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A Tuning-AHELO Conceptual Framework of Expected Desired/ Learning Outcomes in Engineering

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

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The OECD Secretariat, at the invitation of the AHELO GNE, contracted the Tuning Association to undertake initial development work on expected/intended learning outcomes in the two disciplines selected for the AHELO Feasibility Study —achieved through a Tuning-AHELO project. Academics from various countries reflected and agreed upon definitions of expected learning outcomes for bachelor's-type programmes in economics and engineering. This working paper presents the outcomes of their work in the engineering discipline.

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TABLE OF CONTENTS

OECD DIRECTORATE FOR EDUCATION 4
OECD EDUCATION WORKING PAPERS SERIES 4
Abstract 5
Résumé 5
FOREWORD BY THE OECD SECRETARIAT 6
INTRODUCTION 7
1. PROJECT CONTEXT 11
2. ENGINEERING AND ITS TEACHING 13
3. OVERVIEW OF TYPICAL DEGREES OFFERED IN ENGINEERING 15
4. OVERVIEW OF TYPICAL ENGINEERING OCCUPATIONS WITH A FIRST CYCLE (BACHELOR'S) DEGREE AND A SECOND CYCLE (MASTER'S) DEGREE 17
5. ROLE OF LEARNING OUTCOMES, (CYCLE) LEVEL DESCRIPTORS AND QUALIFICATIONS FRAMEWORKS 19
6. OVERVIEW OF PRIOR WORK ON THE LEARNING OUTCOMES APPROACH IN ENGINEERING 24
The Swedish system of qualifications and engineering design degrees 24
The ABET's Engineering Criteria 2000 (EC2000) 24
Tuning educational structures in Europe – the work of the engineering Thematic Networks 24
Learning outcomes in civil engineering – the EUCEET Tuning Task Force 25
ESOEPE, ENAEE and the European Accredited Engineering System 25
Washington Accord 25
The Dutch Criteria for bachelor's and master's engineering curricula 25
Standards for professional engineers in the United Kingdom 25
Criteria for Engineer's degrees in France 26
Comparative summary of engineering learning outcomes in five national/continental systems 26
7. APPROACH USED IN DEFINING LEARNING OUTCOMES STATEMENTS 27
8. OVERVIEW OF AGREED LEARNING OUTCOMES STATEMENTS 30
Generic Skills (d, g, h, i) 30
Basic and Engineering Sciences (a) 30
Engineering Analysis (b, e) 30
Engineering Design (c) 31
Engineering Practice (f, j, k) 31
9. LEARNING OUTCOMES FOR BRANCHES OF ENGINEERING 33
The development of learning outcomes at branch level 33
Specific learning outcomes for electrical engineering – first cycle 33

Specific learning outcomes for civil engineering – first cycle 34
Specific learning outcomes for mechanical engineering – first cycle 35

10. NEW APPROACHES REQUIRED IN TEACHING, LEARNING AND ASSESSMENT FOR OUTCOME-BASED LEARNING 36

11. CONCLUDING REMARKS 39

Challenges and opportunities for the future 39
Recommendations 39

12. REFERENCES 40

13. MEMBERSHIP OF THE TUNING-AHELO EXPERT GROUP ENGINEERING 44

Project coordinator 44
Project assistant 44
List of members 44
Corresponding members 46
Annex 1 Indicative overview of specialisations/branches in the subject area of engineering 47
Annex 2 Comparison of learning outcomes frameworks/statements 48
for engineering degree programmes 48

OECD DIRECTORATE FOR EDUCATION

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Abstract

The OECD Secretariat, at the invitation of the AHELO Group of National Experts, contracted the Tuning Association to undertake initial development work on learning outcomes to be used for valid and reliable assessments of students from diverse institutions and countries. The two disciplines selected for the AEHLO Feasibility Study are engineering and economics.

Following the Tuning approach, academics from various regions and countries in the world reached consensus on definitions of expected learning outcomes for bachelor's-type programmes in both disciplines. This Working Paper presents the outcomes of their work for the engineering discipline.

Members of the Engineering Tuning-AHELO working group defined general learning outcomes for all engineering programmes supplemented by branch specifications for the fields of mechanical, electrical and civil engineering, taking into account different degree profiles and relevant occupations.

In addition to the agreed upon learning outcomes, the paper presents an overview of the field of engineering, the typical degrees and engineering occupations associated to the first and second cycle degrees. The paper also discusses the role of learning outcomes and presents the approach used to defining them. A comparative summary of some of the most influential learning outcomes frameworks in the engineering field is also provided.

Résumé

Le Secrétariat de l'OCDE, à l'invitation du Groupe National d'Experts de AHELO, a mandaté l'association Tuning pour conduire un travail initial sur les résultats d'apprentissage qui seront utilisés dans le cadre d'évaluations valides et fiables d'étudiants provenant de divers établissements et de différents pays. Les deux disciplines sélectionnées pour l'étude de faisabilité AHELO sont l'ingénierie et l'économie.

Suivant l'approche TUNING, des universitaires provenant de divers pays et régions du monde, se sont mis d'accord sur une définition des résultats attendus d'étudiants de 1er cycle universitaire dans les deux disciplines. Ce document de travail présente le produit de leur réflexion s'agissant de l'ingénierie.

Tout en tenant compte des cycles d'études et des professions, les membres du groupe de travail Ingénierie Tuning-AHELO ont défini les résultats d'apprentissage pour l'ensemble des programmes d'ingénierie, et de ceux plus spécifiques à trois branches de l'ingénierie, soient l'ingénierie mécanique, l'ingénierie électrique et l'ingénierie civile.

Le document présente également le champ couvert par l'ingénierie, les types de diplômes et de métiers possibles pour le premier et le second cycle. Il reflète par ailleurs les débats sur le rôle des résultats d'apprentissage et réunit les approches ayant servi à les définir. Un résumé des travaux conduits précédemment sur les résultats d'apprentissage en ingénierie est inclus.

FOREWORD BY THE OECD SECRETARIAT

1. Assessing student performance in the discipline strands of the AHELO feasibility study is intended to complement the information gathered by the generic skills strand. An entirely unique approach to generic competencies would be limiting as it would not assess the kind of subject-matter competencies that many higher education departments or faculties consider their primary objective. Measurements could become too far removed from the actual context in faculties and departments and fail to capture the competencies that are exclusive to higher education institutions (HEIs).

2. To overcome this constraint, the discipline strands of the AHELO feasibility study will seek to assess discipline-related competencies. Economics and engineering assessments will determine the viability of measuring discipline-specific skills in these two contrasted disciplines representing both scientific and social sciences domains, with the understanding that a full-fledged AHELO main study would examine more disciplines over a given period of time.

3. The development of assessment frameworks is, however, a lengthy process and the OECD Secretariat initiated work prior to the completion of the AHELO tendering process in order to save time. In particular, the Secretariat, at the invitation of the AHELO GNE, contracted the Tuning Association to undertake initial development work on expected/intended learning outcomes in the two selected disciplines—achieved through a Tuning-AHELO project. Academics from various countries reflected and agreed upon definitions of expected learning outcomes for bachelor's-type programmes in economics and engineering.

4. This working paper presents the outcomes of their work in the engineering discipline. While further work is needed to develop assessment frameworks, this paper provides a first indication that agreement on expected learning outcomes in the engineering discipline can be achieved cross-culturally. This report could be considered a preliminary output of the AHELO feasibility study, as it will stimulate further reflection on the development of assessment frameworks and spur discussion on the assessment of learning outcomes in the engineering discipline.

INTRODUCTION

1. The OECD has launched a feasibility study, Assessment of Higher Education Learning Outcomes (AHELO), which is a ground-breaking initiative that will assess learning outcomes on an international scale by creating measures that would be valid for all cultures and languages.

2. More students than ever are enrolled in post-secondary degree programmes. As society and employability are rapidly changing, this initiative should be considered within the context of ever more student participation in higher education degree programmes. While many traditional jobs are disappearing or changing in content and form, new jobs are emerging. Both require new knowledge and skills therefore the way education is offered and perceived needs to be adjusted accordingly. Higher education institutions throughout the world are expected to respond to these demands. The higher education sector is aware of its responsibility to prepare their graduates for citizenry as well as for a dynamic job market. Higher education graduates are expected to be flexible, internationally-oriented and be able to remain current within a Life Long Learning context.

3. The AHELO feasibility study contains four complementary strands of work: i) a generic skills or transferable competencies strand; ii) an economics strand; iii) an engineering strand; and iv) a value-added measurement strand that will recommend possible methodologies to capture learning gain during a student's higher education experience notwithstanding their previously attained abilities. The first three strands will contain a contextual dimension to assess the feasibility of capturing information on institutional settings, teaching practices and environment characteristics that may affect learning, as well as indirect proxies of quality.[1]

4. At present, higher education institutions, encompassing research universities, universities of applied sciences (polytechnic schools) as well as colleges, are transforming. The traditional 'staff-centred' and 'knowledge-oriented' approach is slowly giving way to degree programmes which place the student at the centre of the teaching and learning process. In practice this implies that, besides knowledge acquisition, more attention is given to applying subject-specific skills as well as to general academic skills. The aim is for the students to be as competent as possible in a given timeframe for their future role in society by expanding the educational offer and by making optimum use of their interests and capabilities.

5. A methodology has been developed – originally within the framework of the European Bologna Process[2] (2001) – by a large group of universities and their departments in the initiative *Tuning Educational Structures in Europe*[3], to meet the above-mentioned challenges. Since its launch, Tuning has been strongly supported – financially and ethically – by the European Commission.

6. Tuning is a university-driven initiative, which was originally created to offer a concrete approach to the implementation of the European Bologna Process within 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 rather for points of reference, convergence and common understanding. Tuning avoids using the expression "subject area 'standards'", due to its connotation in many higher educational settings as a 'straitjacket' although it acknowledges that in other countries the expression is understood differently. Protecting the wide 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.

7. 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's, master's and doctorate degrees. Having been tested and found successful on several continents, the approach can be considered legitimate internationally. In 2007, groups of high level peers validated the Tuning approach as a methodology as well as an application in numerous disciplines. It is currently applied in more than 30 subject areas, in many institutions throughout Europe and Latin America as well as some countries in (Eur)Asia (*e.g.* Kyrgyz Republic, Georgia)[4]. Information sessions have raised awareness of the Tuning approach in other regions of the world, such as Australia, India and Japan. At present, the Tuning methodology is being tested in three US states[5].

8. Furthermore, Tuning has served and is serving as a platform for developing reference points within subject areas. These reference points are relevant for making study programmes comparable, compatible and transparent. They are expressed in terms of learning outcomes and competencies. 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. Competencies 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 competencies as "demonstrated ability to apply knowledge and skills". All educational programmes aim to foster these competencies, which build on the *knowledge and understanding* developed over a period of many centuries. Competencies are developed in all course units, usually in an integrated and cyclical manner, and assessed at different stages of a programme. Some competencies are subject area-specific (to a field of study); others are generic (common to any degree course). Tuning organised several consultation processes including employers, graduates and academic staff/faculty and students in different parts of the world to identify the most important competencies that should be developed in a degree programme. The outcome of these consultation processes is reflected in sets of reference points – generic and subject specific competencies – identified by each subject area.

9. According to Tuning, the use of the learning outcomes and competencies approach implies changes in the teaching, learning and assessment methods used in a programme. Tuning has identified approaches and best practices to form specific generic and subject-specific competencies. 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 learning outcomes and competencies (Wagenaar, 2003, 2006; ETCS, 2009).

10. Finally, Tuning has developed an approach to improve quality in the process of designing or re-designing, developing and implementing study programmes, which involves all elements of the learning chain. It has also created a number of tools and has identified examples of good practice that can help institutions enhance the quality of their study programmes. The OECD-AHELO project has asked the Tuning Association to define two conceptual frameworks of expected/desired learning outcomes, one in engineering and one in economics following the *Tuning* approach. This document sets out the framework for **engineering** and provides an intermediate output of the AHELO feasibility study. It will also supply useful input for test developers to design and develop (an) instrument(s) to measure/to assess the performance of students who will soon complete their first (cycle) or bachelor's degree. The coverage of this framework, however, is not seen as a prescriptive requirement at the feasibility study stage. This assessment should provide high-quality data to be used to improve the quality of higher education

programmes throughout the world. This report presents and explains the framework, which follows the structure:

i. Project context

ii. Engineering and its teaching

iii. Overview of typical degrees offered in engineering

iv. Overview of typical engineering occupations, with a first-cycle (or bachelor's) degree and a second-cycle (master's) degree

v. Role of learning outcomes, (cycle) level descriptors and qualifications frameworks

vi. Overview of prior work on the learning outcomes approach in engineering

vii. Approach used in defining learning outcomes statements

viii. Overview of agreed learning outcomes statements

ix. Learning outcomes for a selected number of branches of engineering

x. New approaches required in teaching, learning and assessment for outcome-based learning

xi. Concluding remarks

xii. References

xiii. Membership of the engineering expert group

11. A group of experts defined this conceptual framework. It was previously agreed that the group should cover a range of continents and thirteen countries, as well as various specialisations and branches of engineering. These experts should have a good overview of the field as well as the issues at stake. A distinction was made between full members and corresponding members whereas full members actually met in Brussels on 4 and 5 May 2009 to discuss the report. Both full members and corresponding members have received all documents and were invited to reflect and advise on all materials.

12. To establish the experts' group for engineering, representative organisations were contacted [for Europe FEANI (Fédération Européenne d'Associations Nationales d'Ingénieurs/European Federation of National Engineering Associations) 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)]. In setting up the group, discussions were held with, in particular, the president of ENAEE, Prof. Giuliano Augusti and 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 provided useful advice on the composition of the engineering experts' group. Furthermore, members of the AHELO Group of National Experts (GNE)[6] were instrumental in assisting the Tuning Association to identify a number of the experts.

13. This report's actual text was prepared by 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 co-ordinator for

engineering, Robert Wagenaar. They used the contributions of the other members. The final result is collaborative work of all members involved.

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1 AHELO Website: www.oecd.org/edu/ahelo

2 Bologna Process Website: www.ond.vlaanderen.be/hogeronderwijs/bologna/

3 Tuning Europe Website: http://tuning.unideusto.org/tuningeu/

4 Nearly 100 academic communities applied the Tuning methodology in 58 countries.

See also the following Websites:

Tuning América Latina Website: http://tuning.unideusto.org/tuningal/
Tuning Kyrgyz Republic Website: www.bolognakg.net/default2.html
Tuning Georgia Website: www.mes.gov.ge
Tuning Russia Website: www.iori.hse.ru/tuning/

5 Tuning USA Website: www.luminafoundation.org/newsroom/news_releases/2009-04-08.html and www.luminafoundation.org/our_work/tuning/

6 The AHELO feasibility study is jointly steered by governments, HEIs and agencies through the Programme for Institutional Management in Higher Education (IMHE) Governing Board – which brings together these different groups with a common interest in improving institutional management and effectiveness. However the technical nature of the project has led the IMHE Governing Board and the Education Policy Committee to delegate decisions on the methods, timing and principles of the AHELO feasibility study to an AHELO Group of National Experts.

1. PROJECT CONTEXT

14. The higher education environment is changing. Universities now need to play more of a role in our knowledge-based society. Information and communication technologies are having greater impact and innovation is becoming increasingly essential. Diversity should be fostered and managed while improving and maintaining quality. New skills have to be developed and adapted to fit new, emerging occupational contexts.

15. These rapid changes are raising new challenges. All types of education institutions are dealing with management, organisation and financing reforms. HEIs' educational strategy reforms are dramatic and affecting how they position themselves and their mission. In particular, there is a major shift, accompanied by significant impacts, "from teaching to learning organisations". The perspective is moving from a "knowledge-oriented approach," with the teacher as the key element, to a "learner-oriented approach," in which degree programmes are student-centric and improve the development of student capacities.

16. These programmes should foster knowledge and understanding of the various and complex areas of an ever-changing society and workforce. They also need to develop the capacity to manage this knowledge and apply it in practical contexts. This knowledge must include the capacity to judge inconsistencies, the ability to create solutions, communicate results and focus on a number of subject-specific as well as transversal competencies. Learners have to be able to meet future academic and professional challenges. Quality programmes should be created to deliver what they promise, be relevant to social needs and, above all, develop the capacity of learners to make optimal use of their time, interests and capacities.

17. Although some countries still focus on the knowledge base, using learning outcomes to assess the quality of provision is becoming increasingly important or of serious interest to those involved in higher education. This is especially true for educators tracking the Bologna Process not only in Europe but also in Australia, Latin America, New Zealand, South Africa and the United States. HEIs are striving to reform their educational strategies to reflect a student outcome-based approach. This reform process could be the most dramatic ever experienced within higher education due to its intensity, extent and depth.

18. Engineering is a unique and broad subject area which has switched over to a more student-centred approach. Accrediting/regulatory bodies have contributed to establishing competencies and learning outcomes to be achieved in degree programmes. Within the field, three different educational tracks or profiles are distinguished: engineers, engineering technologists and engineering technicians. These categories may have different titles or designations and different legal empowerment or restrictions within individual (national) jurisdictions.

19. The specific elements covered in this report include:

- Different aspects of engineering, specialisations and branches. Discussions among some experts from different approaches and selected regions of the world led to the identification of programme-level learning outcomes for the first-cycle bachelor's degree (following secondary school).

- Expression of student learning outcomes in competencies. In the language of the Tuning Project, learning outcomes indicate the specific level at which a competence is attained.

- An accepted understanding of higher education cycle levels to shape the perception of degrees.

- Use of the *Tuning* approach, which is based on establishing consensus and has been developed, constructed and widely accepted by over 94 academic communities[7] in 57 countries[8] throughout the world.

- The challenges that emerge when attempting to describe higher-level student learning outcomes or competencies in an evolving field.

20. The overall aim of the project is to reach agreement, ideally at the global level, regarding the descriptors for the key competencies (expected or intended learning outcomes) for the first-cycle bachelor's degree. In developing these descriptors and learning outcomes, different degree profiles and relevant occupations have been taken into account.

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7 Nearly 100 academic communities applied the Tuning methodology in 58 countries.

8 Argentina, Austria, Belgium, Bolivia, Bosnia and Herzegovina, Brazil, Bulgaria, Chile, Colombia, Costa Rica, Croatia, Cuba, Cyprus, Czech Republic, Denmark, Dominican Republic, Ecuador, El Salvador, Estonia, Finland, France, Georgia, Germany, Greece, Guatemala, Honduras, Hungary, Iceland, Ireland, Italy, Kyrgyz Republic, Latvia, Lithuania, Luxembourg, Malta, Mexico, Moldova, the Netherlands, Nicaragua, Norway, Panama, Paraguay, Peru, Poland, Portugal, Romania, Russia, Serbia, Slovak Republic, Slovenia, Spain, Sweden, Switzerland, United States, United Kingdom, Ukraine, Uruguay, Venezuela.

2. ENGINEERING AND ITS TEACHING

21. The fundamental inventions as devised by early man, such as the pulley, lever, and wheel, are consistent with the modern definition of engineering, exploiting basic mechanical and scientific principles to develop useful tools, objects, and solutions to problems.

22. The original formal use of the term *engineer* applied to the constructor of military engines[9] such as catapults. Later, as the design of civilian structures such as bridges and buildings evolved as a technical discipline, the term *civil engineering* entered the lexicon as a way to distinguish between those specialising 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* emerged.

23. Engineering has classically been defined as the profession that deals with the application of technical, scientific, and mathematical knowledge in order to use natural laws and physical resources to help design and implement materials, structures, machines, devices, systems and processes that safely accomplish a desired objective. As such, engineering is the interface between scientific and mathematical knowledge and human society. The primary activity of engineers is to conceive, design, implement, and operate[10] 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.

24. "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.[11]"

25. "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." (National Academy of Engineering, 2004)

26. "The idea of design – of making something that has not existed before – is central to engineering." (Petroski, 1985). While scientists attempt to explain what is, engineers create what has never been. While scientists ask "why," engineers ask "why not."

27. As the focus of the world has shifted from past technological inventions such as electrification, telephony, the computer, radio and television, and the automobile (Constable, 2001) to the more complex and challenging modern societal problems such as food, health, energy, water, and the environment (National Academy of Engineering, 2008a), the definition of engineering has similarly evolved so that it now: "No profession unleashes the spirit of innovation like engineering. From research to real-world applications, engineers constantly discover how to improve our lives by creating bold new solutions that connect science to life in unexpected, forward-thinking ways (National Academy of Engineering, 2008b)".

28. As noted above, the engineering field now consists of 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 specialisations. Interestingly, as these new branches were emerging, the complex future challenges are demanding more interdisciplinary knowledge of all engineers hence breaking down the barriers between different areas of engineering.

29. With engineers facing challenging expectations, including the ability to address complex societal problems, engineering education must be carefully planned and executed so that the student obtains the necessary skills and competencies to be a successful professional engineer. This education must include a strong grounding in mathematics and science, both natural and life, as well as training in the specialty–specific engineering sciences. As design is a critically important skill of an engineer, students must deal with increasingly complex problems as they proceed through the educational process. The complexity of modern challenges facing engineers also requires that the education include sound foundation in topics such as economics, communications, team skills, and the current global geo-political environment.

30. Engineering professionals are expected to exhibit the highest standards of honesty and integrity. Engineering has a direct and vital impact on people's quality of life. Accordingly, the services provided by engineers require honesty, impartiality, fairness and equity. Engineers must be dedicated to the protection of public health, safety and welfare. They must uphold a standard of professional behaviour, adhering to the highest principles of ethical conduct.

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

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[9] 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.

[10] See Website: www.cdio.org

[11] UK Standard for Professional Engineering Competence (2008); Website Engineering Council UK; www.engc.org.uk

3. OVERVIEW OF TYPICAL DEGREES OFFERED IN ENGINEERING

32. As noted previously, military and civil engineering were the earliest engineering disciplines and applied engineering skills to solve military and civilian (*e.g.* roads and bridges) problems respectively. Chemical, electrical and mechanical engineering were then added. There are now more engineering specialisations with over thirty named degree programmes and new programmes being added regularly. See Annex 1 for an overview of degree programmes indicating the various branches in the engineering field.

33. The first cycle (bachelor's) degree in engineering is typically referred to as the Bachelor of Science in a specialisation such as civil engineering. The degree may be labelled 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,* as well as other variations.

34. In reference to the Bologna[12] Process, first cycle graduates should 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.

35. Depending on the country, first cycle degrees may be either a three or four year programme. There are ongoing discussions with regard to the equivalence of a three-year first cycle degree and the traditional four-year bachelor's 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 qualify for entry into the engineering practice.

36. Some would suggest that the traditional bachelor's degree falls between the European three-year first cycle and second cycle degrees. Although Engineers Australia has provisionally accredited the Master's of Engineering degree at a few universities (European style five-year degree structure), their engineering competency level is considered the same as that of the conventional four-year bachelor's degree. A meaningful measurement of the learning outcomes as defined in this report should add some much needed information to this discussion.

37. In some countries, there are two tracks for first-cycle degrees. One[13] (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 second track[14] (BEng) is more focused on theoretical and abstract thinking and creative analysis in problem solving. It sets the ground for continuing on to advanced degrees in engineering.

38. Second cycle (Master's) degrees follow a similar pattern of specialised branches. However, because students at this level are now focusing more on one technical area, more specialised degrees could be offered. Some institutions or countries offer integrated first and second cycle programmes.[15] In some cases, these integrated programmes are a combination of a first and second cycle programme. In other cases (*e.g.* the UK MEng degree), the programmes are more fully integrated.

39. Some educational institutions offer five-year degrees leading to the historical "Diplom Engr" or similarly entitled degree. These degrees are not discussed in this report.

[12] Bologna Process Website: www.ond.vlaanderen.be/hogeronderwijs/bologna/

[13] 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*. In the UK Incorporated Engineer (IEng) is a professional qualification in engineering offered through professional associations that act as subsidiary instruments of the Engineering Council UK, the regulatory authority for professional registration of engineers in the United Kingdom. Incorporated Engineers currently require an IEng accredited Bachelors or honours degree in engineering or technology, or a Higher National Certificate or Diploma or a Foundation Degree in engineering or technology, plus appropriate further learning. The academic requirements must be accompanied by the appropriate experience in employment. Incorporated Engineers' academic degrees are recognized internationally through the Sydney Accord academic agreement.

[14] *E.g.*, in the UK this route prepares for qualification as *Chartered Engineer.* In many countries, professional engineers are called Chartered Engineers. It is a qualification which is formally registered. The title Chartered Engineer is protected by civil law. The details of registration vary from country to country. However, in all cases the qualification is based on the combination of university education at masters level and demonstration of appropriate level of professional competence to practice, through evidence gained from records of initial professional development, and by professional review. Overall it usually takes a minimum of 8 years but usually 10 years of university education and post graduate training to achieve the Chartered Engineer qualification. Chartered Engineers' academic degrees are recognized internationally through the Washington Accord academic agreement.

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

4. OVERVIEW OF TYPICAL ENGINEERING OCCUPATIONS WITH A FIRST CYCLE (BACHELOR'S) DEGREE AND A SECOND CYCLE (MASTER'S) DEGREE

40. Graduates with a first cycle degree in one of the engineering fields may enter various positions in many different types of organisations. There are many graduates of engineering programmes who use their engineering education as an entry into other professions such as law or medicine. They may also choose to enter fields such as financial services, sales, or non-engineering management where their engineering skills can help them in 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 students' engineering education is valuable preparation for these career choices.

41. In most cases, first cycle graduates go to work directly for organisations that 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 duties ranging through the full life cycle of these products and services. Such roles might include limited basic research, design of the organisation's products or services, the production of the product or service, selling of the product or services to other technical or non-technical organisations, or the operation, servicing and/or maintenance of the product or service in field applications.

42. In some countries[16], the type of work open to graduates with only a first cycle degree may be limited. Some professional organisations in several countries[17] require a second cycle degree or its equivalent to become registered or to practice. Other professional organisations have opposed such a requirement and believe that a first cycle degree is sufficient to enter those professions.

43. In some cases, graduates choose to form new companies or 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.

44. The legality for graduates 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.

45. Many[18] first cycle graduates will pursue additional education often leading to second cycle degrees. In some cases, the students will continue their education while being employed as a practicing engineer.

46. 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 that primarily focus on the 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 higher level specialised engineering positions with a research focus, more loosely defined problems, and management responsibility.

[16] *E.g*. France.

[17] *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/)

[18] *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.

5. ROLE OF LEARNING OUTCOMES, (CYCLE) LEVEL DESCRIPTORS AND QUALIFICATIONS FRAMEWORKS

47. The higher education environment now relies on a combination of elements. These include the rise of the 'network' society, the restructuring of the economic world system, the political reshaping of world order, the growing real but also virtual mobility of people, capital and knowledge, the erosion of the nation-state and the very complex cultural developments, with an increasing cultural exchange and elements of cultural differentiation and segregation (Van Damme, 2001). Higher education institutions are therefore facing challenges such as the creation of new and more demanding strategies, ever more people throughout the world wanting to access higher education, tension in the national regulatory and policy frameworks, the emergence of borderless education and as a consequence the growing need for an international regulatory framework and the capacity to understand, transfer and recognise qualifications.

48. Trans-national education has developed as citizens have become more mobile with the emergence of the global society, the need to continue learning in formal and non-formal contexts in different geographical settings. The political will of regions has been a powerful force in this development, In Europe it was decided to create a common higher education area. Together they developed the Bologna Process as a dynamic tool to create a common framework for teaching and learning within higher education.

49. Globalisation in higher education has led to the creation of descriptors and agreed frameworks and therefore linked to the concept of learning outcomes. This concept in educational policies began in the 1990s and has gained momentum. Today it can be considered a prime change agent in higher education. The Quality Assurance Agency (QAA) for the United Kingdom and the Tuning process for Europe and beyond have been driving forces and sources of inspiration, as have others.

50. Within the framework of the Bologna Process, the importance of learning outcomes has risen ever higher on the political agenda. In the original 1999 Bologna Declaration and the Prague Communiqué of 2001[19] no reference was made to learning outcomes, although they figure prominently in all ensuing ministerial communiqués.

51. At the Berlin Bologna follow-up conference held 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 complete coherence with the Tuning approach. This is obvious in the language used, where ministers indicate that degrees should be described in terms of workload, level, learning outcomes, competencies and profile.

52. Subsequent to the Berlin conference, the Bologna follow-up group developed an overarching *Framework for Qualifications of the European Higher Education Area* (QF of the EHEA) which, in concept and language, is again fully aligned with the Tuning approach. This framework was adopted at the Bergen Bologna follow-up conference held in May 2005. The QF of the EHEA has capitalised on 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 with regard to subject area. 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 as it provides guidance for the construction of national qualifications frameworks based on learning outcomes and competencies as well as on credits. In addition, 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.

53. In 2006, the European Commission launched a European Qualifications Framework for Life Long Learning (EQF for LLL) seeking to encompass all types of learning in one overall framework. This framework is the outcome of the Copenhagen Process, which focuses on the Vocational Educational and Training sector. The EQF meta-framework intends to act as a translation device between member states' national qualifications systems. It provides employers and educational establishments across Europe the opportunity to compare and better understand the qualifications presented by individuals. The core of the EQF system is its eight reference levels, covering the range from basic to highest level qualifications. Within this framework every new qualification issued in the EU should have a reference to the appropriate EQF reference level, "so the benefits to mobility and lifelong learning that the EQF brings will be visible and available to every EU citizen". National Qualifications Frameworks (NQFs) are presently being mapped to the QF for the EHEA and/or the EQF for LLL.

54. In providing descriptors and key competencies (expected or intended learning outcomes) for the first cycle, the use of meta-frameworks and their points of reference are critical because they:

- are the result of debate and agreement by a large group of academics and stakeholders from various regions,
- have been considered relevant indicators and signify important landmarks in the educational processes,
- offer a common direction and context for the development of a common understanding and co-ordination,
- prompt reflection and mutual learning around critical issues related to the outcomes at specific moments in the educational process, as well as the recognition of the need for equity, and
- provide a comprehensive context for the indicators giving them meaning and value.

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

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

57. In the London Communiqué of 2007, 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."* [20]

58. Today, the Bologna Process has encouraged the transition of HE focus on knowledge possession to understanding performances, from a teaching- to a student-centred 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*" (Adam, 2008).

59. In spite of this common political agenda, the learning outcomes for European bachelor's (and master's) programmes, agreed by the 46 members of the European Higher Education Area and referred to as "Dublin Descriptors" (see above), have been very difficult to operationalise. This is because they are generic in nature and do not address various learning outcomes at the disciplinary level. Given the considerable diversity of the education systems in EHEA member states, this departure might be understandable. In recent years, however, there has been growing demand by academics and employers alike to develop sectoral qualifications profiles and learning outcomes. In addition, at the political level, the ministers of education for the first time stressed the importance of learning outcomes at the disciplinary level in their recent Leuven/Louvain-la-Neuve Communité Communiqué:

> "*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 further implementation of the European Standards and Guidelines for quality assurance*". [21]

60. Qualifications Frameworks are not limited to Europe. Already in the 1990s, Australia developed its "comprehensive national system of cross-sectoral educational qualifications capable of supporting the increasingly diverse needs of students in education and training". This Australian Qualifications Framework (AQF) was implemented on 1 January 1995 and based on nine levels of qualifications and associated titles in tertiary education. The AQF was, and is, the principal assurance mechanism for Australia's education and training qualifications. However, the 1995 AQF is not based on learning outcomes. In May 2008, an AQF Council was established, which, as one of its first tasks, strengthened the existing AQF by basing it on learning outcomes. On 18 May 2009 the AQF Council published a consultation paper.[22]

61. New Zealand and South Africa are the other non-European countries with Qualifications Systems based on the concept of learning outcomes - i.e. knowledge, skills and competencies. The National Qualifications Framework (NQF) of New Zealand is designed to provide nationally recognised standards and qualifications as well as recognition and credit for a wide range of knowledge and skills. The framework, which contains ten levels, makes a distinction between "achievement standards" and "unit standards". The Ministry of Education develops all achievement standards. Each standard registered on the NQF describes what a learner needs to know or what they must be able to achieve.[23]

62. The *Tuning definition* of learning outcomes was provided in the introduction of this report. It is repeated 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*." (González, 2008, European Commission, 2009).

63. This definition of learning outcomes (Harvey, 2004-9), has obtained wide acceptance although there are many other definitions.

64. 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."

65. One has to differentiate between

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

66. A quality education can be assumed when a student has acquired knowledge, skills and wider competencies as described through the learning outcomes. Learning outcomes are 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 providing information on courses and programmes as well as study guidance, study planning. They can help assess learning and teaching methods and establish feedback mechanisms for students, employers and other stakeholders assessing the quality of the education at hand in relation to learning outcomes. In all the discussions, however, there is an underlying caveat that learning outcomes should not be used as a tool to standardise curricular content at 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 Group of National Experts.

67. As has been shown above, the learning outcomes concept has been, and is being, used in many different settings. It has been instrumental in developing qualifications frameworks in the LLL discussion, in developing the European Credit Transfer and Accumulation System, reforming curricular, in quality assurance and most importantly, as the primary vehicle for recognising qualifications and the corresponding academic and professional mobility.

68. In the field of engineering, the usefulness of the learning outcomes approach was identified early on and has paved the way for similar developments in other areas, as will be shown in the following section.

[19] Website: www.bologna-bergen2005.no/Docs/00-Main_doc/010519PRAGUE_COMMUNIQUE.PDF

[20] London Communiqué: Website: www.dcsf.gov.uk/londonbologna

[21] 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

[22] Website: www.aqf.edu.au/aboutaqf.htm

See also a publication of National Qualifications Authority of Ireland (2006), *Review of Qualifications Frameworks – International Practice* in which an overview is given of existing Qualifications Framework, including the ones from South Africa, Australia and New Zealand. www.nqai.ie/docs/framework/researchreports/review%20of%20qualifications%20frameworks.doc

[23] Website: www.nzqa.govt.nz/framework/ ;
text NQF: www.nzqa.govt.nz/news/featuresandspeeches/docs/nqf-background.pdf

6. OVERVIEW OF PRIOR WORK ON THE LEARNING OUTCOMES APPROACH IN ENGINEERING

69. In the field of engineering, the concept of learning outcomes was introduced prior to the above mentioned developments. In the 1990s and early 2000s, numerous methodologies were developed; some of the most influential are briefly described below.

The Swedish system of qualifications and engineering design degrees

70. The Swedish Higher Education Ordinance, which lists the national requirements for Swedish engineering degrees, was issued as early as 1993 with amendments in 2006[24]. It lists higher education qualifications for the first, second, and third level and the requirements that must be fulfilled for each qualification. The amendments include the first level professional qualifications as a Swedish engineer, whereby a distinction is made between knowledge and understanding, skills and abilities, judgement and approach.

The ABET's Engineering Criteria 2000 (EC2000)

71. One of the most important developments in the United States was the introduction of the Engineering Criteria 2000 (EC2000) for the Accreditation of Engineering Education by the Accreditation 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 facilities. 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. Consequently, the EC2000 criteria were elaborated. In terms of EC2000, the ABET's main requirement was for HE engineering programmes to be guided by a coherent quality scheme, starting with the institution's mission, learning outcomes for the individual engineering programmes, operationalisation of performance indicators, and a quality assurance system guaranteeing that the learning outcomes were actually being met. Next to programme-specific learning outcomes, ABET had formulated eleven generic outcomes to be reached by every engineering programme (criteria 3 a-k) at the bachelor's 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

72. From the start of the Tuning Project in 2001, many Erasmus Thematic Network Programmes (TNPs) linked up with the project as synergy groups, one of which was engineering. This TNP built on the experience obtained from the Thematic Network H3E (Higher Engineering Education for Europe 1996-99). The Thematic Network E4, "Enhancing Engineering Education in Europe" (E4) identified eleven competencies and learning outcomes to be achieved by (accredited) engineering programmes. At the same time, it demanded that those learning outcomes, at the end of the first cycle for a professional engineering programme from Europe, should be at least comparable to the above-mentioned ABET criteria.

73. Recently, the TNP for Electrical and Information Engineering in Europe (EIE) tested the Tuning approach. It organised a broad consultation with their stakeholders (academic staff, employers, graduates and students) following the Tuning model. This resulted in an extremely useful and interesting report.[25]

Learning outcomes in civil engineering – the EUCEET Tuning Task Force

74. In a report by the EUCEET-Tuning Task Force (European Civil Engineering Education and Training) 18 learning outcomes were presented to academics and employers in civil engineering. None of the items showed a significant heterogeneity among the countries involved (Manoliu, 2006).

ESOEPE, ENAEE and the European Accredited Engineering System

75. The European Standing Observatory was founded in September 2000 and later turned into the European Network for the Accreditation of Engineering Education (ENAEE). In the course of a number of European Accredited Engineer (EUR-ACE) Projects ("EUR-ACE"-, "EUR-ACE"- Implementation and "EUR-ACE"- Spread), five groups of learning outcomes were jointly conceived and agreed upon as minimum requirements for entry into the profession: i) Basic and Engineering Sciences, ii) Engineering Analyses and Investigations, iii) Engineering Design, iv) Engineering Practice, and v) Generic Skills. Today, these groups of learning outcomes are used in seven countries[26] in Europe as guidelines for curricular development and accreditation practice, recognition of engineering qualifications by the Fédération Européenne d'Associations Nationales d'Ingénieurs (FEANI) and the European Engineering indices and in the long term, as the basis for mutual recognition of accreditation decisions.

Washington Accord

76. The Washington Accord (WA) 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, the United Kingdom and the 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[27].

The Dutch Criteria for bachelor's and master's engineering curricula

77. The Dutch Technical Universities of Delft, Eindhoven and Twente formulated criteria for bachelor's and master's curricula at technical universities which is set out in a joint publication.

Standards for professional engineers in the United Kingdom

78. With the development of a mass higher education system and the associated need for transparency and quality assurance, some initiatives tried to provide a transparent, understandable description of the abilities that UK graduate engineers should possess. 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.

79. The ECUK Standard for Professional Engineering Competence (UK-SPEC) decides whether a programme is accredited based on whether the programme delivered the learning outcomes set out by professional institution. 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 achieved and at what level.

Criteria for Engineer's degrees in France

80. In France, the CTI (Commission des Titres d'Ingénieur) accredits engineering programmes. In their Self–Evaluation Guide for Engineering Education Programmes, expected outcomes have been designed (Part D2), although these outcomes are expected for integrated five-year programmes leading directly to a master's degree.[28]

Comparative summary of engineering learning outcomes in five national/continental systems

81. A comparative summary of some of the most influential learning outcomes frameworks in the engineering field is set out in Annex 2. That there is a common understanding throughout the world of what an engineer is supposed to know and be able to do is most striking and probably differentiates engineering from many other disciplines.

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24 Ministry of Education and Research of Sweden (2008), Higher Education Ordinance, pp. 51-52, 73-74. Website: www.regeringen.se/sb/d/574/a/21541

25 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*.

26 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 d'Ingénieur, 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.

27 Information about the Washington Accord can be found at the Website: www.washingtonaccord.org

28 CTI Website: www.cti-commission.fr

7. APPROACH USED IN DEFINING LEARNING OUTCOMES STATEMENTS

82. The Tuning-AHELO experts group for the engineering strand decided to synthesise the learning outcomes used by the European Network for the Accreditation of Engineering Education and the American Accreditation Board of Engineering and Technology for this project's set of commonly agreed learning outcomes because:

i. Both sets of criteria, ABET's EC2000 Criteria and the EUR-ACE learning outcomes, for first cycle bachelor's degrees of ENAEE have been recognised internationally. EUR-ACE learning outcomes and corresponding criteria have meanwhile been integrated into national learning outcomes and accreditation requirements of altogether seven European countries: France, Germany, Great Britain, Ireland, Portugal, Russia and Turkey (Adam, 2008).

ii. The ABET EC2000 standards have also been influential in the development of learning outcomes/accreditation standards in many other countries and regions, as well as through ABET accreditation activities outside the United States.

iii. With EC2000 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). In addition, the FEANI, the European Federation of Engineering Societies in 30 European Countries, has, in principle, agreed to recognise the EUR-ACE learning outcomes and Accreditation Results for their own index of accredited engineering courses and the European Engineering register of professional engineers. ABET is part of the "Washington Accord", which essentially is a mutual recognition agreement between twelve accreditation agencies in many countries, including Australia, Canada, Chinese Taipei, Hong Kong China, Ireland, Japan, Korea, New Zealand, Singapore, South Africa, the United Kingdom and the United States. Some institutions even have a membership in both ENAEE and WA. All these signatories are working on learning outcomes comparable to those of ABET, so that they are all taken into account.

iv. When comparing EUR-ACE learning outcomes for first cycle European degrees and ABET EC2000 learning outcomes, the members of the Tuning-AHELO experts group, 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 was feasible as set out in the following table:

Table 6.1

General Learning Outcomes Statements for Engineering

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 analyse engineering products, processes and methods; - The ability to select and apply relevant analytic and modelling methods.	b. An ability to design and conduct experiments, as well as to analyse 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 analyse 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 realise 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.		

Table 6.1 (continued)

EUR-ACE Framework Standards for the Accreditation of Engineering Programmes	ABET-USA Criteria for Accrediting Engineering Programmes	Tuning-AHELO framework of Learning Outcomes
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; - Recognise 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 recognise the need for and engage in independent life-long learning; - The ability to demonstrate awareness of the wider multidisciplinary context of engineering.

8. OVERVIEW OF AGREED LEARNING OUTCOMES STATEMENTS

83. The Tuning-AHELO project on learning outcomes is the result of a comparative review of the EUR-ACE Framework Standards for the Accreditation of Engineering Programmes and the ABET criteria for accrediting engineering programmes. It is consistent with other frameworks/sets of learning outcomes, relevant 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.

84. First cycle programme learning outcomes in engineering developed in the framework of the Tuning-AHELO project:

Generic Skills (d, g, h, i)

85. Graduates should possess generic skills needed to practice engineering. Among these are: the capacity to analyse and synthesise, apply knowledge to practice, adapt to new situations, ensure quality, manage information, and generate new ideas (creativity)[29]. 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 communicate effectively with the engineering community and with society at large;
- the ability to recognise the need for and engage in independent life-long learning; and
- the ability to demonstrate awareness of the wider multidisciplinary context of engineering.

Basic and Engineering Sciences (a)

86. In general, the underpinning knowledge and understanding of science, mathematics and engineering fundamentals are essential to satisfy other programme outcomes. Graduates should be able to demonstrate their knowledge and understanding of their engineering specialisation, 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; and
- the ability to demonstrate comprehensive knowledge of their branch of engineering including emerging issues.

Engineering Analysis (b, e)

87. Graduates should be able to solve engineering problems consistent with the level of knowledge and understanding expected at the end of a first cycle study programme, and may involve experience from outside their field of specialisation. Analysis can include the identification, specification and clarification

of the problem, determination of possible solutions, selection of the most appropriate solution method, and effective implementation. First cycle graduates should be able to use various methods, including mathematical analysis, computational modelling, or practical experiments, and should be able to recognise societal, health and safety, environmental and commercial constraints. Furthermore, graduates should be able to use appropriate research or other detailed investigative methods of technical issues consistent with the level of knowledge and understanding expected at the end of a first cycle study programme. Investigation may involve literature research, design and execution of experiments, interpretation of data, and computer simulation. It 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 analyse engineering products, processes and methods;
- the ability to select and apply relevant analytic and modelling methods;
- the ability to conduct literature searches, use databases and other sources of information; and
- the ability to design and conduct appropriate experiments, interpret the data and draw conclusions.

Engineering Design (c)

88. Graduates should be able to create engineering designs consistent with the level of knowledge and understanding expected at the end of a first cycle study programme, working in co-operation with engineers and non-engineers. The design may be of processes, methods or artefacts. The specifications should be wider than technical aspects, 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; and
- the ability to demonstrate an understanding of design methodologies, and be able to use them.

Engineering Practice (f, j, k)

89. 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 recognise the wider, non-technical aspects, 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 within a societal and environmental context, and commitment to professional ethics, responsibilities and norms of engineering practice; and
- the ability to demonstrate knowledge of project management and business practices, such as risk and change management, and awareness of their limitations.

[29] This list is based on an extensive 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 competencies / skills identified in the survey are included in the explicit lists of Learning Outcomes identified for the groups of programme Learning Outcomes.

9. LEARNING OUTCOMES FOR BRANCHES OF ENGINEERING

The development of learning outcomes at branch level

90. The Tuning-AHELO experts group considers the above-mentioned learning outcomes in engineering a significant development of the "Dublin Descriptors" and an important tool for fostering academic and professional mobility within the 34 OECD countries. The members of the experts group, however, went one step further and agreed to develop learning outcomes for certain engineering branches. They decided to concentrate on mechanical engineering, electrical engineering and civil engineering, three of the main engineering branches. 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 EC2000 learning outcomes for these three branches.

91. These branch specific learning outcomes statements should be read along with the general learning outcomes statements for the engineering subject area as presented in section 7. The general outcomes are specified in Table 6.1. These outcomes can be contextualised for subject areas but this should not lead to over-rigid specification. Care must be given so that assessment of such outcomes recognises the diversity of material which even mainstream subjects now encompass.

92. The result of this comparative approach and the synergetic result are set out below:

Specific learning outcomes for electrical engineering – first cycle

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

Required knowledge and understanding framework:

	Specific learning outcomes	*Relation to the general learning outcomes statement for engineering (section 7, Table 6.1)*
A	The ability to demonstrate knowledge of probability and statistics relevant to Electrical Engineering.	Basic and Engineering Sciences
B	The ability to demonstrate knowledge of mathematics including, at a minimum, differential and integral calculus, linear algebra, and discrete mathematics.	Basic and Engineering Sciences
C	The ability to demonstrate sound knowledge in the subject-specific fundamentals of electrical engineering 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.	Engineering Analysis

D	The ability to demonstrate 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.	Engineering Analysis
E	The ability to attribute fundamental phenomena of electrical engineering to electro-dynamic principles; and to design components and processes from electro-dynamic principles.	Engineering Analysis/Engineering Design
F	The ability to design analogue and digital, electric and electronic circuits, systems, and products.	Engineering Design

Specific learning outcomes for civil engineering – first cycle

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

Required knowledge and understanding framework:

	Specific learning outcomes	*Relation to the general learning outcomes statement for engineering (section 7, Table 6.1)*
A	The ability to demonstrate 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.	Basic and Engineering Sciences
B	The ability to demonstrate 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.	Basic and Engineering Sciences
C	The ability to demonstrate 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.	Basic and Engineering Sciences
D	The 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.	Engineering Analysis
E	The ability to demonstrate 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	Engineering Design/Engineering Practice

	networks, etc.), information technology, economics and sustainability.	
F	The ability to demonstrate 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.	Engineering Practice

Specific learning outcomes for mechanical engineering – first cycle

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

Required knowledge and understanding framework:

	Specific learning outcomes	*Relation to the general learning outcomes statement for engineering (section 7, Table 6.1)*
A	The ability to demonstrate knowledge and understanding of the basics of • mathematics including differential and integral calculus, linear algebra, and numerical methods; • high-level programming; • solid and fluid mechanics; • material science and strength of materials; • thermal science: thermodynamics and heat transfer; • operation of common machines: pumps, ventilators, turbines, and engines.	Basic and Engineering Sciences
B	The ability to analyse • mass and energy balances, and efficiency of systems; • hydraulic and pneumatic systems; • machine elements.	Engineering Analysis
C	The ability to carry out the design of elements of machines and mechanical systems using computer-aided design tools.	Engineering Design
D	The ability to select and use control and production systems.	Engineering Practice

10. NEW APPROACHES REQUIRED IN TEACHING, LEARNING AND ASSESSMENT FOR OUTCOME-BASED LEARNING

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

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

98. 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[30] 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 through blogs, wikis, virtual worlds and e-portfolios which are used in an Action-Research[31] programme with teachers as students.

99. *Design-Based Learning* (DBL) is another interesting new collaborative approach to successfully learn, teach and assess key learning outcomes in engineering. DBL is conceived as 'an educational model in which a major part of the curriculum and study programme is aimed at learning to design in engineering'. In DBL, not only are the resulting products important, the underlying process is highly relevant as well. DBL explicitly involves a form of university education giving academic skills a prominent position. These would include strategic thinking regarding activities, critical analysis of design tasks, broad interpretation of design requirements, incorporation of contemporary scientific views, etc. DBL could be characterised particularly as integrative, multidisciplinary, practice-oriented, creative, co-operative (teamwork), competence-oriented (skills), activating, fostering responsibility, synthesising, and leading to professionalisation. In DBL, once the design task is set, the teacher 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. It is believed that students are truly thinking critically when they formulate their own constructs and solutions. By making use of DBL, students are stimulated to develop higher level thinking skills, gain a positive attitude toward the subject matter, practice modelling societal and work-related roles, and generate more and better design questions and solutions. DBL is assumed to increase knowledge retention, develop students' general problem-solving skills, improve integration of basic science concepts into real-life problems, stimulate the development of self-directed learning skills, and strengthen intrinsic motivation (Wijnen, 1999).

100. In addition to the standard, summative teacher-course evaluations, face-to-face interactions between students and "trusted" advisors can be used to obtain more detailed information regarding the "success" of the education experiences. The Tuning consultations[32] have shown that alumni and employer surveys are also a useful source of information.

101. As these assessment tools are used to evaluate learning outcomes, it is important to develop a process by which these data will be analysed to identify actions leading to improvements. Without such a process, the evaluations will lose much of their value and students and others will not take them seriously.

102. Using learning outcomes should help faculty members take a more holistic view of the students' educational experiences. This, in turn, should lead to discussions of innovative learning activities and experiences to meet the desired learning outcomes.

103. There is clear evidence that a wide variety of educational tools need to be used to achieve the desired learning outcomes. Students' abilities should also be evaluated/assessed often with increasing expectations. In addition to the standard lecture mode, the student should also be provided with various professionally relevant experiential learning opportunities including international experiences, co-op and intern (sandwich programmes) opportunities, multidisciplinary design experiences, and participation in learning communities.

104. Well understood and formulated learning outcomes can help students obtain credit for "prior" experience.[33] To do this effectively, it is essential to understand how to test for competencies at various levels.

105. Many experiments are now being conducted regarding the use of technology including such items as tablet PCs and smart boards. Learning outcomes will help evaluate their added value in the teaching and learning process.

106. Creating an education innovation culture is crucial to improve the educational experience as well as achieve the desired learning outcomes (ASEE, 2009). Within this culture, the learning experience can be greatly improved and learning outcomes are a key element in this process.

107. Many engineering faculty members enter the education environment with little or no understanding of desired learning outcomes or how to design and execute a learning experience for such outcomes to be achieved. Institutions should create a supportive environment for education innovation and consider strengthening faculty development programmes so faculty members may more familiar with desired learning outcomes and therefore carry out their duties more effectively. Some countries have advanced programmes in raising awareness of learning outcomes, while others have little or offer no additional faculty training.[34]

108. Students need an intellectually stimulating, inductive, and co-operative leadership environment in order to be more engaged in the learning experience. Active, collaborative learning as well as design-based or problem-based/inductive learning approaches are particularly effective (Johnson, 1991).

109. 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 valuable teaching sources and, as noted above, help assess learning outcomes.

110. Institutions should also examine their mathematics and science departments to ensure 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 partnerships with cognitive scientists and other disciplines that focus on planning and evaluating learning experiences.

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

[31] Website: http://portaal.e-uni.ee/ejump

[32] Tuning has organised large scale consultations in Europe in 2002 and 2008, as well as in Latin America in 2005 to find out more about the views of employers, graduates, students and academic staff regarding the importance of a listed number of generic and subject specific competencies. Tens of thousands of stakeholders participated in these consultation rounds. Stakeholders were ask to offer their opinion regarding the importance of the generic and the subject specific competence to their profession and the level of achievement that they estimated graduates reached as a result of taking the degree programme on a scale from 1 to 4. They were also asked to rank the five generic competencies they thought being the most important. The outcomes show remarkable agreement with respect to the most crucial generic competencies to be trained in educational programmes.

Tuning Europe Website: http://tuning.unideusto.org/tuningeu/
Tuning América Latina Website: http://tuning.unideusto.org/tuningal/

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

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

11. CONCLUDING REMARKS

Challenges and opportunities for the future

111. Creating and implementing a learning outcomes approach is not easy. Given governments' authority over educational issues, much depends on local conditions and cultural settings. Local and national autonomy influence how learning outcomes 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 limit academic freedom. The concept of learning outcomes within the field of engineering, on the other hand, has proven to be well-established and has been welcomed by most stakeholders. Engineers have an easier task than other disciplines, as in OECD countries and throughout 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 Tuning-AHELO working group, representing 13 different countries, came up with general learning outcomes for all engineering programmes, supplemented by branch specifications for the fields of mechanical, electrical and civil engineering.

112. Besides these general reflections on the main task undertaken, the experts group offers four recommendations of which the experts assume they will be of use for further development of the OECD-AHELO feasibility study.

Recommendations

i. The expert group urges continued interaction with the AHELO project team with respect to the assessment activities. The Expert Group can then provide feedback as to whether the assessment process is targeted at the appropriate priorities and if the learning outcomes have been correctly interpreted.

ii. The AHELO feasibility study 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. Methods addressing this important benefit should be identified.

iii. The AHELO feasibility study could be helpful in improving the mobility of engineering graduates. Close co-ordination with the major engineering accreditation and regulatory programmes should be achieved.

iv. The expert group urges active roles for both engineering academics and practitioners in the development and implementation of the feasibility study. This will add significant credibility to the resulting work products.

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Annex 1

Indicative overview of specialisations/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's 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 honours (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 of the branch; - Awareness of the wider multidisciplinary context of engineering.	**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 analyse and interpret data; 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; 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;	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 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];	**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 their chosen area of engineering and relevant knowledge in mathematics and natural sciences.	**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 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

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		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; 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.	- 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].		scientific science and engineering tools to the analysis of problems; - 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 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.

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	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 analyse engineering products, processes and methods; - The ability to select and apply relevant analytic and modelling 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 concerned [ks].	**Skills and abilities** - Demonstrate an ability, taking a holistic approach, to independently and creatively identify, formulate and manage issues, and to analyse 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; - 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.	**Specific learning outcomes** 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 understanding of other engineering disciplines to support study of their own engineering discipline.

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	Engineering design - The ability to apply their knowledge and understanding to develop and realise 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 analyse key engineering processes; - Ability to identify, classify and describe the performance of systems and components through the use of analytical methods and modelling techniques; - Ability to apply quantitative methods and computer software relevant to their engineering discipline, in order to solve engineering problems; - Understanding of and ability to apply a system approach to engineering problems.

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	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 characterised 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 research and design with a view to contributing to the development of knowledge in the field and beyond [ksa].	**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.

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	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 recognise 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 analysing 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 skills, and has an understanding of orders of magnitude [ks].		**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.

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	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; - Recognise the need for, and have the ability to engage in independent, life-long learning.				**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 (e.g. 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.