation of Engineering Societies in 30 European Countries, has in principle accepted to recognize the EUR-ACE Learning Outcomes and Accreditation Results for their own index of accredited engineering courses and the European Engineering register of professional engineers. As to ABET, it is part of the "Washington Accord", which essentially is a mutual recognition agreement between twelve accreditation agencies in as many countries, including Australia, Canada, Chinese Taipei, Hong Kong China, Ireland, Japan, Korea, New Zealand, Singapore, South Africa, United Kingdom and United States. Some institutions even have a simultaneous membership in ENAEE and W.A. at the same time. All these signatories are working on LO comparable to those of ABET, so that they are indirectly taken care of.

3) The members of the AHELO experts group, when comparing "EUR-ACE" Learning Outcomes for First Cycle European Degrees and ABET EC 2000 Learning Outcomes, quickly came to the conclusion that in spite of a different ordering, they were highly compatible. The synthesis of the two sets of Learning Outcomes proved to be a feasible task, the result of which can be checked in the following table:

Table 6.1

EUR-ACE Framework Standards for the Accreditation of Engineering Programmes	**ABET-USA Criteria for Accrediting Engineering Programmes**	**Tuning-AHELO framework of Learning Outcomes**
Knowledge and Understanding - Knowledge and understanding of the scientific and mathematical principles underlying their branch of engineering; - A systematic understanding of the key aspects and concepts of their branch of engineering - Coherent knowledge of their branch of engineering including some at the forefront of the branch; - Awareness of the wider multidisciplinary context of engineering.	a. An ability to apply knowledge of mathematics, sciences, and engineering;	***Basic and Engineering Sciences*** - The ability to demonstrate knowledge and understanding of the scientific and mathematical principles underlying their branch of engineering; - The ability to demonstrate a systematic understanding of the key aspects and concepts of their branch of engineering; - The ability to demonstrate comprehensive knowledge of their branch of engineering including emerging issues.
Engineering Analysis - The ability to apply their knowledge and understanding to identify, formulate and solve engineering problems using established methods; - The ability to apply their knowledge and understanding to analyze engineering products, processes and methods; - The ability to select and apply relevant analytic and modeling methods.	b. An ability to design and conduct experiments, as well as to analyze and interpret data; e. An ability to identify, formulate, and solve engineering problems;	***Engineering Analysis*** - The ability to apply their knowledge and understanding to identify, formulate and solve engineering problems using established methods; - The ability to apply knowledge and understanding to analyze engineering products, processes and methods; - The ability to select and apply relevant analytic and modelling methods; - The ability to conduct searches of literature, and to use data bases and other sources of information; - The ability to design and conduct appropriate

		experiments, interpret the data and draw conclusions.
Engineering Design - The ability to apply their knowledge and understanding to develop and realize designs to meet defined and specified requirements; - An understanding of design methodologies, and an ability to use them.	c. An ability to design a system, component, or process to meet desired needs within the realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability;	***Engineering Design*** - The ability to apply their knowledge and understanding to develop designs to meet defined and specified requirements; - The ability to demonstrate an understanding of design methodologies, and an ability to use them.
Investigations - The ability to conduct searches of literature, and to use data bases and other sources of information; - The ability to design and conduct appropriate experiments, interpret the data and draw conclusions; - Workshop and laboratory skills.		
Engineering Practice - The ability to select and use appropriate equipment, tools and methods; - The ability to combine theory and practice to solve engineering problems; - An understanding of applicable techniques and methods, and their limitations; - An awareness of the non-technical implications of engineering practice.	f. An understanding of professional and ethical responsibility j. A knowledge of contemporary issues k. An ability to use the techniques, skills, and modern engineering tools necessary for engineering practice	***Engineering Practice*** - The ability to select and use appropriate equipment, tools and methods; - The ability to combine theory and practice to solve engineering problems; - The ability to demonstrate understanding of applicable techniques and methods, and their limitations; - The ability to demonstrate understanding of the non-technical implications of engineering practice; - The ability to demonstrate workshop and laboratory skills; - The ability to demonstrate understanding of the

		health, safety and legal issues and responsibilities of engineering practice, the impact of engineering solutions in a societal and environmental context, and commit to professional ethics, responsibilities and norms of engineering practice; - The ability to demonstrate knowledge of project management and business practices, such as risk and change management, and be aware of their limitations.
Transferable Skills - Function effectively as an individual and as a member of a team; - Use diverse methods to communicate effectively with the engineering community and with society at large; - Demonstrate awareness of the health, safety and legal issues and responsibilities of engineering practice, the impact of engineering solutions in a societal and environmental context, and commit to professional ethics, responsibilities and norms of engineering practice; - Demonstrate awareness of project management and business practices, such as risk and change management, and understand their limitations; - Recognize the need for, and have the ability to engage in independent, life-long learning.	d. An ability to function on multidisciplinary teams; g. An ability to communicate effectively h. The broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context i. A recognition of the need for, and the ability to engage in life-long learning	***Generic Skills*** - The ability to function effectively as an individual and as a member of a team; - The ability to use diverse methods to communicate effectively with the engineering community and with society at large; - The ability to recognize the need for and engage in independent life-long learning; - The ability to demonstrate awareness of the wider multidisciplinary context of engineering.

7. Overview of agreed Learning Outcomes statements

As pointed out, the Tuning-AHELO programme Learning Outcomes are the result of a comparative review between the EUR-ACE Framework Standards for the Accreditation of Engineering Programmes and the ABET criteria for accrediting engineering programmes and consistent with a number of other frameworks / sets of Learning Outcomes, identified as being of relevance for defining the Tuning-AHELO set of Learning Outcomes for first cycle engineering programmes in general. The corresponding ABET criteria are included between round brackets after the title of each identified group of Learning Outcomes.

First Cycle Programme Learning Outcomes in Engineering developed in the framework of the AHELO feasibility study:

Generic Skills (d, g, h, i)

Graduates should possess generic skills which are necessary for the practice of engineering and are applicable more broadly. Among these are the identified capacity for analysis and synthesis, capacity for applying knowledge in practice, capacity to adapt to new situations, concern for quality, information management skills and capacity for generating new ideas (creativity)[33]. More particularly graduates are expected to have achieved the following Learning Outcomes:

- The ability to function effectively as an individual and as a member of a team;
- The ability to use diverse methods to communicate effectively with the engineering community and with society at large;
- The ability to recognize the need for and engage in independent life-long learning;
- The ability to demonstrate awareness of the wider multidisciplinary context of engineering.

Basic and Engineering Sciences (a)

In general, the underpinning knowledge and understanding of science, mathematics and engineering fundamentals are thought essential to satisfying the other programme outcomes. Graduates should be able to demonstrate their knowledge and understanding of their engineering specialization, and also the wider context of engineering. More particularly graduates are expected to have achieved the following Learning Outcomes:

- The ability to demonstrate knowledge and understanding of the scientific and mathematical principles underlying their branch of engineering;
- The ability to demonstrate a systematic understanding of the key aspects and concepts of their branch of engineering;
- The ability to demonstrate comprehensive knowledge of their branch of engineering including emerging issues.

Engineering Analysis (b, e)

In general, graduates should be able to solve engineering problems consistent with a level of knowledge and understanding to be expected at the end of a first cycle programme of studies, and which may involve considerations from outside their field of specialization. Analysis can include the identification of the problem, clarification of the specification, consideration of possible methods of solution, selection of the most appropriate method, and correct implementation. First cycle graduates should be able to use a variety of methods, including mathematical analysis, computational modelling, or practical experiments, and should be able to recognize the importance of societal, health and safety, environmental and commercial constraints. Furthermore, graduates should be able to use appropriate methods to pursue research or other detailed investigations of technical issues consistent with a level of knowledge and understanding to be expected at the end of a first cycle programme of studies. Investigations may involve literature searches, the design and execution of experiments, the

interpretation of data, and computer simulation. They may require that databases, codes of practice and safety regulations are consulted.
More particularly graduates are expected to have achieved the following Learning Outcomes:
- The ability to apply their knowledge and understanding to identify, formulate and solve engineering problems using established methods;
- The ability to apply knowledge and understanding to analyze engineering products, processes and methods;
- The ability to select and apply relevant analytic and modelling methods;
- The ability to conduct searches of literature, and to use databases and other sources of information;
- The ability to design and conduct appropriate experiments, interpret the data and draw conclusions.

Engineering Design (c)
In general, graduates should be able to realize engineering designs consistent with a level of knowledge and understanding to be expected at the end of a first cycle programme of studies, working in cooperation with engineers and non-engineers. The design may be of processes, methods or artefacts, and the specifications should be wider than technical, including awareness of societal, health and safety, environmental and commercial considerations. More particularly graduates are expected to have achieved the following Learning Outcomes:
- The ability to apply their knowledge and understanding to develop designs to meet defined and specified requirements;
- The ability to demonstrate an understanding of design methodologies, and an ability to use them.

Engineering Practice (f, j, k)
In general, graduates should be able to apply their knowledge and understanding to developing practical skills for solving problems, conducting investigations, and designing engineering devices and processes. These skills may include the knowledge, use and limitations of materials, computer modelling, engineering processes, equipment, workshop practice, and technical literature and information sources. They should also recognize the wider, non-technical, such as ethical, environmental, commercial and industrial, implications of engineering practice, ethical, environmental, commercial and industrial. More particularly graduates are expected to have achieved the following Learning Outcomes:
- The ability to select and use appropriate equipment, tools and methods;
- The ability to combine theory and practice to solve engineering problems;
- The ability to demonstrate understanding of applicable techniques and methods, and their limitations;
- The ability to demonstrate understanding of the non-technical implications of engineering practice;
- The ability to demonstrate workshop and laboratory skills;
- The ability to demonstrate understanding of the health, safety and legal issues and responsibilities of engineering practice, the impact of engineering solutions in a societal and environmental context, and commitment to professional ethics, responsibilities and norms of engineering practice;
- The ability to demonstrate knowledge of project management and business practices, such as risk and change management, and be aware of their limitations.

---

[33] This list is based on an extended survey held among stakeholders (employers, academic staff, graduates and students) executed by the European Association for Education in Electrical and Information Engineering: EIE-Surveyor Project. *Final Report for Task on: The alignment of generic, specific and language skills within the Electrical and Information Engineering discipline, Application of the Tuning approach.* (2009). Other key generic competences / skills identified in the survey are included in the explicit lists of Learning Outcomes identified for the groups of programme Learning Outcomes.

8. Learning Outcomes for branches of Engineering

The development of Learning Outcomes at branch level

The AHELO experts group considers the above mentioned Learning Outcomes in engineering an important further development of the "Dublin Descriptors" and a most important tool for fostering academic and professional mobility with the 30 OECD countries in the future. The members of the experts group however went one step further and agreed to develop FCD Learning Outcomes for certain engineering branches. They decided to concentrate in this pilot feasibility study on three of the main engineering branches, that is mechanical engineering, electrical engineering and civil engineering. As common reference points the working group checked the Learning Outcomes formulated by the German Accreditation Agency for Study Programmes in Engineering (ASIIN), the Subject Benchmarks of the British Quality Assurance Agency (QAA), the work done by EUCEET in the field of Civil Engineering and the ABET EC 2000 LO for the three branches mentioned.

These branch specific Learning Outcomes statements should be read in close relation with the overall Learning Outcomes statements for the subject area of engineering as presented in chapter 7. **The important outcomes are the generic ones specified in the table. These can be contextualised for subject areas but care must be taken that this does not lead to over-rigid specification and that assessment against such outcomes recognises the diversity of material which even mainstream subjects now encompass.**

The result of this comparative approach and the synergetic result are shown below:

Specific Learning Outcomes for Electrical Engineering – 1st Cycle

First cycle degrees facilitate professionally qualifying studies in electrical engineering with early professional careers (professional qualification) and to qualify the graduates for advanced scientific degree programmes or for additional degree programmes other than electrical engineering.

Required Knowledge and Understanding Framework:

A. The ability to demonstrate a knowledge of probability and statistics relevant to Electrical Engineering.

B. The ability to demonstrate a knowledge of mathematics including, at a minimum, differential and integral calculus, linear algebra, and discrete mathematics.

C. The ability to demonstrate a sound knowledge in the subject-specific fundamentals of electrical. In the fields of electric DC circuits, electric field, magnetic field, complex AC circuits, network theory and analysis, distorted currents and voltages, energy conversion and energy transport, measurement and control engineering, circuit elements, switching processes in electrical networks, linear and non-linear circuits.

D. The ability to demonstrate an advanced knowledge of at least one of the fields of theoretic electrical engineering, control engineering, electric machines, electric systems, communication technology, micro electronics, high-frequency technology.

E. The ability to attribute fundamental phenomena of electrical engineering to electro-dynamic principles; and design components and processes from electro-dynamic principles.

F. The ability to design analogue and digital, electric and electronic circuits, systems, and products.

Specific Learning Outcomes for Civil Engineering – 1st Cycle

First cycle degrees facilitate professionally qualifying studies in civil engineering with early professional careers (professional qualification) and to qualify the graduates for advanced scientific degree programmes or for additional degree programmes other than civil engineering.

Required Knowledge and Understanding Framework:

A. *Knowledge of fundamentals in the fields of mathematics and sciences:* mathematics, physics, chemistry, geology, probability and statistics, technical mechanics (fundamentals of statics and strengths of materials), fluid mechanics, continuum mechanics.

B. *Knowledge in the subject-specific fundamentals* of civil engineering like building materials, environmental sciences, building physics, surveying, fundamentals of planning, structural theory, engineering drawing, operations research.

C. *Advanced knowledge of the subject-specific fundamentals of civil engineering* like structural statics, constructive engineering (steel, timber and masonry wall construction), science of materials, geotechnical/foundation engineering, water engineering, urban planning, road engineering, railway engineering or community water management, safety, ecology.

D. *Advanced knowledge of the subject-specific applied civil engineering areas like* construction industry/construction operation/construction management, construction informatics, tendering, contracting and laws, project management and control, building services engineering, design of components and of simple systems (structures, foundations, water supply systems, sewer networks, etc.), information technology, economics, sustainability.

E. *Ability to identify, formulate and solve common civil engineering problems* in at least one of the following areas: buildings, hydraulic works, water supply, road and railroad constructions, transportation, bridges, geotechnical structures.

F. *Understanding of the elements of project and of construction of common civil engineering works* like construction, public works, equipment, project and construction planning, labour, contract, safety and health, cost analysis and control, professional ethics, subcontracting, environmental issues, information management.

Specific Learning Outcomes for Mechanical Engineering – 1st Cycle

First cycle degrees facilitate professionally qualifying studies in mechanical engineering with early professional careers (professional qualification) and to qualify the graduates for advanced scientific degree programmes or for additional degree programmes other than mechanical engineering.

Required Knowledge and Understanding Framework:

A. The ability to demonstrate knowledge and understanding of the basics of

- a. mathematics including differential and integral calculus, linear algebra, and numerical methods
- b. high-level programming
- c. solid and fluid mechanics
- d. material science and strength of materials
- e. thermal science: thermodynamics and heat transfer
- f. operation of common machines: pumps, ventilators, turbines, and engines

B .The ability to perform analysis of

- a. mass and energy balances, and efficiency of systems
- b. hydraulic and pneumatic systems
- c. machine elements

C. The ability to carry out the design of elements of machines and mechanical systems using computer aided design tools

D. The ability to select and use control and production systems

9. Required New Approaches to Learning, Teaching, and Assessment

Although the use of the Learning Outcomes approach seems to have been implemented widely in the field of engineering, this does not always imply that teaching, learning and assessment strategies are applied which are in line with this approach. Student-centred programmes based on the development of compentences, measured in Learning Outcomes require other methodologies and strategies than more traditional, staff-centred degree programmes. Key in the approach is that Learning Outcomes must be measurable in terms of assessment criteria and can be taught and/or learned.

The development of meaningful and measurable Learning Outcomes for engineering programmes and the related accurate assessment tools are critical to systematic improvement of the educational experience for engineering students. One can map the Learning Outcomes across the curriculum/educational experiences of the students to determine where and when each Learning Outcomes is to be met. It is then possible to use both formative and summative evaluations to determine how well the desired Learning Outcomes are being met and can also determine the positive or negative impact of any educational innovation.

The Learning Outcomes, especially when mapped to specific educational experiences, can also be used by students to assess their own progress. A valuable tool in this regard is e-portfolios[34] which may be used by both students and their teachers to assess knowledge, attitudes and skills in engineering. This approach can also be extended to assessment methods using WEB 2.0 tools using blogs, wikis, virtual worlds and e-portfolios are used in an Action-Research[35] programme with teachers as students.

Another tool is collaborative *Design-Based Learning* (DBL). DBL is conceived as 'an educational model in which a major part of the curriculum and the study programme is aimed at learning to design in engineering'. In DBL, not only the resulting products are important; the underlying process is highly relevant as well. DBL explicitly involves a form of university education with a prominent position for academic skills, such as reflection on activities, critical analysis of design tasks, broad interpretation of design requirements, incorporation of contemporary scientific views, etc.. DBL could be characterized particularly as integrative, multidisciplinary, practice-oriented, creative, co-operative (teamwork), competence-oriented (skills), activating, fostering responsibility, synthesizing, and leading to professionalization. In DBL, the teacher – once the design task is set – transfers all authority to (a group of) students. The students' tasks are open ended and students become actively involved in defining design questions in their own language and working out solutions together instead of reproducing material presented by the teacher or the textbook. The idea behind this is that only when students formulate their own constructs and solutions are they truly thinking critically. By making use of DBL, students are stimulated to develop higher level thinking skills, gain a positive attitude toward the subject matter, practice modeling societal and work related roles, and generate more and better design questions and solutions. DBL is assumed to foster increased retention of knowledge, to improve students' general problem-solving skills, to enhance integration of basic science concepts into real-life problems, to stimulate the development of self-directed learning skills, and to strengthen intrinsic motivation.[36]

In addition to the standard, summative teacher-course evaluations, one can also use information live interactions between students and "trusted" advisors to obtain more detailed information regarding the "success" of the education experiences. Alumni and employer surveys are also a useful source of information as the Tuning consultations has shown.

As one begins to use any of these assessment tools to evaluate Learning Outcomes, it is important to develop a process by which these data will be analyzed to obtain actionable improvements. Without such a process the evaluations will lose much of their value and students and others will not take them seriously.

The use of Learning Outcomes should cause faculty members to take a more holistic view of the educational experiences of the students. This, in turn, will lead to discussions of innovative learning activities and experiences to meet the desired Learning Outcomes.

There is clear evidence that it is important to use a wide variety of educational tools to achieve the desired Learning Outcomes. It is also import to evaluate/assess often with increasing expectations of the students' abilities. In addition to the standard lecture mode, it is important to provide the student with a variety of professionally relevant experiential learning opportunities including global experiences, coop and intern (sandwich programmes) opportunities, multidisciplinary design experiences, and participation in learning communities.

The existence of well understand and formulated Learning Outcomes can also be used to credit students for "prior" experience.[37] In order to do this effectively, it is important to learn how to test for competences at various levels.

Many experiments are now being conducted regarding the use of technology including such items as tablet PCs and smart boards. The existence of Learning Outcomes will allow one to decide whether they have added value in the process of teaching and learning.

One of the critical elements in improving the educational experience and enhancing the achievement of the desired Learning Outcomes is the creation of a culture of engineering education innovation.[38] In this culture, there can be solid research-based improvements in the learning experience. The existence of Learning Outcomes is a key element in this process. Without Learning Outcomes, it is impossible to truly determine if a specific innovation is effective in improving the educational experience.

Many engineering faculty members enter the education environment with little or no understanding of desired Learning Outcomes and how to design and execute a learning experience to achieve them. Institutions should consider strengthening faculty development programmes so that faculty members may more effectively execute their duties. Some countries have highly developed programmes in this area, but others have little or nothing.[39] Institutions should also create a supportive environment for education innovation by clearly recognizing such behaviour.

For students to engage more successfully in the learning experience, it is important that they be provided with an intellectually stimulating, inductive, and cooperative leadership environment. The use of active and collaborative learning[40] approaches is of particular note as is the use of design-based or problem-based/inductive learning approaches.

The process of improving the educational experience will be greatly assisted by re-examining old partnerships and creating new ones. Educational institutions need to make better/different use of their industrial partners who can provide input to curriculum/education experience design. These industrial partners can also be useful sources of valuable teaching. As noted above they can also be use to help with the assessment of Learning Outcomes.

Institutions should also examine their partnership with mathematics and science departments to be sure that there is a common understanding of the desired Learning Outcomes. In order to better understand how to design and conduct valid educational innovation experiments, it is important to create new partnership with cognitive scientists and other disciplines that focus on planning and evaluating learning experiences

[34] The Experience of e-portfolios in Student Learning Objectives, Bologna Seminar (2008) "Development of a common understanding of Learning Outcomes and ECTS Porto, June

[35] Web site http://portaal.e-uni.ee/ejump

[36] Wijnen, W.H.F.W. (1999), *Towards design-based learning* TU/e OGO, Eindhoven.

[37] Copenhagen Process: http://ec.europa.eu/education/policies/2010/vocational_en.html

[38] ASEE (2009) *Creating a Culture for Systematic and Scholarly Engineering Educational Innovation (draft)*, June

[39] Certificate of Learning and teaching in Higher Education (CLTHE) Postgraduate, Certificate in Higher Education (PGCHE). http://www.lsbu.ac.uk/sdu/clthe.html

[40] Johnson, D.W., R. T. Johnson, K. A. Smith: Books. *Active Learning, cooperation in the college classroom*, , Interaction Book Company, 1991

10. Concluding remarks

Challenges and Opportunities for the Future

The creation and implementation of Learning Outcomes is not an easy task. Given the sovereignty of national authorities in educational matters, a lot depends on local conditions and cultural settings. It is always a matter of local and national autonomy exactly how they might be best introduced in practice with the appropriate mix of top-down and bottom-up measures. Learning Outcomes are often viewed as a threat that will streamline education and constrict academic liberties. The members of the experts group have taken these considerations seriously. In the field of engineering, the concept of Learning Outcomes on the other hand has proven to be well established and has been welcomed by most stakeholders in the field. Engineers have an easier task than other disciplines, as in the OECD countries and all around the world there is a great degree of consensus concerning what an engineer is supposed to know and be able to do. In spite of the comparatively short time, the members of the AHELO working group, representing 13 different nations, managed to come up with general Learning Outcomes for all engineering programmes, supplemented by branch specifications for the fields of mechanical, electrical and civil engineering.

Besides these general reflections on the main task executed, the experts group takes the liberty to offer four recommendations of which the experts assume they will be of use for the further development of the OECD-AHELO feasibility study.

Recommendations

1. The Expert Group urges the AHELO project team to continue interactions with the Expert Group with respect to the assessment activities. This will allow the Expert Group to provide feedback with regard to whether the assessment process is targeted at the appropriate priorities and if the Learning Outcomes have been correctly interpreted.
2. The AHELO programme may have the beneficial effect of helping institutions learn how the better institutions (i.e. those that achieve better Learning Outcomes) present their educational experiences. Some methods of addressing this important benefit should be found.
3. This programme could be helpful in improving the mobility of engineering graduates. Close coordination with the major engineering accreditation and regulatory programmes should be achieved.
4. The Expert Group urges active roles for both engineering academics and practitioners in the development and execution of the survey. This will help to add significant credibility to the resulting work products.

11. References

- Accrediation Board of Engineering and Technology (ABET)Web site www.abet.org for the ABET Criteria, http://www.abet.org/Linked%20Documents-UPDATE/Criteria%20and%20PP/E001%2009-10%20EAC%20Criteria%2012-01-08.pdf and for the Summary of the so-called *Penn StateReport* commissioned by ABET: http://www.abet.org/Linked%20Documents-UPDATE/White%20Papers/Engineering%20Change.pdf

- Adam, S. (2008): "Learning Outcomes based higher education: the Scottish experiences", paper presented to the Bologna Seminar, Edinburgh, February. Web site http://www.ond.vlaanderen.be/hogeronderwijs/bologna/BolognaSeminars/Edinburgh2008.htm

- American Society for Civil Engineering (ASCE) Web site www.asce.org/professional/educ/

- The American Society for Engineering Education (ASEE) Web site www.asee.org

- ASCE (2007), *Civil Engineering Body for the 21st Century*: *Preparing the Civil Engineer for the Future.* Web site http://www.asce.org/files/pdf/BOK2_Draft10_071507.pdf

- Australian Council for Educational Research (ACER) Web site: www.acr.edu.au

- Bologna Process Web site; www.ond.vlaanderen.be/hogeronderwijs/bologna/

- Bologna Seminar Development of a Common Understanding of Learning Outcomes and ECTS (2008), Final Report and Recommendations, Porto, June. Web site http://portobologna.up.pt/documents/BS_P_Report_20080915_FINAL.pdf

- Coates, H. and A.Radloff (2008),*Tertiary Engineering Capability Assessment (TECA)Concept Design* , the Australian Council for Educational Research (Draft version), November. http://www.rug.nl/let/faculteit/onderwijsinstituut/TECA%20DRAFT%20CONCEPT%20DESIGN%2013-11-08.pdf

- CDIO Web site www.cdio.org

- Constable, G. and B. Somerville (2001) *A Century Of Innovation: Twenty Engineering Achievements That Transformed Our Lives*, Joseph Henry Press, Washington, DC.

- Copenhagen Process: http://ec.europa.eu/education/policies/2010/vocational_en.html

- Crawley, E.F.(2001*),The CDIO Syllabus.A Statement of Goals for Undergraduate Engineering Education.*

- Commission des Titres d' Ingenieur (CTI) Web site http://www.cti-commission.fr

- EIE Surveyor Project (2009), *Final Report for Task on: The alignment of generic, specific and language skills within the Electrical and Information Engineering discipline, Application of the TUNING approach.* Web site www.eie-surveyor.org

- E-Jump 2.0 Web site http://portaal.e-uni.ee/ejump

- Engineering Council UK Web site: www.engc.org.uk for UK standard for Accreditation http://www.engc.org.uk/documents/EC0005_AHEPBrochure_MR.pdf

- European Commission (2009), *ECTS Users' Guide.* Web site http://ec.europa.eu/education/lifelong-learning-policy/doc/ects/guide_en.pdf

- EUA (2006), *Bologna Handbook. Making Bologna Work.* European University Association, Berlin.

- European Universities' Association Web site for the Bologna Handbook http://www.eua.be/publications/bolognahandbook/

- European Network for Accreditation of Engineering Education (ENAEE) Web site www.enaee.eu for the documents concerning EUR-ACE, such as the EUR-ACE Framework Standards for the Accreditation of Engineering Programmes: www.enaee.eu/pdf/EUR-ACE_Framework_Standards_20110209.pdf

- Engineering Professors Council (EPC) Web site: http://www.epc.ac.uk/publications/standards/index.php for the following publications: *Report of the Employers' Working Group: The EPC Engineering Graduate Output Standard*; *an employer-group* interpretation (2002);
  Report of the Assessement Working Group: The EPC Engineering Graduate Output Standard;assessment of complex outcomes(2002);
  Report of the Professional Bodies' Working Group: The EPC Engineering Graduate Output Standard; Output standards and professional body accreditation (2002);
  Report of the Ieng Working Group: The EPC Engineering Graduate Output Standard; examplar benchmarks for Ieng (2002).

- Fédération Européenne d'Associations Nationales d'Ingénieurs (FEANI) http://www.feani.org

- Feyo de Azevedo, S.(2009), High Level Qualifications Frameworks and the EUR-ACE Standards – Do they fit together?, paper presented to ENAEE workshop, Brussels, January. Web site www.enaee.eu/pdf/Feyo_GA220109_Paper.pdf

- Freeston, I. (2008), *Progressing Towards Global Standards in Engineering* , paper presented to ENAEE Workshop, Brussels, January. Web site www.enaee.eu/pdf/Freeston_GAss220109_v2.pdf

- González, J. and R. Wagenaar (eds.) (2001), *Tuning Educational Structures in Europe. Final Report. Pilot Project - Phase 1* Deusto-Groningen.

- González J. and R. Wagenaar (eds.),(2008), *Tuning Educational Structures in Europe. Universities' contribution to the Bologna Process. An Introduction. 2nd. Ed,.* Bilbao-Groningen.

- Harvey, L., (2004-9), Analytic Quality Glossary, Quality Research International, Web site; http://www.qualityresearchintrnational.com/glossary

- IEM Graduate Attributes and Professional Competencies (2005), www.ieagreements.com/IEM_Grad_AttrProf_Competencies_v11(2).pdf

- Institution of Engineers Singapore (IES) (2008), Accreditation Manual pp. 13-21 Web site http://www.ies.org.sg/eab/EABAM060808.pdf

- ISO 9000 (2005), § 3.16 Web site www.iso.org/iso/catalogue_detail?csnumber=42180

- Johnson, D.W., R. T. Johnson, K. A. Smith: Books (1991). *Active Learning, cooperation in the college classroom*, , Interaction Book Company.

- Leuven and Louvain-la-Neuve Communiqué (2009) "The Bologna Process 2020 – the European Higher Education Area in the new decade", pp. 3-4., April. Web site http://www.ond.vlaanderen.be/hogeronderwijs/bologna/documents/declarations_communiques.htm

- London Communiqué: Web site http://www.dcsf.gov.uk/londonbologna

- London Southbank University Web site http://www.lsbu.ac.uk/sdu/clthe.html for Certificate of Learning and teaching in Higher Education (CLTHE) Postgraduate, Certificate in Higher Education (PGCHE).

- Manoliu, I. (2006)"Report of the EUCEET- Tuning Task Force on the Cooperation as a Synergy Group of the Thematic Network EUCEET" in I. Manoliu (ed.), *Inquiries into European Higher Education in Civil Engineering*, fifth EUCEET volume, Independent Film, Bucharest.

- Meijers, A.W.M, C.W.A.M. van Overveld, J.C. Perrenet, with the co-operation of V.A.J. Borghuis and E.J.P.J. Mutsaers (2005), *Criteria for Academic Bachelor's and Master's Curricula,* Eindhoven.

- Ministry of Education and Research of Sweden (2003), Higher Education Ordinance, pp. 51-52, 73-74. Web site: http://www.regeringen.se/sb/d/574/a/21541

- National Academy of Engineering (2004), *The Engineer of 2020: Visions of Engineering in the New Century,*, The National Academies Press, Washington, DC.

- National Academy of Engineering (2008), *Grand Challenges for Engineering*, National Academies Press, Washington, DC.

- National Academy of Engineering (2008), *Changing The Conversation*, National Academies Press, Washington, DC.

- OECD (2008), Roadmap for the OECD Assessment of Higher Education Learning Outcomes (AHELO) Feasibility Study, *July.* http://www.oecd.org/dataoecd/50/50/41061421.pdf

- Petroski, H. (1985) *To Engineer is Human; The Role of Failure in Successful Design* , St. Martin's Press, New York.

- Prague Communiqué http://www.bologna-bergen2005.no/Docs/00-Main_doc/010519PRAGUE_COMMUNIQUE.PDF

- Quality Assurarnce Agency (QAA) Web site www.qaa.ac.uk/academicinfrastructure/benchmark/statements/engineering06.pdf for the Subject Benchmark Statement Engineering, 2006 by the QAA.

- Schreyer Institute for Teaching Excellence *Sample Learning Outcomes: Engineering*, Web site www.assess.psu.edu/files/Engineering_Outcomes.pdf

- Thematic Network E4, "Final Report on the Synergy group with Tuning' in "Outputs of E4 Volume B, Part 2. Web site http://www.rug.nl/let/faculteit/onderwijsinstituut/E4%20Network%20Outcomes.Volume%20B.pdf

- Tuning Europe Web site http://tuning.unideusto.org/tuningeu/

- Tuning América Latina Web site http://tuning.unideusto.org/tuningal/;

- Tuning USA Web site: http://www.luminafoundation.org/newsroom/news_releases/2009-04-08.html and http://www.luminafoundation.org/our_work/tuning/

- Wijnen, W.H.F.W. (1999), *Towards design-based learning* TU/e OGO, Eindhoven.

12. Membership of the expert group Engineering

Project coordinator: Robert Wagenaar
Joint coordinator of theTuning initiative
Director of Undergraduate and Post-Graduate Studies
University of Groningen
Oude Kijk in 't Jatstraat 26
9712 EK Groningen
The Netherlands
Tel. + 31 50 363 5176
r.wagenaar@rug.nl

Project assistant: Ingrid van der Meer
University of Groningen
Oude Kijk in 't Jatstraat 26
9712 EK Groningen
The Netherlands
Tel. + 31 50 363 6059
Fax: + 31 50 363 5704
y.van.der.meer@rug.nl

List of members

Australia
Yinghe He
School of Engineering & Physical Sciences
James Cook University
Tel. + 61 7 4781 4270
Fax + 61 7 4781 6788
Yinghe.He@jcu.edu.au

Belgium
Philippe Wauters
FEANI Secretary General (Federation of European National Engineers' Associations)
Tel. + 32 2 6390390
philippe.wauters@feani.org

Chile
Paulino Alonso
President of the Council of Engineering Deans of Chile (CONDEFI)
Dean Faculty of Engineering
Pontificia Universidad Católica de Valparaiso
Tel. 56 32 227 3601
palonso@ucv.cl

France
Pierre Compte
Vice-president of the Commission des titres d'ingénieur
Laboratoire régional des Ponts & Chaussées

8-10 rue Bernard Palissy
63017 Clermont-Ferrand Cedex
Tel: + 33 4 73 42 10 93
pierre.compte@developpement-durable.gouv.fr

Germany
Iring Wasser (RAPPORTEUR)
Chief Executive Officer
Accreditation Agency for Degree Programmes in Engineering, Informatics, Natural Sciences and Mathematics (ASIIN E. V)
Robert-Stolz-Straße 5
D-40470 Düsseldorf
Tel. + 49 211 900977-10
gf@asiin.de

Italy
Giuliano Augusti
Professor of Structural Mechanics
Università La Sapienza
Faculty of Engineering
Via Eudossiana 18; I-00184
Roma
Coordinator of the EUR-ACE, EUR-ACE implemention andEUR-ACE Spread projects
President of ENAEE (European Network for the Accreditation of Engineering Education)
Giuliano.Augusti@uniroma1.it

Japan
Kikuo Kishimoto
Tokyo Institute of Technology
c/o Mr. Ryo Watanabe: ryo@nier.go.jp
c.c. himiyana@mext.go.jp, kfukuda@mext.go.jp, miho-k@mext.go.jp

Netherlands
Eric van der Geer-Rutten-Rijswijk
Vice Director Education
Industrial Engineering and Innovation Sciences
Eindhoven University of Technology
Den Dolech 2
Paviljoen, room A46a
P.O. Box 513
5600 MB Eindhoven
Tel. + 31 (0)40 247 2465
e.v.d.geer@tue.nl

Portugal
Alfredo Soeiro
University of Porto
Faculty of Engineering
Rua Dr. Roberto Frias, s/n 4200-465
Porto
avsoeiro@fe.up.pt

Romania

Iacint Manoliu
Professor of Soil Mechanics and Foundation Engineering
Technical University of Civil Engineering
Bucharest
manoliu@utcb.ro

Sweden

Mats Hanson
Mechatronics
Machine Design
School of Industrial Engineering and Management
KTH- Royal Institute of Technology
Maskinkonstruktion Brinellvägen 83
KTH Learning Lab Osquars backe 33
Stockholm
Tel. + 46 8 790 6309
mats@md.kht.se

United Kingdom

Rob Best
Deputy Dean
Faculty of Engineering, Science & the Built Environment
London South Bank University
103 Borough Road
London, SE1 0AA
rjbest@lsbu.ac.uk
www.lsbu.ac.uk/esbe
Tel. + 44 20 7815 7910

USA (CHAIR)

James L Melsa
College of Engineering
Iowa State University
Ames, IA 50011
Tel. + 1 630 420 1859
Fax + 1 630 420 1843
melsa@iastate.edu

Corresponding members

Australia

Andrew Downing
Head, School of Electrical and Information Engineering
University of South Australia
Australia
Tel. + 61 8 8302 5342
Fax + 61 8 8302 3384
andrew.downing@unisa.edu.au

Roger Hadgraft
Melbourne School of Engineering
The University of Melbourne, VIC 3010
Tel. + 61 3 8344 4226
Fax: + 61 3 9349 2182
roger.hadgraft@unimelb.edu.au

Italy
Francesco Maffioli
Professor of operational research
Coordinator of several European Thematic Networks in Engineering Education (H3E, E4, TREE).
Politecnico di Milano
Italy
maffioli@elet.polimi.it

Netherlands
Peter Wieringa
Director of education / vice dean
Faculty of Mechanical, Maritime, & Materials Engineering
Delft University of Technology
The Netherlands
P.A.Wieringa@tudelft.nl

Sweden
Johan Malmqvist
Professor Johan Malmqvist
Department of Product and Production Development
Chalmers University of Technology
SE-412 96 Göteborg
Sweden
joma@chalmers.se
Tel. + 46 31 772 1382

United Kingdom
Jim Birch
Head of International Recognition
Engineering Council UK
246 High Holborn, London WC1V 7EX
United Kingdom
Tel + 44 20 3206 0578
jbirch@engc.org.uk

USA
Patricia Daniels
Professor Emerita
Seattle University
daniels@seattleu.edu
Tel. +1-206-322-4857

Edwin C Jones Jr
University Professor Emeritus
Electrical and Computer Engineering
Iowa State University
USA
Mailing Address: 5289 Nolan Parkway, Oak Park Heights, MN 55082
Phone--Home: +1 651 275 3700
n2ecj@iastate.edu

- Washington Accord Web site www.washingtonaccord.org

Annex 1

Indicative overview of specializations / branches in the subject area of engineering.

- **Aerospace Engineering** – other forms include Aeronautical Engineering and Astronautical Engineering
- **Agricultural Engineering** – other forms include Forest Engineering and Biosystems Engineering
- **Architectural Engineering**
- **Bioengineering and Biomedical Engineering**
- **Biological Engineering**
- **Ceramic Engineering** – other forms include Glass Engineering
- **Chemical, Biochemical, and Bimolecular Engineering**
- **Civil Engineering**
- **Construction Engineering**
- **Computer Engineering**
- **Electrical Engineering** – other forms include Electronics Engineering
- **Engineering Management**
- **Engineering Mechanics**
- **Environmental Engineering** -- other forms include Sanitary Engineering
- **General Engineering** – other forms include Engineering Physics and Engineering Science
- **Geological Engineering**
- **Industrial Engineering**
- **Manufacturing Engineering**
- **Materials Engineering** -- other forms include Metallurgical Engineering and Polymer Engineering
- **Mechanical Engineering**
- **Mining Engineering**
- **Naval Architecture Engineering** -- other forms include Marine Engineering
- **Nuclear** -- other forms include Radiological Engineering
- **Ocean Engineering**
- **Petroleum Engineering** -- other forms include Natural Gas Engineering
- **Software Engineering**
- **Surveying Engineering**

Annex 2

COMPARISON OF LEARNING OUTCOMES FRAMEWORKS / STATEMENTS FOR ENGINEERING DEGREE PROGRAMMES

Cycle / Level (of degree)	**EUR-ACE Framework Standards for the Accreditation of Engineering Programmes**	**ABET-USA Criteria for Accrediting Engineering Programmes**	**Netherlands Criteria for Bachelor's and Master's Curricula, Technical Universities**	**Swedish System of Qualifications and Engineering Design Degrees**	**UK Quality Assurance Agency Subject benchmark statement for Engineering**
First cycle / Level 6 EQF/ BA	Minimum 180 ECTS credits (3 full-time years of study)	Bachelor degree 4 full-time years of study	180 ECTS credits Bachelor of Science (3 full-time years of study)	180 ECTS credits Bachelor of Science (3 full-time years of study)	360-420 CATS Bachelor's degree with honors (3-4 full-time years of study)
Type of descriptors / expected or desired Learning Outcomes	**Knowledge and Understanding** - Knowledge and understanding of the scientific and mathematical principles underlying their branch of engineering; - A systematic understanding of the key aspects and concepts of their branch of engineering - Coherent knowledge of their branch of engineering including some at the forefront	Engineering programmes must demonstrate that their students attain the following outcomes: a. An ability to apply knowledge of mathematics, sciences, and engineering; b. An ability to design and conduct experiments, as well as to analyze and interpret data; c. An ability to	**Explanatory note:** K = knowledge S = skills A= attitude Competent in one or more scientific disciplines - Understands the knowledge base of the relevant fields (theories, methods, techniques) [ks] - Understands the structure of the relevant fields, and the connection between sub-fields [ks] - Has knowledge of and some skill in the way in which truth-finding and the	**Knowledge and Understanding** - demonstrate knowledge of the scientific basis of their chosen area of engineering and its proven experience, as well as an awareness of current research and development work; - demonstrate broad knowledge in	**General Learning Outcomes** (Graduates with the exemplifying qualifications, irrespective of registration category or qualification level, must satisfy the following criteria); *Knowledge and Understanding* - be able to demonstrate their knowledge and understanding of essential facts, concepts, theories and principles of their engineer discipline, and its underpinning sciences and mathematics; - an appreciation of the wider

	of the branch; - Awareness of the wider multidisciplinary context of engineering.	design a system, component, or process to meet desired needs within the realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability , and sustainability; d. An ability to function on multidisciplinary teams; e. An ability to identify, formulate, and solve engineering problems; f. An understanding of professional and ethical responsibility g. An ability to communicate effectively h. The broad education necessary to understand the	development of theories and models take place in the relevant fields [ks]; - Has knowledge of and some skill in the way in which interpretations (texts, data, problems, results) take place in the relevant fields [ks]; - Has knowledge of and some skill in the way in which experiments, gathering of data and simulations take place in the relevant fields [ks]; - Has knowledge of and some skill in the way in which decision-making takes place in the relevant fields [ks]; - Is aware of both the presuppositions of the standard methods and their importance [ksa]; - Is able (with supervision) to spot gaps in his / her own knowledge, and to revise and extend it through study [ks].	their chosen area of engineering and relevant knowledge in mathematics and natural sciences	multidisciplinary engineering context and its underlying principles; - appreciate the social, environmental, ethical, economic and commercial considerations affecting the exercise of their engineering judgment. *Intellectual Abilities* - be able to apply appropriate quantitative scientific science and engineering tools to the analysis of problems; - be able to demonstrate creative and innovative ability in the synthesis of solutions and in formulating designs; - be able to comprehend the broad picture and thus work with an appropriate level of detail. *Practical skills* - possess practical engineering skills acquired through, for example, work carried out in laboratories and workshops; in industry through supervised work experience; in individual and group project work; in design work; and in development and use of

		impact of engineering solutions in a global, economic, environmental, and societal context; i. A recognition of the need for, and the ability to engage in life-long learning; j. A knowledge of contemporary issues k. An ability to use the techniques, skills, and modern engineering tools necessary for engineering practice Programme outcomes are outcomes (a) through (k) plus additional outcomes that may be articulated by the programme.			computer software in design, analysis and control; - evidence of group working and of participation in a major project (individual professional bodies may require particular approaches to this requirement). *General transferable skills* - developed transferable skills of value in a wide range of situations, these include problem solving, communication, and working with others, as well as effective use of general IT facilities and information retrieval skills, as well as planning self-learning and improving performance as the foundation of LLL.

	Engineering Analysis - The ability to apply their knowledge and understanding to identify, formulate and solve engineering problems using established methods; - The ability their knowledge and understanding to analyze engineering products, processes and methods; - The ability to select and apply relevant analytic and modeling methods.		**Competent in doing research** - Is able to reformulate ill-structured research problems. Also takes account of the system boundaries in this. Is able to defend the new interpretation against involved parties[ksa]; - Is observant, and has the creativity and the capacity to discover in apparently trivial matters certain connections and viewpoints [ksa]; - Is able (with supervision) to produce and execute a research plan [ks]; - Is able to work at different levels of abstraction [ks]; - Understands, where necessary, the importance of other disciplines (interdisciplinarity) [ka]; - Is aware of the changeability of the research process through external circumstances or advancing insight [ka]; - Is able to assess research within the discipline on its usefulness [ks]; - Is able (with supervision) to contribute to the development of scientific knowledge in one or more areas of the discipline	**Skills and Abilities** - demonstrate an ability, taking a holistic approach, to independently and creatively identify, formulate and manage issues, and to analyze and assess different technical solutions; - demonstrate an ability to plan and, using appropriate methods , carry out tasks within specified parameters; - demonstrate an ability to use knowledge critically and systematically and to model, stimulate, predict and evaluate events on the basis of relevant information;	Specific Learning Outcomes in Engineering (Graduates from accredited programmes must achieve the following LO, defined by broad areas of learning): *Knowledge and Understanding* - Knowledge and understanding of scientific principles and methodology necessary to underpin their education in their engineering discipline, to enable appreciation of its scientific and engineering context, and to support their understanding of historical, current and future developments and technologies; - Knowledge and understanding of mathematical principles necessary to underpin their education in their engineering disciple and to enable them to apply mathematical methods, tools and notations proficiently in the analysis and solution of engineering problems; - Ability to apply and integrate knowledge and

			concerned [ks]	- demonstrate an ability to design and manage products, processes and systems taking into account people's situations and needs and society's objectives economically, socially and ecologically sustainable development; - demonstrate an ability to engage in teamwork and cooperation in groups of varying composition - demonstrate an ability to present and discuss information, problems and solutions in dialogue with different groups, orally and in writing	understanding of other engineering disciplines to support study of their own engineering discipline.

	Engineering Design - The ability to apply their knowledge and understanding to develop and realize designs to meet defined and specified requirements; - An understanding of design methodologies, and an ability to use them;		**Competent in designing** - Is able to reformulate ill-structured design problems. Also takes account of the system boundaries in this. Is able to defend this new interpretation against the involved parties[ksa]; - Has creativity and synthetic skills with respect to design problems [ksa]; - Is able (with supervision) to produce and execute a design plan [ks]; - Is able to work at different levels of abstraction including the system level [ks]; - Understands, where necessary, the importance of other disciplines (interdisciplinarity) [ks]; - Is aware of the changeability of the design process through external circumstances or advancing insight [ka]; - Is able to integrate existing knowledge in a design [ks]; - Has the skill to take design decisions, and to justify and evaluate these in a systematic manner [ks]	**Judgments and Approach** - demonstrate an ability to make assessments, taking into account relevant scientific, social and ethical aspects; - demonstrate insight into the potential and limitations of technology, its role in society and people's responsibility for its use, including social and economic aspects, as well as environmental and work environmental aspects; - demonstrate an ability to identify their need of further knowledge and to continuously upgrade their capabilities -	*Engineering Analysis* - Understanding of engineering principles and the ability to apply them to analyze key engineering processes; - Ability to identify, classify and describe the performance of systems and components through the use of analytical methods and modeling techniques; - Ability to apply quantitative methods and computer software relevant to their engineering discipline, in order to solve engineering problems; - Understanding of ad ability to apply a systems approach to engineering problems.

	Investigations - The ability to conduct searches of literature, and to use data bases and other sources of information; - The ability to design and conduct appropriate experiments, interpret the data and draw conclusions; - Workshop and laboratory skills;		**A scientific approach** - Is inquisitive and has an attitude of lifelong learning [ka] - Has a systematic approach characterized by the development and use of theories, models and interpretations [ksa]; - Has the knowledge and the skill to use, justify and assess as their value models for research and design (models understood broadly: from mathematical model to scale model). Is able to adapt models for his or her own use [ks]; - Has insight into the nature of science and technology (purpose, methods, differences and similarities between scientific fields, nature of laws, theories, explanations, role of the experiment, objectivity, etc).[k]; - Has insight into the scientific practice (research system, relation with clients, publication system, importance of integrity, etc.). [k]; - Is able to document adequately the results of	**Others** - completed an independent project (degree project) worth at least 15 higher education credits, within the framework of the course requirements	*Design* Graduates need the knowledge, understanding and skills to: - Investigate and define a problem and identify constraints including environmental and sustainability limitations, health and safety and risk assessment issues; - Understand customer and user needs and the importance of considerations such as aesthetics; - Identify and manage cost drivers; - Use creativity to establish innovative solutions; - Ensure fitness for purpose for all aspects of the problem including production, operation, maintenance and disposal; - Manage the design process and evaluate outcomes.

			research and design with a view to contributing to the development of knowledge in the field and beyond [ksa]. -		
	Engineering Practice - The ability to select and use appropriate equipment, tools and methods; - The ability to combine theory and practice to solve engineering problems; - An understanding of applicable techniques and methods, and their limitations; - An awareness of the non-technical implications of engineering practice;		**Basic intellectual skills** - Is able (with supervision) to critically reflect on his or her own thinking, decision making, and acting and to adjust these on the basis of this reflection [ks]; - Is able to reason logically within the field and beyond; both 'why' and 'what-if' reasoning [ks]; - Is able to recognize modes of reasoning (induction, deduction, analogy, etc.) within the field [ks] - Is able to ask adequate questions, and has a critical yet constructive attitude towards analyzing and solving simple problems in the field [ks]; - Is able to form a well-reasoned opinion in the case of incomplete or irrelevant data [ks]; - Is able to take a standpoint with regard to a scientific argument in the field [ksa]; - Possesses basic numerical		*Economic, social and environmental context* - Knowledge and understanding of commercial and economic context of engineering processes; - Knowledge of management techniques which may be used to achieve engineering objectives within that context; - Understanding of the requirement of engineering activities to promote sustainable development; - Awareness of the framework of relevant legal requirements governing engineering activities, including personnel, health safety, and risk (including environmental risk) issues; - Understanding of the need for a high level of professional and ethical conduct in engineering.

			skills, and has an understanding of orders of magnitude [ks].		
	Transferable Skills - Function effectively as an individual and as a member of a team; - Use diverse methods to communicate effectively with the engineering community and with society at large; - Demonstrate awareness of the health, safety and legal issues and responsibilities of engineering practice, the impact of engineering solutions in a societal and environmental context, and commit to professional ethics, responsibilities and norms of engineering practice; - Demonstrate awareness of project management and				*Engineering Practice* - Knowledge of characteristics of particular materials, equipment, processes, or products; - Workshop and laboratory skills; - Understanding of contexts in which engineering knowledge can be applied (rg. Operations and management, technology development, etc.); - Understanding use of technical literature and other information sources; - Awareness of nature properly and contractual issues; - Understanding of appropriate codes of practice and industry standards.

	business practices, such as risk and change management, and understand their limitations; - Recognize the need for, and have the ability to engage in independent, life-long learning.				