



Tuning

Tuning
Educational
Structures
in Europe

Guidelines and
Reference
Points for the
Design and
Delivery
of Degree
Programmes
in **Civil
Engineering**

Edition 2018



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**Guidelines and Reference Points
for
the Design and Delivery of
Degree Programmes in
Civil Engineering**

Edition 2018

Alfredo Squarzoni and Alfredo Soeiro, eds.

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University of Groningen
Groningen

Tuning Educational Structures in Europe

TUNING reflects the idea that universities do not look for uniformity in their degree programmes or any sort of unified, prescriptive or definitive European curricula, but rather for points of reference, convergence and common understanding. The protection of the rich diversity of European education has been paramount in TUNING from the very start and it in no way seeks to restrict the independence of academic and subject specific specialists, or undermine local and national academic authority.

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Executive summary

This is the first document in Civil Engineering that is published in the framework of a series of *Tuning Reference Points* for subject areas which started in 2008. It builds on documents published in the past, in particular the publication *A Tuning-AHELO Conceptual Framework of Expected Desired/Learning Outcomes in Engineering*, documents of the European Civil Engineering Education and Training (EUCEET) Association and the *EUR-ACE Framework Standards and Guidelines* (EAFSG).

The document addresses degree profiles, tasks and societal roles graduates will perform in Civil Engineering. It tries to address how the programs try to fit into the wider context of overarching qualifications frameworks like the National and European Qualification Frameworks. These guidelines present general descriptors for the first and the second cycle (bachelor and master levels). There are easy-to-read tables suggested to be used as reference points for the design and delivery of individual degree programmes. According to the Tuning philosophy, each degree programme has its own unique profile, based on the mission of the institution and taking into account its social-cultural setting, its student body, and the strengths of its academic staff.

The document is the result of long and intense collaboration by several experts supported by the Tuning Educational Structures in Europe and financed by the CALOHEE project. CALOHEE means Measuring and Comparing Achievements of Learning Outcomes in Higher Education in Europe and is co-financed and strongly supported by the European Commission as part of its Action Programmes for Higher Education. The document is a contribution to the Tuning's mission to offer a platform for debate and reflection to ensure that graduates are well prepared for their societal role, both in terms of employability and as citizens.

The document suggests learning outcomes of civil engineering programmes for first and second cycles of higher education. Learning outcomes are defined in this document as statements of what a learner is expected to know, understand and be able to demonstrate after completion of a learning experience. These learning outcomes are grouped in terms of knowledge, skills and wider competences (attitudes). Some competences are subject-area related (specific to a subject area) and others are generic (relevant for many or all degree programmes).

The document was produced after a thorough analysis of the Civil Engineering sector and occupations and tasks performed by graduates, a global study of typical degree programmes and of main sub-fields or specializations. That was followed by a methodical verification of existing Civil Engineering qualification systems and quality assurance procedures like ENAEE, ABET, ASCE and CDIO. A framework was then produced with the synthesis of existing lists of required competences. Associated with the list of learning outcomes expected for civil engineering programmes the group involved researched teaching methods, learning approaches and assessment techniques that were proposed for each learning outcome. The teaching methods and learning approaches were proposed based on surveys, desk research and group members' contributions. The assessment techniques were obtained using an existing model (TALOE) to align these with the different types of learning outcomes.

The result presented in this document is complemented by the Assessment Framework where conclusions are structured. This document is a powerful suggestion to allow comparison and benchmarking of Civil Engineering programmes fostering quality improvement and better qualified graduates.

The Tuning-CALOHEE Civil Engineering Subject Area Group

TUNING Qualifications Reference Framework of General Descriptors in the Subject Area of CIVIL ENGINEERING

Explanation

The Subject Area Qualifications Reference Frameworks (Meta-Profiles) presented here are the outcomes of elaborations by groups of informed academics and students and of consultations of a wide circle of stakeholders. The frameworks have been developed in the setting of the project *Measuring and Comparing Achievements of Learning Outcomes in Higher Education in Europe*, which is an integral part of the TUNING initiative to modernize higher education.

The Reference Frameworks are based on a merger of the Qualifications Framework of the European Higher Education Area (QF of the EHEA) and the European Qualifications Framework for Lifelong Learning (EQF for LLL). Their integration allows for combining two different philosophies and facilitates the use of the frameworks presented here in different contexts. While the QF of the EHEA covers in particular the learning process, the EQF focusses on the preparation for life in society and the world of work.

The descriptors in the Reference Frameworks are organized on the basis of 'dimensions'. A dimension indicates a constructive key element, which defines a subject area. Each subject area is based on a multiple of dimensions. These dimensions are linked to the five strands of the QF of the EHEA. By applying the categories of the EQF for LLL each dimension involves three descriptors – knowledge, skills and autonomy and responsibility ('wider competences') -, which reflect a progressive level of achievement.

The Subject Area Qualifications Reference Frameworks are meant to serve as a sound basis for defining the *programme learning outcomes* of individual degree programmes of the first and second cycle (BA and MA). Basing the individualized sets of learning outcomes on the frameworks will guarantee that 'standards' which have been agreed and validated internationally are fully respected. It also implies full alignment with the overarching descriptors of the two European Qualifications Frameworks and, consequently, with the National Qualifications Frameworks. Templates in WORD are available on the CALOHEE website:

<https://www.calohee.eu>

TUNING Qualifications Reference Framework (Meta-Profile) of General Descriptors of a Bachelor Programme in the Subject Area of CIVIL ENGINEERING (LEVEL 6)

QF EHEA 1 st cycle descriptors	SQF domain dimensions Level 6 (BACHELOR)	EQF descriptor Knowledge Level 6 <i>Advanced knowledge of a field of work or study, involving a critical understanding of theories and principles</i>	EQF descriptor Skills Level 6 <i>Advanced skills, demonstrating mastery and innovation, required to solve complex and unpredictable problems in a specialised field of work or study</i>	EQF descriptor Autonomy and Responsibility (Wider Competences) Level 6 <i>- Manage complex technical or professional activities or projects, taking responsibility for decision-making in unpredictable work or study contexts - Take responsibility for managing professional development of individuals and groups</i>
Special feature degree programme		Demonstrate knowledge and understanding of the disciplinary, professional, personal and interpersonal requirements necessary to solve / design / investigate / conduct complex civil engineering problems / products, processes and systems / issues / activities.	Apply knowledge and understanding to solve / design / investigate / conduct complex civil engineering problems / products, processes and systems / issues / activities.	Identify appropriate and relevant established method to solve / design / investigate / conduct complex civil engineering problems / products, processes and systems / issues / activities and be aware of professional, ethical and social responsibilities.
I. <i>Have demonstrated knowledge and understanding in a field of study that builds upon ...</i>	1. Knowledge and Understanding	Demonstrate knowledge and understanding of mathematics as well as sciences and engineering disciplines underlying civil engineering specialisation at a level necessary to achieve the other programme outcomes.	Apply knowledge and understanding of mathematics as well as sciences and engineering disciplines underlying civil engineering specialisation to solve / design / investigate / conduct complex civil engineering problems / products, processes and systems / issues / activities.	Identify knowledge and understanding of mathematics as well as sciences and engineering disciplines underlying civil engineering specialisation necessary to solve / design / investigate / conduct complex civil engineering problems / products, processes and systems / issues / activities.
II. <i>Can apply their knowledge and understanding in a manner that indicates a professional approach to their work or vocation, and have competences typically demonstrated through devising and sustaining arguments and solving problems within their field of study</i>	2. Analysis and Problem Solving	Demonstrate knowledge and understanding of the processes and established methods of analysis / solution of engineering issues (products, processes, systems, situations) / engineering problems in the civil engineering subject area and of their limitations.	Analyse / solve complex engineering issues (products, processes, systems, situations) / engineering problems in civil engineering subject area by applying appropriate and relevant established methods of analysis / solution.	Identify appropriate and relevant established methods of analysis / solution of complex civil engineering issues (products, processes, systems, situations) / engineering problems.
	3. Design	Demonstrate knowledge and understanding of the process and established methods of design in civil engineering subject area and of their limitations.	Design complex civil engineering products (devices, artefacts, etc.), processes and systems by applying appropriate and relevant established design methods.	Identify appropriate and relevant established design methods of complex civil engineering products (devices, artefacts, etc.), processes and systems.
	4. Investigations	Demonstrate knowledge and understanding of codes of practice and safety regulations and of investigation methods (consultation of sources of information, simulations, experimental methods) in civil engineering subject area and of their limitations.	Consult and apply codes of practice and safety regulations and conduct investigations (consultation of sources of information, simulations, experimental methods) in civil engineering subject area in order to meet specified needs and report the investigation results.	Identify appropriate and relevant investigation approaches (among codes of practice and safety regulations, consultation of sources of information, simulations, experimental methods) in civil engineering subject area and analyse, explain and interpret the investigation results with respect to the needs to be met.
III. <i>Have the ability to gather and interpret relevant data (usually within their field of study) to inform judgements.</i>	5. Practice	Demonstrate practical knowledge and understanding of materials, equipment and tools, processes and technologies in civil engineering subject area and of their limitations.	Conduct complex engineering activities in civil engineering subject area, using and applying practical knowledge and understanding of materials, equipment and tools, processes and technologies.	Identify practical knowledge and understanding of materials, equipment and tools, processes and technologies necessary to conduct complex engineering activities in civil engineering subject area.
	6. Decision making	Demonstrate awareness of the key aspects of professional, ethical and social responsibilities linked to management of civil engineering activities, decision making and judgment formulation.	Manage work contexts in civil engineering subject area, take decisions and formulate judgments.	Identify appropriate and relevant approaches to manage work contexts in civil engineering subject area and reflect on professional, ethical and social responsibilities in taking decisions and formulating judgments.
IV. <i>Can communicate information, ideas, problems and solutions to both specialist and non-specialist audiences</i>	7. Team-working	Demonstrate knowledge and understanding of functioning methods of teams that may be composed of different disciplines and levels.	Function effectively in national and international contexts as member of teams that may be composed of different disciplines and levels contributing to meet deliverable, schedule and budget requirements.	Identify appropriate functioning methods and relevant management strategies of teams that may be composed of different disciplines and levels and elements of successful teamwork.
	8. Communication	Demonstrate knowledge and understanding of established communication methods and tools and of their limitations.	Communicate effectively, clearly and unambiguously information, describe activities and communicate their exits/results to engineers or wider audiences in national and international contexts, using appropriate established communication methods and tools.	Identify appropriate and relevant established communication methods and tools.
V. <i>Have developed those learning skills that are necessary for them to continue to undertake further study ...</i>	9. Lifelong Learning	Demonstrate knowledge and understanding of the learning methods necessary to follow developments in science and technology in civil engineering subject area.	Engage in independent lifelong learning and follow developments in science and technology in civil engineering subject area autonomously.	Identify appropriate learning methods in independent lifelong learning to follow developments in science and technology in civil engineering subject area.

TUNING Qualifications Reference Framework (Meta-Profile) General Descriptors of a Master Programme in the Subject Area of CIVIL ENGINEERING (LEVEL 7)

QF EHEA 2 nd cycle descriptors	SQF domain dimensions Level 7 (MASTER)	EQF descriptor Knowledge Level 7 - Highly specialised knowledge, some of which is at the forefront of knowledge in a field of work or study, as the basis for original thinking and/or research - Critical awareness of knowledge issues in a field and at the interface between different fields	EQF descriptor Skills Level 7 - Specialised problem-solving skills required in research and/or innovation in order to develop new knowledge and procedures and to integrate knowledge from different fields	EQF descriptor Autonomy and Responsibility (Wider Competences) Level 7 - Manage and transform work or study contexts that are complex, unpredictable and require new strategic approaches - Take responsibility for contributing to professional knowledge and practice and/or for reviewing the strategic performance of teams
Special feature degree programme		Demonstrate knowledge and understanding of the disciplinary, professional, personal and interpersonal requirements necessary to solve / design / investigate / conduct very complex civil engineering problems / products, processes and systems / issues / activities	Apply knowledge and understanding to solve / design / investigate / conduct very complex civil engineering problems / products, processes and systems / issues / activities.	Identify and justify appropriate and relevant established method or new and innovative methods to solve / design / investigate / conduct very complex civil engineering problems / products, processes and systems / issues / activities and behave according to professional, ethical and social responsibilities.
I. have demonstrated knowledge and understanding that is ...	1. Knowledge and Understanding	Demonstrate in-depth knowledge and understanding of mathematics as well as sciences and engineering disciplines underlying civil engineering specialisation at a level necessary to achieve the other programme outcomes.	Apply knowledge and understanding of mathematics as well as sciences and engineering disciplines underlying civil engineering specialisation to solve / design / investigate / conduct very complex civil engineering problems / products, processes and systems / issues / activities.	Identify and justify knowledge and understanding of mathematics as well as sciences and engineering disciplines underlying civil engineering specialisation necessary to solve / design / investigate / conduct very complex civil engineering problems / products, processes and systems / issues / activities.
II. can apply their knowledge and understanding, and problem solving abilities in new or unfamiliar environments within broader (or multidisciplinary) contexts related to their field of study	2. Analysis and Problem Solving	Demonstrate comprehensive knowledge and understanding of the processes and methods of analysis / solution of engineering issues (products, processes, systems, situations) / engineering problems in the civil engineering subject area, including new and innovative methods, and of their limitations.	Analyse / solve very complex engineering issues (products, processes, systems, situations) / engineering problems in civil engineering subject area by applying appropriate and relevant methods of analysis / solution.	Identify and justify appropriate and relevant methods of analysis / solution of very complex civil engineering issues (products, processes, systems, situations) / engineering problems from established or new and innovative methods.
	3. Design	Demonstrate comprehensive knowledge and understanding of the process and methods of design in civil engineering subject area, including new and original methods, and of their limitations.	Conceive and design very complex civil engineering products (devices, artefacts, etc.), processes and systems by applying appropriate and relevant design methods.	Identify and justify appropriate and relevant design methods of very complex civil engineering products (devices, artefacts, etc.), processes and systems from established or new and innovative methods.
	4. Investigations	Demonstrate comprehensive knowledge and understanding of codes of practice and safety regulations and of investigation methods (consultation of sources of information, simulations, experimental methods) in civil engineering subject area, including new and original emerging methods, and of their limitations.	Consult and apply codes of practice and safety regulations and conduct investigations (consultation of sources of information, simulations, experimental methods) in civil engineering subject area and within broader or multidisciplinary contexts in order to meet specified needs and report the investigation results.	Identify and justify appropriate and relevant investigation approaches (among codes of practice and safety regulations, consultation of sources of information, simulations, experimental methods) in civil engineering subject area and within broader or multidisciplinary contexts, and analyse, explain and critically evaluate the investigation results with respect to the needs to be met.
	5. Practice	Demonstrate comprehensive practical knowledge and understanding of materials, equipment and tools, processes and technologies in civil engineering subject area and of their limitations.	Implement and conduct complex engineering activities in civil engineering subject area and within broader or multidisciplinary contexts, using and applying practical knowledge and understanding of materials, equipment and tools, processes and technologies.	Identify and justify practical knowledge and understanding of materials, equipment and tools, processes and technologies necessary to conduct complex engineering activities in civil engineering subject area and within broader or multidisciplinary contexts.
III. have the ability to integrate knowledge and handle complexity, ...	6. Decisions making	Demonstrate critical awareness of the key aspects of professional, ethical and social responsibilities linked to management of work contexts, decision making and judgment formulation in civil engineering subject area.	Manage work contexts in civil engineering subject area and within broader or multidisciplinary contexts that may be unpredictable and require new strategic approaches, take decisions and formulate judgments.	Identify and justify appropriate and relevant strategic approaches and analyse professional, ethical and social responsibilities linked to the management of work contexts in civil engineering subject area and within broader or multidisciplinary contexts, taking coherent decisions and formulating coherent judgments.
IV. can communicate their conclusions, and the knowledge and rationale underpinning these, to specialist and non-specialist audiences clearly and unambiguously	7. Team-working	Demonstrate knowledge and understanding of functioning methods and management strategies of teams that may be composed of different disciplines and levels and awareness of leadership responsibilities.	Function effectively in national and international contexts as member/leader of teams that may be composed of different disciplines and levels meeting deliverable, schedule and budget requirements.	Identify and justify appropriate and relevant functioning methods and management strategies of teams that may be composed of different disciplines and levels and elements of successful teamwork.
	8. Communication	Demonstrate knowledge and understanding of communication strategies, methods and tools, including new and innovative ones, and of their limitations.	Communicate effectively, clearly and unambiguously information, describe activities and communicate their exits/results – and the knowledge and rationale underpinning these – to specialist and non-specialist audiences in national and international contexts and society at large, using appropriate communication strategies, methods and tools.	Identify and justify appropriate and relevant communication strategies, methods and tools from established or new and innovative ones.
V. have the learning skills to allow them to continue to study in a manner that may be largely ...	9. Lifelong Learning	Demonstrate knowledge and understanding of the learning methods necessary to follow developments in science and technology and undertake further studies in new and emerging technologies in civil engineering subject area and within broader or multidisciplinary contexts.	Engage in independent lifelong learning and follow developments in science and technology and undertake further studies in new and emerging technologies in civil engineering subject area and within broader or multidisciplinary contexts autonomously.	Identify and justify appropriate learning strategies and methods in independent lifelong learning to follow developments in science and technology and undertake further studies in new and emerging technologies in civil engineering subject area and within broader or multidisciplinary contexts.

The Tuning - CALOHEE Civil Engineering Subject Area Group (2016-2018)

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Guidelines and Reference Points for the Design and Delivery of Degree Programmes in Civil Engineering

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1. General introduction

This *Tuning Guidelines and Reference Points 2018 for the Design and Delivery of Degree Programmes in Civil Engineering* is the first document of its kind that is published in the framework of a series of *Tuning Reference Points* for subject areas which started in 2008. This does not imply that there has not been done any work in this respect. The brochure presented here builds on documents published in the past, in particular the publication *A Tuning-AHELO Conceptual Framework of Expected Desired/Learning Outcomes in Engineering*, documents of the European Civil Engineering Education and Training (EUCEET) Association and the *EUR-ACE Framework Standards and Guidelines* (EAFSG). Although together these present a rather complete overview of the field, a need is felt to combine this work in one comprehensive publication. Because some of these documents have been prepared several years ago, an update is thought necessary, reflecting developments in the subject area, but most of all in society. Since this kind of brochures serve as an international reference point for an academic discipline in the European Higher Education Area (EHEA) framework, it is essential that it represents the current state of affairs.

The new editions of the *Tuning Guidelines and Reference Points*, of which the subject area of Civil Engineering is now part, concern degree profiles and the tasks and societal roles graduates will take on, but also show how different degrees fit into the wider context of overarching qualifications frameworks. In other words, which are the essential elements that constitute a particular subject area in higher education? Among other aspects, these *Guidelines* include general descriptors for the first and the second cycle, the bachelor and master, presented in easy-to-read tables, and are meant to be used as reference points for the design and delivery of individual degree programmes. According to the Tuning philosophy, each degree programme has its own unique profile, based on the mission of the institution and taking into account its social-cultural setting, its student body, and the strengths of its academic staff.

The *Guidelines and Reference Points* are the outcome of a long and intense collaboration, starting in 2001, in conjunction with the early phases of the Bologna Process, which has now come to include 48 European countries. They are a result of the grassroots university-driven initiative called Tuning Educational Structures in Europe, or simply 'Tuning', that aims to offer a universally useful approach to the modernisation of higher education at the level of institutions and subject areas. The Tuning initiative has developed a methodology to (re-) design, develop, implement and evaluate study programmes for each of the Bologna cycles. Validated in 2007-2008 by a large group of respected academics from numerous academic sectors it still stands.

The Tuning methodology is based on the student-centred and active learning approaches it has promoted since its very launch. Tuning's mission is to offer a platform for debate and reflection which leads to higher education models able to ensure that graduates are well prepared for their societal role, both in terms of employability and as citizens. Graduates need to have obtained as the outcome of their learning process the optimum set of competences required to execute their future tasks and take on their expected roles. As part of their education, graduates should have developed levels of critical thinking and awareness that foster civic, social and cultural engagement.

Using the Tuning reference points makes study programmes comparable, compatible and transparent. They are expressed in terms of learning outcomes and competences. Learning outcomes are statements of what a learner is expected to know, understand and be able to demonstrate after completion of a learning experience. According to Tuning, learning outcomes are expressed in terms of the *level of competence* to be obtained by the learner. Competences represent a dynamic combination of cognitive and meta-cognitive skills, knowledge and understanding, interpersonal, intellectual and practical skills,

and ethical values. Fostering these competences is the object of all educational programmes. Competences are developed in all course units and assessed at many different stages of a programme. Some competences are subject-area related (specific to a subject area), others are generic (relevant for many or all in degree programmes). According to the Tuning philosophy, subject specific competences and generic competences or general academic skills should be developed together. Normally competence development proceeds in an integrated and cyclical manner throughout a programme.

The initial core competences of the subject area were identified in a consultation process involving four stakeholder groups - academics, graduates, students and employers - during the period 2001-2008. Since then similar consultation processes have been organised in many other parts of the world: these have been taken into consideration in developing this new edition. This edition has been elaborated as part of the CALOHEE project (*Measuring and Comparing Achievements of Learning Outcomes in Higher Education in Europe*), co-financed and strongly supported by the European Commission as part of its Action Programmes for Higher Education. CALOHEE project aims to develop an infrastructure which allows for comparing and measuring learning in a (trans)national perspective. Besides updating and enhancing the reference points brochures it has also developed Assessment Frameworks which offer even more detailed descriptors than those presented in this document. The Assessment Frameworks are published separately.

To make levels of learning measurable, comparable and compatible across Europe academics from the single subject areas have developed cycle (level) descriptors expressed in terms of learning outcomes statements. In this edition, for the first time these are related one-to-one to the two overarching European qualifications frameworks, the 'Bologna' Qualifications Framework for the EHEA (QF for the EHEA) and the EU European Qualifications Framework for Lifelong Learning (EQF for LLL). In the CALOHEE project these two meta-frameworks have been merged into one model to combine 'the best of two worlds'. While the EQF for LLL is focused on the application of knowledge and skills in society, the focus of the QF for the EHEA is more related to the learning process itself: it applies descriptors which cover different areas or 'dimensions' of learning: knowledge and understanding, application of knowledge and understanding in relation to problem solving, making judgments, communicating information and conclusions, and finally: knowing how to learn.

In developing the CALOHEE Tuning model, we realised that 'dimensions' are an indispensable tool, because they make it possible to distinguish the principal aspects that constitute the subject area. Dimensions help give structure to a particular sector or subject area and also make its basic characteristics more transparent. Furthermore, the 'dimension approach' is complementary to the categories included in the EQF for LLL, which uses the categories of knowledge, skills and competences to structure its descriptors. Thus, in CALOHEE terms, the three columns correspond to a 'knowledge reference framework', a 'skills reference framework' and a 'competency reference framework', linked by level. The last column, the 'competency reference framework', refers to the wider world of work and society and identifies the competences required to operate successfully in the work place and as a citizen. It builds on the first two elements: knowledge and understanding and the skills necessary to develop and apply this knowledge.

In addition to addressing cycle-level descriptors, Tuning has given attention to the Europe-wide use of the student workload based European Credit Transfer and Accumulation System (ECTS) to ensure the feasibility of student-centred degree programmes. Some ten years ago it transformed the original credit transfer system into a transfer and accumulation system. According to Tuning, ECTS not only allows student mobility across Europe and in other countries as well; it can also facilitate programme design and development, particularly with respect to coordinating and rationalising the demands made on

students by concurrent course units. In other words, ECTS permits us to plan how best to use students' time to achieve the aims of the educational process, rather than considering teachers' time as the primary constraint and students' time as basically limitless.

The use of the learning outcomes and competences approach implies changes regarding the teaching, learning and assessment methods. Tuning has identified approaches and best practices to form the key generic and subject specific competences. Some examples of good practice are included in this brochure. More detailed examples can be found in the subject area based Assessment Reference Frameworks.

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

This publication reflects the outcomes of the work done by the Subject Area Group (SAG) in **Civil Engineering** which was established in the context of the CALOHEE project. They are presented according to a template used for all Tuning Guidelines and Reference Points brochures to facilitate readability and rapid comparison across the subject areas. It aims to provide, in a succinct manner, the basic elements for a quick introduction into the subject area. It shows in synthesis the consensus reached by a subject area group after intense and lively discussions in the group.

We hope that this publication will be of interest to many, and look forward to receiving comments and suggestions from the stakeholders, in view of further improvement.

Tuning-CALOHEE Management Team,
Robert Wagenaar, CALOHEE project-coordinator

2. Introduction to the Sector and the Subject Area

Preface

This document has been drafted in the context of the project ‘Measuring and Comparing the Achievement of Learning Outcomes in Higher Education in Europe (CALOHEE)’ [1], an EU funded project aimed to develop the infrastructure for setting-up multi-dimensional tests for each of five subject areas, representing five significant academic domains: Engineering (Civil Engineering), Health Care (Nursing), Humanities (History), Natural Sciences (Physics) and Social Sciences (Education).

During the first phase of the project, an investigation by questionnaire of the topics considered in paragraphs 2, 3 and 7 of this document was made among the universities that had declared their interest in participating to the project. The number of responses was 16 from 12 universities of the following countries: BG, BE, ES, FR, IT (3 Universities), GR, IE, PT, TR, UK. Four responses came from different programmes of the same IT institution, two from different programmes of the same UK institution.

Besides the results of the investigation [4], the main references for drafting paragraphs 2, 3 and 7 have been:

- the document *A Tuning-AHELO Conceptual Framework of Expected Desired/Learning Outcomes in Engineering* [5], in the parts that present an overview of the field of engineering, the typical degrees and engineering occupations associated to the first and second cycle degrees;
- the documents of the European Civil Engineering Education and Training (EUCEET) Association [6], in the part consistent with the topics considered in paragraphs 2, 3 and 7.

The Tuning-AHELO and EUCEET documents have been also the main references for the drafting of the introduction to the sector and the subject area (paragraph 1).

The document *EUR-ACE Framework Standards and Guidelines* (EAFSG) [7], in the parts that define the EUR-ACE Programme Outcomes, has been the main reference for the drafting of the sectoral and subject area qualification reference frameworks proposed in paragraphs 5 and 6.

2.1 Engineering and Civil Engineering

Engineering has classically been defined as the profession that deals with the application of mathematical, scientific and technical 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 mathematical and scientific knowledge and human society.

The primary activity of engineers is to conceive, design, implement, and operate 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.

The original formal use of the term *engineer* applied to the constructor of military engines such as catapults. Later, as the design of civilian structures such as buildings and bridges 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*, chemical, *electrical* and *electronic engineering* emerged.

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.

Civil engineering is a professional engineering discipline that deals with the design, construction, and maintenance of the physical and naturally built environment, including works like buildings, bridges, canals, dams and roads. There are several specializations, like construction, hydraulics, structures, etc. Several other specializations were created within civil engineering and have gained independent status like mining and mechanical. It is oldest engineering specialization and it is intertwined with architecture. Architecture conceives, civil engineering executes.

Civil engineering provides the majority of the infrastructure and significant parts of the public and private facilities that are used in our day to day lives. It is the area of engineering that most affects and transforms the physical world and is the backbone of modern living related with, buildings, urban planning, environment and materials, running and clean water, transportation infrastructures. Additionally, most civil engineering projects are unique and have a long design life in contrast with the short lifetime/obsolescence of many manufactured products of other engineering fields.

Civil engineering work has an inherently high degree of complexity, where non-engineering issues dealing with social, political, economic and environmental concerns, as ethical issues, have become far more important than previously, with the emerging of new fields of activity such as Urban and Environmental Planning, Strategic Environmental Assessment, Economic Evaluation of Projects and so on. In addition, sustainability calls for civil engineers to be leaders.

3. Typical Degree Programmes: orientation and application and main sub-fields or specializations

Engineering education basically deals with the transfer or theoretical knowledge to engineering applications. 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 competencies to be a successful professional engineer.

This education must include a strong grounding in mathematics and basic science, as well as training in the specialty-specific engineering sciences. Curriculum developments are a delicate balance between keeping up the necessary 'fundamentals', represented by mathematics, basic sciences and core engineering subjects, and their application in engineering design projects and products.

Design problems are increasingly complex and comprise input and assessment over a broad range of fields, combined to produce an 'optimal' solution that will be acceptable for all parties involved.

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. Technical developments and the growing complexity of activities have generated strong pressure on the number of subjects to be given in civil engineering programmes and on the volume/content in each of their components. This has encouraged an increased focus on the concept of lifelong learning in education. It becomes imperative 'to learn how to learn', the 'need to know' is being replaced by the 'need to know where to find'.

Furthermore, 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 in particular 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.

The typical degree programmes in Civil Engineering are denominated in English as:

- a) Bachelor with a total of ECTS credits ranging from 180 to 240;
- b) Master with a total of ECTS credits ranging from 60 to 120;
- c) Integrated Master with a total of ECTS credits ranging from 240 to 300.

Depending on the country, first cycle degrees may be either a three or a four years' programme.

In reference to the Bologna 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. In some countries, there are two tracks for first-cycle degrees. One 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 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.

In general, three years Bachelors are finalised or to enter the practising profession or to prosecute studies in Master programmes, while four years Bachelors prepare students for entering the labour market. Furthermore, four years Bachelors have programme learning outcomes more consistent with the ones of the 2nd cycle Qualification Framework of European Higher Education Area (QF-EHEA) or of the level 7 of

the European Qualification Framework for Lifelong Learning (QF for LLL) than to the ones of QF-EHEA 1st cycle or EQF for LLL level 6. Of course, if the programme learning outcomes are consistent with those of Master programmes, the level of their achievement cannot be the same as in Master programmes, at least in Master programmes of 300 ECTS credits.

The investigation by questionnaire carried out in the framework of the CALOHEE project has shown that the titles of the Bachelors also vary and are, for instance, called in English Civil Engineering, Environmental Engineering, Construction Management and Civil and Territorial Engineering.

Specializations or tracks of the Bachelor programmes can be, in accordance with the major theme, called in English Applied Mechanics, Hydraulics, Hydromechanics, Coastal and Harbour Engineering, Geotechnical Engineering, Structures, Earthquake Engineering, Geodesy, Transportation Engineering, Materials, Construction, Engineering and Management fields, Structural Engineering, Hydraulics and Environmental Engineering, Geotechnical Engineering, Transport, Infrastructure and Regional Planning, Civil Constructions, Hydrology and Transports and Urban Services.

In terms of their profile, Bachelor programmes can be characterized as:

- a) broad programmes covering typical elements of the sector involved, followed later by specialization in a particular subject area / discipline;
- b) specialized programmes focusing (mainly or only) on the subject area involved;
- c) broad programmes covering different paradigms, which are /can be also positioned outside the realm of the sector.

Furthermore, with respect to the teaching and learning approach, the investigation has shown that Bachelor programmes can be characterized as:

- a) traditional programmes in which the focus is mainly on knowledge acquisition and transfer: the programmes are largely based on lecture classes, which might be supported by seminar groups and, if applicable, limited laboratory work;
- b) student-centred programmes, which require active student learning, which is mainly based on seminar/exercise course unit model and, if applicable, extended laboratory work.
 - Some Bachelor programmes include a work based learning component like work placement or traineeship. The number of credits ECTS for this part of the programme range from 5 to 20.
 - Most students in Bachelor programmes are expected to prepare reports or research reports.
 - Second cycle Master degrees are finalised to enter the practising profession.
 - Some institutions or countries offer integrated first and second cycle programmes. 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.

In consideration of the different lengths of the Master programmes (from 60 to 120 ECTS credits, from 240 to 300 ECTS credits in case of integrated Masters), the level of achievement of the programme learning outcomes, consistent with the ones of QF-EHEA 2nd cycle or EQF for LLL level 7, can not be the same.

Because students at this level are now focusing more on one technical area, more specialised degrees could be offered. For instance, the English titles identified in the context of the CALOHEE investigation have been Civil Engineering, Environmental Engineering, Building Engineering, Mathematical Engineering, Construction and Project Management, Structural Engineering, Water Engineering, Architectural Engineering, Structural Engineering and Architecture, Reconstruction and Modernization

of Buildings and Facilities, Environmental Protection and Sustainable Development and Engineering Project Management.

Also Master programmes can have orientations (the ones identified in the context of the CALOHEE investigation have been Structural design and construction, Project management, Rehabilitation and strengthening of civil engineering structures and facilities, Structures, Construction and Geomaterials, Water Resources).

The investigation by questionnaire has also shown that, in terms of their profile, Master programmes can be characterized as:

- a) specialized programmes focusing (mainly or only) on the subject area involved;
- b) broad programmes covering typical elements of the sector involved, followed later by specialization in a particular subject area / discipline.

Furthermore, with respect to the teaching and learning approach, the investigation has shown that Master programmes can be characterized as:

- a) traditional programmes in which the focus is mainly on knowledge acquisition and transfer: the programmes are largely based on lecture classes, which might be supported by seminar groups and, if applicable, limited laboratory work;
- b) student-centred programmes, which require active student learning, which is mainly based on seminar/exercise course unit model and, if applicable, extended laboratory work;
- c) programmes based on research driven education;
- d) programmes based on applied driven education.

Most Master programmes have minor or elective subjects with credits of ECTS ranging from 10 to 45. Some Master programmes include a work based learning component like work placement or traineeship. The number of credits ECTS for this part of the programme range from 5 to 30. All students in Master programmes are expected to prepare a final thesis.

4. Typical occupations and Tasks of Graduates

Graduates with a degree in one of the engineering fields may enter in many different types of organisations. There are also many graduates of engineering programmes who choose to enter fields such as financial services, sales, or non-engineering management where their engineering skills can help them in their success.

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.

The investigation by questionnaire carried out in the framework of the CALOHEE project has shown that the type of sectors where civil engineering graduates find employment are Private Enterprise, Government (including departments, statutory authorities and government owned businesses), Local Government and Public Company. With respect to other engineering specializations, in consideration of their ability to solve important societal problems civil engineers are privileged for entering public service in policy-making or political roles where their engineering education is instrumental.

Furthermore, due to the civil and criminal responsibility of civil engineering activities, the profession of civil engineer is regulated by government agencies, professional bodies or private organizations in many countries. In this case, 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.

Furthermore, in some countries the type of work open to graduates with only a first cycle degree may be limited. Some professional organisations in several countries 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.

Employment sectors of engineering graduates are mainly Engineering manufacturing and production, Property and construction, Energy and utilities, Environment and agriculture, Government and public administration, Business and management, Banking finance and insurance, Further or higher education or research, but also Charities and voluntary work, IT information services and telecommunication, Physical resources (mining, quarrying, oil, gas, ...) and Armed forces and emergency services, Creative arts and culture, Hospitality and social care, Media and publishing, Retail and sales.

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.

Many 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. Graduates with second cycle degrees 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.

For Bachelor graduates, the twelve most common jobs identified in the context of the CALOHEE investigation carried have been Civil engineer, Site engineer, Site manager, Site inspector, Project manager, Design engineer, Structural engineer, Geotechnical engineer, Hydromechanics engineer, Health and Safety coordinator, Teacher, Technician.

The first twelve typical tasks performed by bachelor graduates have been identified in Designing structures, Analysing structural stability of structures, Planning construction of structures, Overseeing construction and maintenance of structures, Testing samples from site and structures, Making cost calculations, Controlling budget, schedule, and quality, Organizing and directing, Analysing data and preparing reports, Inspecting job sites, Overseeing construction and maintenance of building structures and facilities, testing (soil, building materials).

For Master graduates, the twelve most common jobs identified in the context of the CALOHEE investigation carried have been Engineer, Consultant, Analyst, PhD, Structural engineer, Project manager, Associate, Works engineer, Data scientist, Research engineer, Civil engineer, Site engineer. The first twelve typical tasks performed by Master graduates have been identified in Undertaking technical and feasibility studies including site investigations, Using a range of computer packages for developing detailed designs, Undertaking complex and repetitive calculations, Liaising with clients and a variety of professionals including architects and subcontractors, Compiling job specs and supervising tendering procedures, Resolving design and development problems, Managing budgets and project resources, Scheduling material and equipment purchases and deliveries, Making sure the project complies with legal requirements, Assessing the sustainability and environmental impact of projects, Designing structures, Analysing structural stability of structures.

5. Rational, Process and Methodology applied to develop the Sectoral and Subject Area Reference Frameworks

In order to develop the sectoral and the subject area reference frameworks or meta-profiles, the SAG started from the EUR-ACE programme (learning) outcomes recently re-defined by the European Network for Accreditation of Engineering Education (ENAAE) in the document *EUR-ACE Framework Standards and Guidelines* (EAFSG)¹, approved by the Administrative Council of the European Network for the Accreditation of Engineering Education (ENAAE) on March 2016.

The EUR-ACE programme outcomes (POs) are the basis for a European mutual recognition agreement, currently developed under the framework of ENAAE. EUR-ACE programme outcomes (POs) and corresponding accreditation criteria have been integrated into national learning outcomes and accreditation requirements of thirteen European countries: Finland, France, Germany, Great Britain, Ireland, Italy, Poland, Portugal, Romania, Russia, Spain, Switzerland and Turkey.

In addition, FEANI, the European Federation of Engineering Societies in 30 European Countries, recognises the EUR-ACE POs and accreditation results for their own index of accredited engineering programmes and the European engineering register of professional engineers.

EUR-ACE POs describe the knowledge, understanding and skills that an accredited engineering degree programme must enable a graduate to demonstrate. They are described separately for both Bachelor and Master degree programmes, with reference to the following eight 'learning areas':

- Knowledge and understanding;
- Engineering Analysis;
- Engineering Design;
- Investigations;
- Engineering Practice;
- Making Judgements;
- Communication and Team-working;
- Lifelong Learning.

First of all, the SAG has verified the capacity of the EUR-ACE learning areas to include the learning outcomes (LOs) established in the most influential LOs frameworks in the engineering field. In fact, 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.

The frameworks that have been considered are:

- the Tuning-AHELO framework [5];
- the EUCEET framework [8];
- the International Engineering Alliance (IEA) - Washington Accord framework [9];
- the ABET framework [10];
- the Conceiving, Designing, Implementing, Operating (CDIO) Initiative framework [11];
- the National Society of Professional Engineers framework [12];
- the American Society of Civil Engineering (ASCE) framework [13].

¹ http://www.enaee.eu/wp-assets-enaee/uploads/2012/02/EAFSG_full_nov_voruebergehend.pdf

Table 5.1 (where the EUR-ACE learning area 'Communication and Team-working' has been subdivided in the 'Team-working' and 'Communication' learning areas) shows the correlation between the EUR-ACE learning areas and the considered frameworks of LOs and attests the capacity of the EUR-ACE learning areas to include all the LOs established in that frameworks. Consequently, the SAG has assumed the EUR-ACE learning areas as 'dimensions' for constructing the sectoral qualifications framework (SQF) for the engineering domain, renaming them as follows:

- Knowledge and understanding;
- Analysis and Problem Solving;
- Design;
- Investigations;
- Practice;
- Decision Making;
- Team-working;
- Communication;
- Lifelong Learning.

Then, the SAG has checked the correspondence of the EUR-ACE POs with the LOs established in the considered frameworks. The members of the SAGS quickly came to the conclusion that, in spite of a different ordering, the EUR-ACE POs and the LOs established in the considered frameworks were highly compatible, but also that two major revisions of the EUR-ACE POs were necessary in order to improve the compatibility:

- the introduction of a PO regarding the ability to implement and conduct engineering activities;
- the necessity to provide better evidence to the social responsibility associated to the outcomes.

Finally, the EUR-ACE POs have been redefined, according to the template suggested in the context of the CALOHEE project, as described and shown in the next paragraph.

Table 5.1 – Correlation EUR-ACE Learning Areas - LOs of the considered Frameworks

EUR-ACE Learning Area	Tuning- AHELO Conceptual Framework of Expected Desired/Learning Outcomes in Engineering	EUCEET Outcomes of a Civil Engineering Graduate	IEA Graduate Attribute Profiles for Washington Accord Graduate	ABET Criterion 3. Student Outcomes 2015/16	CDIO Initiative Condensed CDIO Syllabus v2.0	National Society of Professional Engineers Capabilities Within the Engineering Body of Knowledge	American Society of Civil Engineers Knowledge, Skills, and Attitudes Necessary for Entry into Professional Practice
Knowledge and Understanding	The ability to demonstrate knowledge and understanding of the scientific and mathematical principles underlying their branch of engineering.	An ability to apply knowledge of mathematics and other basic subjects.	Engineering Knowledge WA1: Apply knowledge of mathematics, natural science, engineering fundamentals and an engineering specialization as specified in WK1* to WK4 respectively to the solution of complex engineering problems.	(a) an ability to apply knowledge of mathematics, science, and engineering	1.1 KNOWLEDGE OF UNDERLYING MATHEMATICS AND SCIENCE 1.2 CORE FUNDAMENTAL KNOWLEDGE OF ENGINEERING <i>1.3 ADVANCED ENGINEERING FUNDAMENTAL KNOWLEDGE, METHODS AND TOOLS ***</i>	1. Mathematics 2. Natural Sciences (3. Humanities and Social Sciences) 7. Engineering Science (23. Global Knowledge and Awareness)	1 Mathematics. Solve problems in mathematics through differential equations and apply this knowledge to the solution of engineering problems. 2 Natural sciences. Solve problems in calculus-based physics, chemistry, and one additional area of natural science and apply this knowledge to the solution of engineering problems. (3 Humanities. Demonstrate the importance of the humanities in the professional practice of engineering.) (4 Social sciences. Demonstrate the incorporation of social sciences knowledge into the professional practice of engineering.)
	The ability to demonstrate a systematic understanding of the key aspects and concepts of their branch of engineering.	An ability to use knowledge of mechanics, applied mechanics and of other core subjects relevant to civil engineering.		((j) a knowledge of contemporary issues) **			
	The ability to demonstrate comprehensive knowledge of their branch of engineering including emerging issues.	An ability to apply knowledge in a specialized area related to civil engineering.					
	The ability to demonstrate awareness of the wider multidisciplinary context of engineering.						

							<p>5 Materials science.</p> <p>Use knowledge of materials science to solve problems appropriate to civil engineering.</p> <p>6 Mechanics.</p> <p>Analyse and solve problems in solid and fluid mechanics.</p>
Analysis and problem Solving	<p>The ability to apply their knowledge and understanding to identify, formulate and solve engineering problems using established methods.</p> <p>The ability to apply knowledge and understanding to analyse engineering products, processes and methods.</p>	An ability to identify, formulate and solve civil engineering problems.	<p>Problem Analysis: Complexity of analysis.</p> <p>WA2: Identify, formulate, research literature and analyse <i>complex</i> engineering problems reaching substantiated conclusions using first principles of mathematics, natural sciences and engineering sciences. (WK1 to WK4)</p>	(e) an ability to identify, formulate, and solve engineering problems	<p>2.1 ANALYTICAL REASONING AND PROBLEM SOLVING</p> <p>(11. Quality Control and Quality Assurance)</p>	10. Problem Recognition and Solving	<p>8 Problem recognition and solving.</p> <p>Formulate and solve an ill-defined engineering problem appropriate to civil engineering by selecting and applying appropriate techniques and tools.</p> <p>14 Breadth in civil engineering areas.</p> <p>Analyse and solve well-defined engineering problems in at least four technical areas appropriate to civil engineering.</p> <p>15 <i>Technical specialization.</i></p> <p>Evaluate the design of a complex system or process, or evaluate the validity of newly created knowledge or technologies in a</p>

							<p><i>traditional or emerging advanced specialized technical area appropriate to civil engineering.</i></p> <p>19 Globalization.</p> <p>Analyze engineering works and services in order to function at a basic level in a global context.</p>
Design	<p>The ability to apply their knowledge and understanding to develop designs to meet defined and specified requirements.</p> <p>The ability to demonstrate an understanding of design methodologies, and be able to use them.</p>	<p>An ability to design a system or a component to meet desired needs.</p> <p><i>An understanding of the interaction between technical and environmental issues and ability to design and construct environmentally friendly civil engineering works.</i></p>	<p>Design/ development of solutions: Breadth and uniqueness of engineering problems i.e. the extent to which problems are original and to which solutions have previously been identified or codified.</p> <p>WA3: Design solutions for <i>complex</i> engineering problems and design systems, components or processes that meet specified needs with appropriate consideration for public health and</p>	<p>(c) an ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability.</p>	<p>2.3 SYSTEM THINKING</p> <p>4.3 CONCEIVING, SYSTEMS ENGINEERING AND MANAGEMENT</p> <p>4.4 DESIGNING</p>	<p>5. Design</p>	<p>9 Design.</p> <p>Evaluate the design of a complex system, component, or process and assess compliance with customary standards of practice, user’s and project’s needs, and relevant constraints.</p> <p><i>15 Technical specialization.</i></p> <p>Evaluate the design of a complex system or process, or evaluate the validity of newly created knowledge or technologies in a traditional or emerging advanced specialized technical area appropriate to civil engineering.</p>

			safety, cultural, societal, and environmental considerations. (WK5)				
Investigations	<p>The ability to conduct literature searches, use databases and other sources of information.</p> <p>The ability to design and conduct appropriate experiments, interpret the data and draw conclusions.</p> <p>The ability to demonstrate workshop and laboratory skills.</p>	<p>An ability to design and conduct experiments, as well as analyse and interpret data.</p> <p>An ability to identify research needs and necessary resources.</p>	<p>Investigation: Breadth and depth of investigation and experimentation.</p> <p>WA4: Conduct investigations of <i>complex</i> problems using research-based knowledge (WK8) and research methods including design of experiments, analysis and interpretation of data, and synthesis of information to provide valid conclusions.</p>	(b) an ability to design and conduct experiments, as well as to analyse and interpret data.	2.2 EXPERIMENTATION, INVESTIGATION AND KNOWLEDGE DISCOVERY	9. Experiments	<p>7 Experiments.</p> <p>Specify an experiment to meet a need, conduct the experiment, and analyse and explain the resulting data.</p>
Practice	<p>The ability to select and apply relevant analytic and modelling methods.</p> <p>The ability to select and use appropriate</p>	An ability to use the techniques, skills and modern engineering tools, including IT, necessary for	<p>Modern Tool Usage: Level of understanding of the appropriateness of the tool.</p> <p>WA5: Create, select and apply appropriate</p>	(h) the broad education necessary to understand the impact of engineering solutions in a global, economic,	1.3 ADVANCED ENGINEERING FUNDAMENTAL KNOWLEDGE, METHODS AND TOOLS	(4. Manufacturing / Construction) 6. Engineering Economics	<p>10 Sustainability.</p> <p>Analyse systems of engineered works, whether traditional or emergent, for sustainable performance.</p>

equipment, tools and methods.	engineering practice.	techniques, resources, and modern engineering and IT tools, including prediction and modelling, to complex engineering problems, with an understanding of the limitations. (WK6)	environmental, and societal context.	4.1 EXTERNAL, SOCIETAL AND ENVIRONMENTAL CONTEXT	8. Engineering Tools	11 Contemporary issues and historical perspectives.
The ability to combine theory and practice to solve engineering problems.	An understanding of the elements of project and construction management.		(k) an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice.	4.2 ENTERPRISE AND BUSINESS CONTEXT	12. Risk, Reliability, and Uncertainty	Analyse the impact of historical and contemporary issues on the identification, formulation, and solution of engineering problems and analyse the impact of engineering solutions on the economy, environment, political landscape, and society.
The ability to demonstrate understanding of applicable techniques and methods, and their limitations.	<i>An understanding of the interaction between technical and environmental issues and ability to design and construct environmentally friendly civil engineering works.</i>	The Engineer and Society: Level of knowledge and responsibility. WA6: Apply reasoning informed by contextual knowledge to assess societal, health, safety, legal and cultural issues and the consequent responsibilities relevant to professional engineering practice and solutions to complex engineering problems. (WK7)		(4.5 IMPLEMENTING)	13. Safety	12 Risk and uncertainty.
The ability to demonstrate understanding of the non-technical implications of engineering practice.				(4.6 OPERATING)	14. Societal Impact	Analyse the loading and capacity, and the effects of their respective uncertainties, for a well-defined design and illustrate the underlying probability of failure (or non-performance) for a specified failure mode.
<i>The ability to demonstrate understanding of the health, safety and legal issues and responsibilities</i>	An understanding of the impact of solutions for civil engineering works in a	Project Management and			15. Systems Engineering	13 Project management.
					(16. Operations and Maintenance)	Formulate documents to be incorporated into the project plan.
					17. Sustainability and Environmental Impact	(17 Public policy.
					18. Technical Breadth	Apply public policy process techniques to simple public policy problems related to civil engineering works.)
					19. Technical Depth	

	<p><i>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.*</i></p> <p>The ability to demonstrate knowledge of project management and business practices, such as risk and change management, and awareness of their limitations.</p>	<p>global and societal context.</p>	<p>Finance: Level of management required for differing types of activity.</p> <p>WA11: Demonstrate knowledge and understanding of engineering management principles and economic decision-making and apply these to one's own work, as a member and leader in a team, to manage projects and in multidisciplinary environments.</p>			<p>20. Business Aspects of Engineering</p> <p>25. Legal Aspects of Engineering</p> <p>(27. Professional Attitudes)</p> <p>28. Project Management</p> <p>(29. Public Policy and Engineering)</p>	<p>(18 Business and public administration.</p> <p>Apply business and public administration concepts and processes.)</p> <p>(22 Attitudes.</p> <p>Demonstrate attitudes supportive of the professional practice of civil engineering.)</p>
<p>Decision Making</p>	<p><i>The ability to demonstrate understanding of the health, safety and legal issues and responsibilities of engineering practice, the impact of engineering solutions</i></p>	<p>An understanding of ethical commitment and professional responsibility of civil engineers.</p>	<p>Ethics: Understanding and level of practice.</p> <p>WA8: Apply ethical principles and commit to professional ethics and responsibilities and norms of</p>	<p>(f) an understanding of professional and ethical responsibility.</p>	<p>2.5 ETHICS, EQUITY AND OTHER RESPONSIBILITIES</p>	<p>22. Ethical Responsibility</p>	<p>24 Professional and ethical responsibility.</p> <p>Justify a solution to an engineering problem based on professional and ethical standards and assess personal professional and ethical development.</p>

	<i>within a societal and environmental context, and commitment to professional ethics, responsibilities and norms of engineering practice.</i>		engineering practice. (WK7)				
Team-working	The ability to function effectively as an individual and as a member of a team.	An ability to function in multi-disciplinary teams. An understanding of the role of the leader and leadership principles and attitude.	Individual and Team work: Role in and diversity of team. WA9: Function effectively as an individual, and as a member or leader in diverse teams and in multi-disciplinary settings.	(d) an ability to function on multidisciplinary teams.	3.1 TEAMWORK	24. Leadership 30. Teamwork	20 Leadership. Organize and direct the efforts of a group. 21 Teamwork. Function effectively as a member of a multidisciplinary team.
Communication	The ability to use diverse methods to communicate effectively with the engineering community and with society at large.	An ability to communicate effectively.	Communication: Level of communication according to type of activities performed. WA10: Communicate effectively on	(g) an ability to communicate effectively.	3.2 COMMUNICATIONS 3.3 COMMUNICATIONS IN	21. Communication	16 Communication. Plan, compose, and integrate the verbal, written, virtual, and graphical communication of a project to technical and non-technical audiences.

			<i>complex</i> engineering activities with the engineering community and with society at large, such as being able to comprehend and write effective reports and design documentation, make effective presentations, and give and receive clear instructions.		FOREIGN LANGUAGES		
Lifelong Learning	The ability to recognise the need for and engage in independent life-long learning.	A recognition of the need for, and the ability to engage in, life-long learning.	Lifelong learning: Preparation for and depth of continuing learning. WA12: Recognize the need for, and have the preparation and ability to engage in independent and life-long learning in the broadest context of technological change.	(i) a recognition of the need for, and an ability to engage in life-long learning.	2.4 ATTITUDES, THOUGHT AND LEARNING	26. Lifelong Learning	23 Lifelong learning. Plan and execute the acquisition of required expertise appropriate for professional practice.

* A *Washington Accord* programme provides:

WK1: A systematic, theory-based understanding of the natural sciences applicable to the discipline

WK2: Conceptually-based mathematics, numerical analysis, statistics and formal aspects of computer and information science to support analysis and modelling applicable to the discipline

WK3: A systematic, theory-based formulation of engineering fundamentals required in the engineering discipline

WK4: Engineering specialist knowledge that provides theoretical frameworks and bodies of knowledge for the accepted practice areas in the engineering discipline; much is at the forefront of the discipline.

WK5: Knowledge that supports engineering design in a practice area

WK6: Knowledge of engineering practice (technology) in the practice areas in the engineering discipline

WK7: Comprehension of the role of engineering in society and identified issues in engineering practice in the discipline: ethics and the professional responsibility of an engineer to public safety; the impacts of engineering activity: economic, social, cultural, environmental and sustainability

WK8: Engagement with selected knowledge in the research literature of the discipline

** (...): no correspondence with EUR-ACE POs

*** *Italics*: correlation with more than one EUR-ACE Learning Area

6. Sectoral Qualifications Reference Framework of General Descriptors for Engineering

The suggested template is based on an interesting merge of the two European overarching qualification frameworks: the *European Qualification Framework for lifelong learning (EQF)* ([http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32008H0506\(01\)&from=EN](http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32008H0506(01)&from=EN)), which identifies three dimensions ('Knowledge', 'Skills' and 'Competence', where competence is described in terms of responsibility and autonomy), and the *Framework for Qualification of the European Higher Education Area (QF)*

(http://ecahe.eu/w/images/7/76/A_Framework_for_Qualifications_for_the_European_Higher_Education_Area.pdf), that identifies five dimensions ('Knowledge and Understanding', 'Applying Knowledge and Understanding', 'Making Judgements', 'Communications Skills', 'Learning Skills').

The template assumes the EQF as the reference framework and asks to provide evidence, for each of the LO of the SQF dimensions, associated to the QF framework, the 'content' in knowledge, in skills and in professional and social responsibilities.

Table 6.1 shows the correspondence between the QF dimensions and the identified dimensions of the SQF for the engineering domain.

Table 6.1 – Correspondence between the QF dimensions and the dimensions of the SQF for the engineering domain

QF dimensions	Dimensions of the SQF for the Engineering domain
Knowledge and Understanding	Knowledge and Understanding
Applying Knowledge and Understanding	Analysis and Problem Solving
	Design
	Investigation
	Practice
Making Judgement	Decision Making
Communications Skills	Team-working
	Communication
Learning Skills	Lifelong Learning

Table 7.2 and 7.3 shows the SQF descriptors' (or 'sectoral learning outcomes') for the Engineering academic domain respectively at Master and Bachelor level. They constitute a revision and an updating of the EUR-ACE POs, in order respectively to provide evidence of their content in terms of knowledge,

skills and competences, according to the EQF requirements, as required by the CALOHEE project with the suggested template, and to improve their compatibility with the most influential LOs frameworks in the engineering field.

As in the EUR-ACE POs, the main difference between the descriptors at Master and Bachelor level regards the typology of problems / products, processes and systems / issues / activities that can be solved / designed / investigated / conducted.

At Bachelor level the engineering problems / products, processes and systems / issues / activities that can be solved / designed / investigated / conducted are problems / etc. in the field of study defined as 'complex', where complex means problems / etc. that cannot be solved / etc. without:

- knowledge and understanding of mathematics, sciences and engineering disciplines underlying engineering specialisation, and/or
- knowledge and understanding that support solving of engineering problems, designing of engineering products, processes and systems, investigation of engineering issues, conducting engineering activities and/or
- knowledge and understanding of engineering practice.

At Master level the engineering problems / products, processes and systems / issues / activities that can be solved / designed / investigated / conducted are problems / etc. in the field of study defined as 'complex' – where 'complex' has the same meaning as for Bachelor level – that may be new or unfamiliar, involve considerations from outside the field of study, incompletely defined and /or conflicting issues and non-technical constraints, and require original/innovative thinking.

These definitions are consistent with the statements of the EQF at levels 6 and 7 and with the statements of the QF for the first and second cycle of the Bologna system.

It seems to be important to note that the definition of complexity here adopted differs from the definition adopted in the context of the International Engineering Alliance (see *Graduate Attributes and Professional Competencies*, Version 3: 21 June 2013 - <http://www.ieagrements.org/IEA-Grad-Attr-Prof-Competencies.pdf>), for which complex problems and complex activities correspond to problems and activities that in the European system can be dealt with only at Master level.

Table 6.2 – TUNING Sectoral Qualifications Reference Framework of General Descriptors at Master level for ENGINEERING (LEVEL 7)

QF EHEA 2 nd cycle descriptors	SQF domain dimensions Level 7 (MASTER)	EQF descriptor Knowledge Level 7 <i>- Highly specialised knowledge, some of which is at the forefront of knowledge in a field of work or study, as the basis for original thinking and/or research</i> <i>- Critical awareness of knowledge issues in a field and at the interface between different fields</i>	EQF descriptor Skills Level 7 <i>- Specialised problem-solving skills required in research and/or innovation in order to develop new knowledge and procedures and to integrate knowledge from different fields</i>	EQF descriptor Wider Competences Level 7 <i>- Manage and transform work or study contexts that are complex, unpredictable and require new strategic approaches</i> <i>- Take responsibility for contributing to professional knowledge and practice and/or for reviewing the strategic performance of teams</i>
Special feature degree programme		Demonstrate knowledge and understanding of the disciplinary, professional, personal and interpersonal requirements necessary to solve / design / investigate / conduct very complex engineering problems / products, processes and systems / issues / activities*/** in the field of study.	Apply knowledge and understanding to solve / design / investigate / conduct very complex engineering problems / products, processes and systems / issues / activities in the field of study.	Identify and justify appropriate and relevant established method or new and innovative methods to solve / design / investigate / conduct very complex engineering problems / products, processes and systems / issues / activities in the field of study and behave according to professional, ethical and social responsibilities.
<i>I. have demonstrated knowledge and understanding that is founded upon and extends and/or enhances that typically associated with Bachelor's level, and that provides a basis or opportunity for originality in developing and/or applying ideas,</i>	Knowledge and Understanding	Demonstrate in-depth knowledge and understanding of mathematics as well as sciences and engineering disciplines underlying specialisation at a level necessary to achieve the other programme outcomes.	Apply knowledge and understanding of mathematics as well as sciences and engineering disciplines underlying specialisation to solve / design / investigate / conduct very complex engineering problems / products, processes and systems / issues / activities in the field of study.	Identify and justify knowledge and understanding of mathematics as well as sciences and engineering disciplines underlying specialisation necessary to solve / design / investigate / conduct very complex engineering problems / products, processes and systems / issues / activities in the field of study.

<i>often within a research context</i>				
<i>II. can apply their knowledge and understanding, and problem solving abilities in new or unfamiliar environments within broader (or multidisciplinary) contexts related to their field of study</i>	Analysis and Problem Solving	Demonstrate comprehensive knowledge and understanding of the processes and methods of analysis / solution of engineering issues (products, processes, systems, situations) / engineering problems in the field of study, including new and innovative methods, and of their limitations.	Analyse / solve very complex engineering issues (products, processes, systems, situations) / engineering problems in the field of study by applying appropriate and relevant methods of analysis / solution.	Identify and justify appropriate and relevant methods of analysis / solution of very complex engineering issues (products, processes, systems, situations) / engineering problems in the field of study from established or new and innovative methods.
	Design	Demonstrate comprehensive knowledge and understanding of the process and methods of design in the field of study, including new and original methods, and of their limitations.	Conceive and design very complex engineering products (devices, artefacts, etc.), processes and systems in the field of study by applying appropriate and relevant design methods.	Identify and justify appropriate and relevant design methods of very complex engineering products (devices, artefacts, etc.), processes and systems in the field of study from established or new and innovative methods.
	Investigations	Demonstrate comprehensive knowledge and understanding of codes of practice and safety regulations and of investigation methods (consultation of sources of information, simulations, experimental methods) in the field of study, including new and original emerging methods, and of their limitations.	Consult and apply codes of practice and safety regulations and conduct investigations (consultation of sources of information, simulations, experimental methods) in the field of study and within broader or multidisciplinary contexts in order to meet specified needs and report the investigation results.	Identify and justify appropriate and relevant investigation approaches (among codes of practice and safety regulations, consultation of sources of information, simulations, experimental methods) in the field of study and within broader or multidisciplinary contexts, and analyse, explain and critically evaluate the investigation results with respect to the needs to be met.
	Practice	Demonstrate comprehensive practical knowledge and understanding of materials, equipment and tools, processes and technologies in the field of study and of their limitations.	Implement and conduct complex engineering activities in the field of study and within broader or multidisciplinary contexts, using and applying practical knowledge and understanding of	Identify and justify practical knowledge and understanding of materials, equipment and tools, processes and technologies necessary to conduct complex engineering activities in the field

			materials, equipment and tools, processes and technologies.	of study and within broader or multidisciplinary contexts.
<i>III. have the ability to integrate knowledge and handle complexity, and formulate judgements with incomplete or limited information, but that include reflecting on social and ethical responsibilities linked to the application of their knowledge and judgements</i>	Decisions making	Demonstrate critical awareness of the key aspects of professional, ethical and social responsibilities linked to management of work contexts, decision making and judgment in the field of study.	Manage work contexts in the field of study and within broader or multidisciplinary contexts that may be unpredictable and require new strategic approaches, take decisions and formulate judgments.	Identify and justify appropriate and relevant strategic approaches and analyse professional, ethical and social responsibilities linked to the management of work contexts in the field of study and within broader or multidisciplinary contexts, taking coherent decisions and formulating coherent judgments.
<i>IV. can communicate their conclusions, and the knowledge and rationale underpinning these, to specialist and non-specialist audiences clearly and unambiguously</i>	Team-working	Demonstrate knowledge and understanding of functioning methods and management strategies of teams that may be composed of different disciplines and levels and awareness of leadership responsibilities.	Function effectively in national and international contexts as member/leader of teams that may be composed of different disciplines and levels meeting deliverable, schedule and budget requirements.	Identify and justify appropriate and relevant functioning methods and management strategies of teams that may be composed of different disciplines and levels and elements of successful teamwork.
	Communication	Demonstrate knowledge and understanding of communication strategies, methods and tools, including new and innovative ones, and of their limitations.	Communicate effectively, clearly and unambiguously information, describe activities and communicate their exits/results – and the knowledge and rationale underpinning these – to specialist and non-specialist audiences in national and international contexts and society at large, using appropriate communication strategies, methods and tools.	Identify and justify appropriate and relevant communication strategies, methods and tools from established or new and innovative ones.
<i>V. have the learning skills to allow them to continue</i>	Lifelong Learning	Demonstrate knowledge and understanding of the learning methods	Engage in independent lifelong learning and follow developments in science and	Identify and justify appropriate learning strategies and methods in independent

<i>to study in a manner that may be largely self-directed or autonomous</i>		necessary to follow developments in science and technology and undertake further studies in new and emerging technologies in the field of study and within broader or multidisciplinary contexts.	technology and undertake further studies in new and emerging technologies in the field of study and within broader or multidisciplinary contexts autonomously.	lifelong learning to follow developments in science and technology and undertake further studies in new and emerging technologies in the field of study and within broader or multidisciplinary contexts.
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*** Very complex engineering problems / products, processes and systems / issues / activities**

Problems / products, processes and systems / issues / activities that cannot be solved / designed / investigated / conducted without:

- knowledge and understanding of mathematics, sciences and engineering disciplines underlying engineering specialisation, and/or
- knowledge and understanding that support solving of engineering problems, designing of engineering products, processes and systems, investigation of engineering issues, conducting engineering activities and/or
- knowledge and understanding of engineering practice, and

that may be unfamiliar or new, involve considerations from outside the field of study, incompletely defined and /or conflicting issues and non-technical constraints, and require original/innovative thinking.

Table 6.3 – TUNING Sectoral Qualifications Reference Framework of General Descriptors at Bachelor level for ENGINEERING (LEVEL 6)

<p>QF EHEA 1st cycle descriptors</p>	<p>SQF domain dimensions Level 6 (BACHELOR)</p>	<p>EQF descriptor Knowledge Level 6 <i>Advanced knowledge of a field of work or study, involving a critical understanding of theories and principles</i></p>	<p>EQF descriptor Skills Level 6 <i>Advanced skills, demonstrating mastery and innovation, required to solve complex and unpredictable problems in a specialised field of work or study</i></p>	<p>EQF descriptor Wider Competences Level 6 <i>- Manage complex technical or professional activities or projects, taking responsibility for decision-making in unpredictable work or study contexts</i> <i>- Take responsibility for managing professional development of individuals and groups</i></p>
<p>Special feature degree programme</p>		<p>Demonstrate knowledge and understanding of the disciplinary, professional, personal and interpersonal requirements necessary to solve / design / investigate / conduct complex engineering problems / products, processes and systems / issues / activities*/** in the field of study.</p>	<p>Apply knowledge and understanding to solve / design / investigate / conduct complex engineering problems / products, processes and systems / issues / activities in the field of study.</p>	<p>Identify appropriate and relevant established method to solve / design / investigate / conduct complex engineering problems / products, processes and systems / issues / activities in the field of study and be aware of professional, ethical and social responsibilities.</p>
<p><i>I. have demonstrated knowledge and understanding in a field of study that builds upon their general secondary education, and is typically at a level that, whilst supported by advanced textbooks, includes some aspects that will be informed by knowledge of the</i></p>	<p>Knowledge and Understanding</p>	<p>Demonstrate knowledge and understanding of mathematics as well as sciences and engineering disciplines underlying engineering specialisation at a level necessary to achieve the other programme outcomes.</p>	<p>Apply knowledge and understanding of mathematics as well as sciences and engineering disciplines underlying engineering specialisation to solve / design / investigate / conduct complex engineering problems / products, processes and systems / issues / activities in the field of study.</p>	<p>Identify knowledge and understanding of mathematics as well as sciences and engineering disciplines underlying engineering specialisation necessary to solve / design / investigate / conduct complex engineering problems / products, processes and systems / issues / activities in the field of study.</p>

<i>forefront of their field of study</i>				
<i>II. can apply their knowledge and understanding in a manner that indicates a professional approach to their work or vocation, and have competences typically demonstrated through devising and sustaining arguments and solving problems within their field of study;</i>	Analysis and Problem Solving	Demonstrate knowledge and understanding of the processes and established methods of analysis / solution of engineering issues (products, processes, systems, situations) / engineering problems in the field of study and of their limitations.	Analyse / solve complex engineering issues (products, processes, systems, situations) / engineering problems in the field of study by applying appropriate and relevant established methods of analysis / solution.	Identify appropriate and relevant established methods of analysis / solution of complex engineering issues (products, processes, systems, situations) / engineering problems in the field of study.
	Design	Demonstrate knowledge and understanding of the process and established methods of design in the field of study and of their limitations.	Design complex engineering products (devices, artefacts, etc.), processes and systems in the field of study by applying appropriate and relevant established design methods.	Identify appropriate and relevant established design methods of complex engineering products (devices, artefacts, etc.), processes and system in the field of study.
	Investigations	Demonstrate knowledge and understanding of codes of practice and safety regulations and of investigation methods (consultation of sources of information, simulations, experimental methods) in the field of study and of their limitations.	Consult and apply codes of practice and safety regulations and conduct investigations (consultation of sources of information, simulations, experimental methods) in the field of study in order to meet specified needs and report the investigation results.	Identify appropriate and relevant investigation approaches (among codes of practice and safety regulations, consultation of sources of information, simulations, experimental methods) in the field of study and analyse, explain and interpret the investigation results with respect to the needs to be met.
	Practice	Demonstrate practical knowledge and understanding of materials, equipment and tools, processes and technologies in the field of study and of their limitations.	Conduct complex engineering activities in the field of study, using and applying practical knowledge and understanding of materials, equipment and tools, processes and technologies.	Identify practical knowledge and understanding of materials, equipment and tools, processes and technologies necessary to conduct complex engineering activities in the field of study.
<i>III. have the ability to gather and interpret relevant data (usually within their field of study) to inform</i>	Decision making	Demonstrate awareness of the key aspects of professional, ethical and social responsibilities linked to management of engineering activities, decision making and judgment formulation.	Manage work contexts in the field of study, take decisions and formulate judgments.	Identify appropriate and relevant approaches to manage work contexts in the field of study and reflect on professional, ethical and social

<i>judgements that include reflection on relevant social, scientific or ethical issues</i>				responsibilities in taking decisions and formulating judgments.
<i>IV. can communicate information, ideas, problems and solutions to both specialist and non-specialist audiences</i>	Team-working	Demonstrate knowledge and understanding of functioning methods of teams that may be composed of different disciplines and levels.	Function effectively in national and international contexts as member of teams that may be composed of different disciplines and levels contributing to meet deliverable, schedule and budget requirements.	Identify appropriate functioning methods and relevant management strategies of teams that may be composed of different disciplines and levels and elements of successful teamwork.
	Communication	Demonstrate knowledge and understanding of established communication methods and tools and of their limitations.	Communicate effectively, clearly and unambiguously information, describe activities and communicate their exits/results to engineers or wider audiences in national and international contexts, using appropriate established communication methods and tools.	Identify appropriate and relevant established communication methods and tools.
<i>V. have developed those learning skills that are necessary for them to continue to undertake further study with a high degree of autonomy</i>	Lifelong Learning	Demonstrate knowledge and understanding of the learning methods necessary to follow developments in science and technology in the field of study.	Engage in independent lifelong learning and follow developments in science and technology in the field of study autonomously.	Identify appropriate learning methods in independent lifelong learning to follow developments in science and technology in the field of study.

*** Complex engineering problems / products, processes and systems / issues / activities**

Problems / products, processes, systems / issues / activities that cannot be solved / designed / investigated / conducted without:

- knowledge and understanding of mathematics, sciences and engineering disciplines underlying engineering specialisation, and/or
- knowledge and understanding that support solving of engineering problems, designing of engineering products, processes and systems, investigation of engineering issues, conducting of engineering activities and/or
- knowledge and understanding of engineering practice.

7. Subject Area Qualifications Reference Framework of General Descriptors for Civil Engineering

The SAG shared the opinion that normally a subject area qualifications reference framework (SAQF) should be coincident with the SQF, but that it should specify:

- the field of study (in this case, Civil Engineering);
- the sciences underlying the subject area that every graduate should know and understand;
- the domain disciplines underlying the subject area that every graduate should know and understand;
- the subject area problems / products, processes and systems / issues / activities that every graduate should be able to solve / design / investigate / conduct.

The resulting LOs descriptors of Master and Bachelor programmes in the civil engineering subject area are shown in the Tables 7.1 and 7.2 respectively. In these tables, the SAG decided not to specify in the statements of the LOs the sciences and the domain disciplines underlying the subject area that every graduate should know and understand and the subject area problems / products, processes and systems / issues / activities that every graduate should be able to solve / design / investigate / conduct, but to gather them in opportune notes at the end of the tables. This in order not to lengthen the statements of the LOs, while making it easier their reading and comprehension.

The SAG has identified the sciences and the engineering disciplines underlying the civil engineering subject area that every graduate should know and understand and the engineering problems / products, processes and systems / issues / activities that every graduate in civil engineering should be able to solve / design / investigate / conduct as follows.

- Sciences underlying the civil engineering subject area that graduates should know and understand:
 - Mathematics; Probability and Statistics; Operational Research; Physics; Mathematical Physics; Chemistry; Material Science; Computer Science; Geology and Geomorphology.
- Engineering disciplines underlying the civil engineering subject area that graduates should know and understand:
 - Technical Drawing; Material Science and Construction Materials; Solid and Structural Mechanics; Construction Technology and Organization; Buildings; Reinforced Concrete Structures; Metallic Structures; Masonry Structures; Timber Structures; Bridges; Structural Dynamics; Assessment and Rehabilitation of Civil Constructions;
 - Soil Mechanics; Geotechnical Engineering; Slope Stability; Retaining Structures; Underground Structures; Tunnelling;
 - Fluid Mechanics; Hydraulics; Hydraulic Constructions; Water Supply and Infrastructures; Coastal Engineering; River Engineering; Hydrology; Water Management;
 - Urban and Regional Infrastructures; Design of Transportation Infrastructures (Roads, Railways, Airports); Transportation Techniques and Economics; Traffic Engineering (*only at Master level*);
 - Environmental Engineering; Safety Engineering; Sanitary Engineering;

- Economics and Management.
- Engineering problems / products, processes and systems / issues / activities that graduates in civil engineering should be able to solve / design / investigate / conduct:
 - Civil & Industrial Buildings; Bridges; Reinforced Concrete Dams; Metallic Structures; Brick and Timber Constructions;
 - Roads; Railways; Airports; Ports; Interconnecting infrastructures; Cableways;
 - Hydraulic Constructions; Water Supply and Sewage Systems; Works for Hydraulic Protection of the Territory; Waste Disposals and Sanitation Works;
 - Foundations; Retaining Structures; Earthworks; Underground Works; Artificial and Natural Slopes;
 - Information Technologies in Civil Engineering.

Table 7.1 – TUNING Qualifications Reference Framework General Descriptors of a Master Course in the Subject Area of CIVIL ENGINEERING (LEVEL 7)

QF EHEA 2 nd cycle descriptors	SQF domain dimensions Level 7 (MASTER)	EQF descriptor Knowledge Level 7 <i>- Highly specialised knowledge, some of which is at the forefront of knowledge in a field of work or study, as the basis for original thinking and/or research</i> <i>- Critical awareness of knowledge issues in a field and at the interface between different fields</i>	EQF descriptor Skills Level 7 <i>- Specialised problem-solving skills required in research and/or innovation in order to develop new knowledge and procedures and to integrate knowledge from different fields</i>	EQF descriptor Wider Competences Level 7 <i>- Manage and transform work or study contexts that are complex, unpredictable and require new strategic approaches</i> <i>- Take responsibility for contributing to professional knowledge and practice and/or for reviewing the strategic performance of teams</i>
Special feature degree programme		Demonstrate knowledge and understanding of the disciplinary, professional, personal and interpersonal requirements necessary to solve / design / investigate / conduct very complex civil engineering problems / products, processes and systems / issues / activities*/**.	Apply knowledge and understanding to solve / design / investigate / conduct very complex civil engineering problems / products, processes and systems / issues / activities.	Identify and justify appropriate and relevant established method or new and innovative methods to solve / design / investigate / conduct very complex civil engineering problems / products, processes and systems / issues / activities and behave according to professional, ethical and social responsibilities.
<i>I. have demonstrated knowledge and understanding that is founded upon and extends and/or enhances that typically associated with Bachelor's level,</i>	Knowledge and Understanding	Demonstrate in-depth knowledge and understanding of mathematics as well as sciences and engineering disciplines underlying civil engineering specialisation at a level necessary to achieve the other programme outcomes.	Apply knowledge and understanding of mathematics as well as sciences and engineering disciplines underlying civil engineering specialisation to solve / design / investigate / conduct very complex civil engineering problems / products, processes and systems / issues / activities.	Identify and justify knowledge and understanding of mathematics as well as sciences and engineering disciplines underlying civil engineering specialisation necessary to solve / design / investigate / conduct very complex civil engineering problems / products, processes and systems / issues / activities.

<p><i>and that provides a basis or opportunity for originality in developing and/or applying ideas, often within a research context</i></p>				
<p><i>II. can apply their knowledge and understanding, and problem solving abilities in new or unfamiliar environments within broader (or multidisciplinary) contexts related to their field of study</i></p>	<p>Analysis and Problem Solving</p>	<p>Demonstrate comprehensive knowledge and understanding of the processes and methods of analysis / solution of engineering issues (products, processes, systems, situations) / engineering problems in the civil engineering subject area, including new and innovative methods, and of their limitations.</p>	<p>Analyse / solve very complex engineering issues (products, processes, systems, situations) / engineering problems in civil engineering subject area by applying appropriate and relevant methods of analysis / solution.</p>	<p>Identify and justify appropriate and relevant methods of analysis / solution of very complex civil engineering issues (products, processes, systems, situations) / engineering problems from established or new and innovative methods.</p>
	<p>Design</p>	<p>Demonstrate comprehensive knowledge and understanding of the process and methods of design in civil engineering subject area, including new and original methods, and of their limitations.</p>	<p>Conceive and design very complex civil engineering products (devices, artefacts, etc.), processes and systems by applying appropriate and relevant design methods.</p>	<p>Identify and justify appropriate and relevant design methods of very complex civil engineering products (devices, artefacts, etc.), processes and systems from established or new and innovative methods.</p>
	<p>Investigations</p>	<p>Demonstrate comprehensive knowledge and understanding of codes of practice and safety regulations and of investigation methods (consultation of sources of information, simulations, experimental methods) in civil engineering subject area, including new and original emerging methods, and of their limitations.</p>	<p>Consult and apply codes of practice and safety regulations and conduct investigations (consultation of sources of information, simulations, experimental methods) in civil engineering subject area and within broader or multidisciplinary contexts in order to meet specified needs and report the investigation results.</p>	<p>Identify and justify appropriate and relevant investigation approaches (among codes of practice and safety regulations, consultation of sources of information, simulations, experimental methods) in civil engineering subject area and within broader or multidisciplinary contexts, and analyse, explain and critically evaluate the investigation results with respect to the needs to be met.</p>

	Practice	Demonstrate comprehensive practical knowledge and understanding of materials, equipment and tools, processes and technologies in civil engineering subject area and of their limitations.	Implement and conduct complex engineering activities in civil engineering subject area and within broader or multidisciplinary contexts, using and applying practical knowledge and understanding of materials, equipment and tools, processes and technologies.	Identify and justify practical knowledge and understanding of materials, equipment and tools, processes and technologies necessary to conduct complex engineering activities in civil engineering subject area and within broader or multidisciplinary contexts.
<i>III. have the ability to integrate knowledge and handle complexity, and formulate judgements with incomplete or limited information, but that include reflecting on social and ethical responsibilities linked to the application of their knowledge and judgements</i>	Decisions making	Demonstrate critical awareness of the key aspects of professional, ethical and social responsibilities linked to management of work contexts, decision making and judgment formulation in civil engineering subject area.	Manage work contexts in civil engineering subject area and within broader or multidisciplinary contexts that may be unpredictable and require new strategic approaches, take decisions and formulate judgments.	Identify and justify appropriate and relevant strategic approaches and analyse professional, ethical and social responsibilities linked to the management of work contexts in civil engineering subject area and within broader or multidisciplinary contexts, taking coherent decisions and formulating coherent judgments.
<i>IV. can communicate their conclusions, and the knowledge and rationale underpinning these, to specialist and</i>	Team-working	Demonstrate knowledge and understanding of functioning methods and management strategies of teams that may be composed of different disciplines and levels and awareness of leadership responsibilities.	Function effectively in national and international contexts as member/leader of teams that may be composed of different disciplines and levels meeting deliverable, schedule and budget requirements.	Identify and justify appropriate and relevant functioning methods and management strategies of teams that may be composed of different disciplines and levels and elements of successful teamwork.

<i>non-specialist audiences clearly and unambiguously</i>	Communication	Demonstrate knowledge and understanding of communication strategies, methods and tools, including new and innovative ones, and of their limitations.	Communicate effectively, clearly and unambiguously information, describe activities and communicate their exits/results – and the knowledge and rationale underpinning these – to specialist and non-specialist audiences in national and international contexts and society at large, using appropriate communication strategies, methods and tools.	Identify and justify appropriate and relevant communication strategies, methods and tools from established or new and innovative ones.
<i>V. have the learning skills to allow them to continue to study in a manner that may be largely self-directed or autonomous</i>	Lifelong Learning	Demonstrate knowledge and understanding of the learning methods necessary to follow developments in science and technology and undertake further studies in new and emerging technologies in civil engineering subject area and within broader or multidisciplinary contexts.	Engage in independent lifelong learning and follow developments in science and technology and undertake further studies in new and emerging technologies in civil engineering subject area and within broader or multidisciplinary contexts autonomously.	Identify and justify appropriate learning strategies and methods in independent lifelong learning to follow developments in science and technology and undertake further studies in new and emerging technologies in civil engineering subject area and within broader or multidisciplinary contexts.

*** Very complex engineering problems / products, processes and systems / issues / activities**

Problems / products, processes and systems / issues / activities that cannot be solved / designed / investigated / conducted without:

- knowledge and understanding of mathematics, sciences and engineering disciplines underlying engineering specialisation, and/or
- knowledge and understanding that support solving of engineering problems, designing of engineering products, processes and systems, investigation of engineering issues, conducting engineering activities and/or
- knowledge and understanding of engineering practice, and

that may be unfamiliar or new, involve considerations from outside the field of study, incompletely defined and /or conflicting issues and non-technical constraints, and require original/innovative thinking.

**** Engineering problems / products, processes and systems / issues / activities that graduates in civil engineering at Master level should be able to solve / design / investigate / conduct:**

- Civil & Industrial Buildings; Bridges; Reinforced Concrete Dams; Metallic Structures; Brick and Timber Constructions;
- Roads; Railways; Airports; Ports; Interconnecting infrastructures; Cableways;
- Hydraulic Constructions; Water Supply and Sewage Systems; Works for Hydraulic Protection of the Territory; Waste Disposals and Sanitation Works;

- Foundations; Retaining Structures; Earthworks; Underground Works; Artificial and Natural Slopes;
- Information Technologies in Civil Engineering.

***** Sciences underlying civil engineering subject area that graduates in civil engineering at Master level should know and understand:**

- Mathematics; Probability and Statistics; Operational Research; Physics; Mathematical Physics; Chemistry; Material Science; Computer Science; Geology and Geomorphology.

****** Engineering disciplines underlying civil engineering subject area that graduates in civil engineering at Master level should know and understand:**

- Technical Drawing; Material Science and Construction Materials; Solid and Structural Mechanics; Construction Technology and Organization; Buildings; Reinforced Concrete Structures; Metallic Structures; Masonry Structures; Timber Structures; Bridges; Structural Dynamics; Assessment and Rehabilitation of Civil Constructions;
- Soil Mechanics; Geotechnical Engineering; Slope Stability; Retaining Structures; Underground Structures; Tunnelling;
- Fluid Mechanics; Hydraulics; Hydraulic Constructions; Water Supply and Infrastructures; Coastal Engineering; River Engineering; Hydrology; Water Management;
- Urban and Regional Infrastructures; Design of Transportation Infrastructures (Roads, Railways, Airports); Transportation Techniques and Economics; Traffic Engineering;
- Environmental Engineering; Safety Engineering; Sanitary Engineering;
- Economics and Management.

Table 7.2 – TUNING Qualifications Reference Framework General Descriptors of a Bachelor Course in the Subject Area of CIVIL ENGINEERING (LEVEL 6)

QF EHEA 1 st cycle descriptors	SQF domain dimensions Level 6 (BACHELOR)	EQF descriptor Knowledge Level 6 <i>Advanced knowledge of a field of work or study, involving a critical understanding of theories and principles</i>	EQF descriptor Skills Level 6 <i>Advanced skills, demonstrating mastery and innovation, required to solve complex and unpredictable problems in a specialised field of work or study</i>	EQF descriptor Wider Competences Level 6 <i>- Manage complex technical or professional activities or projects, taking responsibility for decision-making in unpredictable work or study contexts</i> <i>- Take responsibility for managing professional development of individuals and groups</i>
Special feature degree programme		Demonstrate knowledge and understanding of the disciplinary, professional, personal and interpersonal requirements necessary to solve / design / investigate / conduct complex civil engineering problems / products, processes and systems / issues / activities*/**	Apply knowledge and understanding to solve / design / investigate / conduct complex civil engineering problems / products, processes and systems / issues / activities.	Identify appropriate and relevant established method to solve / design / investigate / conduct complex civil engineering problems / products, processes and systems / issues / activities and be aware of professional, ethical and social responsibilities.
<i>I. have demonstrated knowledge and understanding in a field of study that builds upon their general secondary education, and is typically at a level that, whilst supported by advanced textbooks, includes</i>	Knowledge and Understanding	Demonstrate knowledge and understanding of mathematics as well as sciences and engineering disciplines underlying civil engineering specialisation at a level necessary to achieve the other programme outcomes.	Apply knowledge and understanding of mathematics as well as sciences and engineering disciplines underlying civil engineering specialisation to solve / design / investigate / conduct complex civil engineering problems / products, processes and systems / issues / activities.	Identify knowledge and understanding of mathematics as well as sciences and engineering disciplines underlying civil engineering specialisation necessary to solve / design / investigate / conduct complex civil engineering problems / products, processes and systems / issues / activities.

<i>some aspects that will be informed by knowledge of the forefront of their field of study</i>				
<i>II. can apply their knowledge and understanding in a manner that indicates a professional approach to their work or vocation, and have competences typically demonstrated through devising and sustaining arguments and solving problems within their field of study;</i>	Analysis and Problem Solving	Demonstrate knowledge and understanding of the processes and established methods of analysis / solution of engineering issues (products, processes, systems, situations) / engineering problems in the civil engineering subject area and of their limitations.	Analyse / solve complex engineering issues (products, processes, systems, situations) / engineering problems in civil engineering subject area by applying appropriate and relevant established methods of analysis / solution.	Identify appropriate and relevant established methods of analysis / solution of complex civil engineering issues (products, processes, systems, situations) / engineering problems.
	Design	Demonstrate knowledge and understanding of the process and established methods of design in civil engineering subject area and of their limitations.	Design complex civil engineering products (devices, artefacts, etc.), processes and systems by applying appropriate and relevant established design methods.	Identify appropriate and relevant established design methods of complex civil engineering products (devices, artefacts, etc.), processes and systems.
	Investigations	Demonstrate knowledge and understanding of codes of practice and safety regulations and of investigation methods (consultation of sources of information, simulations, experimental methods) in civil engineering subject area and of their limitations.	Consult and apply codes of practice and safety regulations and conduct investigations (consultation of sources of information, simulations, experimental methods) in civil engineering subject area in order to meet specified needs and report the investigation results.	Identify appropriate and relevant investigation approaches (among codes of practice and safety regulations, consultation of sources of information, simulations, experimental methods) in civil engineering subject area and analyse, explain and interpret the investigation results with respect to the needs to be met.
	Practice	Demonstrate practical knowledge and understanding of materials, equipment and tools, processes and technologies in civil engineering subject area and of their limitations.	Conduct complex engineering activities in civil engineering subject area, using and applying practical knowledge and understanding of materials, equipment and tools, processes and technologies.	Identify practical knowledge and understanding of materials, equipment and tools, processes and technologies necessary to conduct

				complex engineering activities in civil engineering subject area.
<i>III. have the ability to gather and interpret relevant data (usually within their field of study) to inform judgements that include reflection on relevant social, scientific or ethical issues</i>	Decision making	Demonstrate awareness of the key aspects of professional, ethical and social responsibilities linked to management of civil engineering activities, decision making and judgment formulation.	Manage work contexts in civil engineering subject area, take decisions and formulate judgments.	Identify appropriate and relevant approaches to manage work contexts in civil engineering subject area and reflect on professional, ethical and social responsibilities in taking decisions and formulating judgments.
<i>IV. can communicate information, ideas, problems and solutions to both specialist and non-specialist audiences</i>	Team-working	Demonstrate knowledge and understanding of functioning methods of teams that may be composed of different disciplines and levels.	Function effectively in national and international contexts as member of teams that may be composed of different disciplines and levels contributing to meet deliverable, schedule and budget requirements.	Identify appropriate functioning methods and relevant management strategies of teams that may be composed of different disciplines and levels and elements of successful teamwork.
	Communication	Demonstrate knowledge and understanding of established communication methods and tools and of their limitations.	Communicate effectively, clearly and unambiguously information, describe activities and communicate their exits/results to engineers or wider audiences in national and international contexts, using appropriate established communication methods and tools.	Identify appropriate and relevant established communication methods and tools.
<i>V. have developed those learning skills that are necessary for them to continue to undertake further study with a high degree of autonomy</i>	Lifelong Learning	Demonstrate knowledge and understanding of the learning methods necessary to follow developments in science and technology in civil engineering subject area.	Engage in independent lifelong learning and follow developments in science and technology in civil engineering subject area autonomously.	Identify appropriate learning methods in independent lifelong learning to follow developments in science and technology in civil engineering subject area.

*** Complex engineering problems / products, processes and systems / issues / activities**

Problems / products, processes and systems / issues / activities that cannot be solved / designed / investigated / conducted without:

- knowledge and understanding of mathematics, sciences and engineering disciplines underlying engineering specialisation, and/or
- knowledge and understanding that support solving of engineering problems, designing of engineering products, processes and systems, investigation of engineering issues, conducting engineering activities and/or
- knowledge and understanding of engineering practice.

**** Engineering problems / products, processes and systems / issues / activities that graduates in civil engineering at Master level should be able to solve / design / investigate / conduct:**

- Civil & Industrial Buildings; Bridges; Reinforced Concrete Dams; Metallic Structures; Brick and Timber Constructions;
- Roads; Railways; Airports; Ports; Interconnecting infrastructures; Cableways;
- Hydraulic Constructions; Water Supply and Sewage Systems; Works for Hydraulic Protection of the Territory; Waste Disposals and Sanitation Works;
- Foundations; Retaining Structures; Earthworks; Underground Works; Artificial and Natural Slopes;
- Information Technologies in Civil Engineering.

***** Sciences underlying civil engineering subject area that graduates in civil engineering at Master level should know and understand:**

- Mathematics; Probability and Statistics; Operational Research; Physics; Mathematical Physics; Chemistry; Material Science; Computer Science; Geology and Geomorphology.

****** Engineering disciplines underlying civil engineering subject area that graduates in civil engineering at Master level should know and understand:**

- Technical Drawing; Material Science and Construction Materials; Solid and Structural Mechanics; Construction Technology and Organization; Buildings; Reinforced Concrete Structures; Metallic Structures; Masonry Structures; Timber Structures; Bridges; Structural Dynamics; Assessment and Rehabilitation of Civil Constructions;
- Soil Mechanics; Geotechnical Engineering; Slope Stability; Retaining Structures; Underground Structures; Tunnelling;
- Fluid Mechanics; Hydraulics; Hydraulic Constructions; Water Supply and Infrastructures; Coastal Engineering; River Engineering; Hydrology; Water Management;
- Urban and Regional Infrastructures; Design of Transportation Infrastructures (Roads, Railways, Airports); Transportation Techniques and Economics;
- Environmental Engineering; Safety Engineering; Sanitary Engineering;
- Economics and Management.

8. Learning, Teaching and Assessment

The development of meaningful and measurable learning outcomes (LOs) for engineering programmes is critical to the systematic improvement of the educational experience for engineering students, but it is not sufficient. LOs must be taught and learned and the level of their achievement assessed. The adoption of appropriate teaching and learning methods or modes and of accurate assessment tools is equally critical.

Although the use of the LOs approach seems to have been implemented widely in the engineering domain, this does not imply that applied teaching, learning and assessment strategies are appropriate to this approach. Student-centred programmes based on the development of competencies, measured in LOs, require other methodologies and strategies than more traditional, staff-centred degree programmes.

One can map LOs throughout students' curriculum/educational experiences to determine where, how and when each LO should be met. There is clear evidence that a wide variety of educational tools need to be used to achieve the desired LOs. In addition to the standard lecture mode, the student should also be provided with various professionally relevant experiential learning opportunities. It is then possible to use both formative and summative evaluations to determine how well the desired LOs are being met.

Learning & Teaching

The SAG worked at identifying teaching and learning activities through which the LOs could be achieved by students who are attending a civil engineering degree programme at their institution and how their achievement could be assessed by the academic staff.

In the investigation by questionnaire carried out in the framework of the CALOHEE project, the question posed in the questionnaire to investigate the teaching / learning modes adopted by civil engineering departments of European Universities was: "What are the main modes / strategies for teaching and learning in your bachelor/master programme?", followed by a list of possible teaching/learning modes.

The results of the investigation are shown in table 8.1.

Table 8.1 – Results of the CALOHEE investigation on teaching / learning modes

Bachelor		Master	
Teaching/Learning Modes	Number of citations	Teaching/Learning Modes	Number of citations
Lectures	9	Lectures	14
Seminars	7	Seminars	10
Tutorials	7	Tutorials	8

Exercise courses / Practical classes	9	Exercise courses / Practical classes	14
Fieldwork	8	Fieldwork	9
Oral assignments	5	Oral assignments	8
Written assignments	6	Written assignments	13
Role play	0	Role play	3
Peer reviewing	1	Peer reviewing	3
Work based practice	4	Work based practice	8
Problem-solving sessions	6	Problem-solving sessions	10
Flipped classroom (<i>combination of Internet instruction and classes</i>)	1	Flipped classroom (<i>combination of Internet instruction and classes</i>)	4
Blended learning	2	Blended learning	3
Laboratory assignments	6	Laboratory assignments	10
Others: design-project based	1	Others: design-project based	1
Others: individual supervision	1	Others: individual supervision	1
Others	0	Others	0

The SAG discussed the results of the investigation by questionnaire and shared the opinion that the identified teaching and learning methods, integrated with two other modes: 'Investigation assignment' and 'Numerical modelling assignment', and redefined as shown in Table 8.2 identify effectively the main teaching and learning approaches through which the LOs can be achieved by students who are attending a civil engineering degree programme.

Table 8.2 - Teaching / learning methods for the achievement of LOs of civil engineering programmes

Lectures
Seminars
Tutorials
Flipped classroom

Blended learning
Exercise courses / Practical classes
Oral assignments
Written assignments
Investigation assignments
Laboratory assignment
Numerical modelling assignment
Problem-based learning
Design-based learning
Work-based practice (internship/traineeship)
Fieldwork
Role play
Peer reviewing
Individual supervision

Examples of good practices of teaching and learning for each descriptor of Tables 7.1 and 7.2 are defined in the document *Assessment Reference Frameworks for Civil Engineering Programmes* [14].

The SAG shared completely what stated in the document *A Tuning-AHELO Conceptual Framework of Expected /Desired Learning Outcomes in Engineering* [5] about Design-Based Learning:

«*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, cooperative (teamwork), competence-oriented (skills), activating, fostering responsibility, synthesising, and leading to professionalization. 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».

The SAG shared also the following considerations:

- independently from the educational activity involved, an 'active learning' approach should always be pursued. Students need an intellectually stimulating, inductive, and co-operative leadership environment in order to be more engaged in the learning experience. To this regard, active, collaborative learning approach appears particularly effective.
- Many engineering faculty members enter the education environment with little or no understanding of desired LOs 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 LOs and therefore carry out their duties more effectively.

Assessment

The CALOHEE questionnaire did not foresee any question about assessment of the level of achievement of the established LOs.

There have been initiatives to find proper assessment methods for the different types of LOs. The more recent is the TALOE project [15], which delivered a web-tool that advises about proper methods of assessment aligned with the different types of LOs to be verified. The tool is applicable to all areas of knowledge as long as there is a definition of LOs. The web-tool was the implementation made of the ALOA model that is based on the revised Bloom's taxonomy and on the work of alignment of Anderson et al. [16]. The ALOA model was developed for engineering programmes and the web-tool was afterwards extended to all fields of knowledge.

The ALOA model identifies the assessment methods listed in Table 8.3.

Table 8.3 - Assessment modes identified by the ALOA model

Assessment Methods	Sub-categories
Multiple Choice Questions (MCQ)	A) Remember B) Understand C) Apply D) Analyse E) Evaluate F) Create
Essays	3.1. Essay – Speculative essay 3.2. Essay – Quote to discuss

	<p>3.3. Essay – Assertion</p> <p>3.4. Essay – Write on</p> <p>3.5. Essay – Describe/Explain</p> <p>3.6. Essay – Discuss</p> <p>3.7. Essay – Compare</p> <p>3.8. Essay – Evaluate</p> <p>3.9. Essay – Problem</p>
Problem solving	<p>4.1. Problem solving – Routines</p> <p>4.2. Problem solving – Diagnosis</p> <p>4.3. Problem solving – Strategy</p> <p>4.4. Problem solving – Interpretation</p> <p>4.5. Problem solving – Generation</p>
Practical work	<p>5.1. Practical work – Demonstration</p> <p>5.2. Practical work – Exercise</p> <p>5.3. Practical work – Structured enquiry</p> <p>5.4. Practical work – Open ended enquiry</p> <p>5.5. Practical work – Project</p>
Short-answer questions (SAQ)	<p>6.1. SAQ – Select crucial evidence</p> <p>6.2. SAQ – Explain methods, procedures and relationships</p> <p>6.3. SAQ – Present arguments</p> <p>6.4. SAQ – Describe limitations of data</p> <p>6.5. SAQ – Formulate valid conclusions</p> <p>6.6. SAQ – Identify assumptions</p> <p>6.7. SAQ – Formulate hypothesis</p> <p>6.8. SAQ – Formulate action plans</p>
Reflective Practice Assignments	<p>7.1. Reflective practice assignments – Concrete experience</p> <p>7.2. Reflective practice assignments – Reflective observation</p> <p>7.3. Reflective practice assignments – Abstract conceptualization</p> <p>7.4. Reflective practice assignments – Active experimentation</p>

The SAG used the assessment methods identified by the ALOA model for the definition of examples of good practices of assessment for each descriptor of Tables 7.1 and 7.2, shown in the document *Assessment Reference Frameworks for Civil Engineering Programmes* [14].

Discussion among the members of the SAG evidenced that assessment is mostly by written or oral end-of-semester examination, often supplemented by mid-term examinations, homework exercises, and where relevant project assignments and programming assignments.

If end-of-semester examinations are the sole assessment there is of course less feedback, and therefore less opportunity to learn through assessment, available to the students. It has been noted that shortcomings in students' understanding of what is required of them often only becomes apparent at the time of assessment.

The SAG shared also the following considerations:

- final year projects and second cycle dissertations have feedback built in as part of the supervision process. Some students perform better in this situation than in the traditional examination format. They also afford the opportunity to assess the acquisition of the generic and subject-specific competences for each cycle.
- LOs, 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, which may be used by both students and their teachers to assess knowledge, skills and attitudes in engineering.
- 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.

9. Concluding remarks

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 Europe and throughout the world there is a great degree of consensus concerning what an engineer is supposed to know and be able to do. It is opinion of the SAG that the systems of learning outcomes for the engineering domain and then for the civil engineering subject domain, defined starting from the EUR-ACE programme outcomes, which combine EQF for LLL and the QF-EHEA approaches and are consistent with the most influential learning outcomes frameworks in the engineering field, can be a useful reference for the definition of engineering LOs at national level in the European countries and in other areas of the world.

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Assessment Reference Framework

A table containing the learning outcomes or descriptors defined as part of a Subject Area Qualifications Reference Framework of Meta-Profile and more precise subsets of each one of them. Each subset, taken together, describes in some detail the core elements and topics covered by a learning outcome statement. In addition, the Assessment Reference Framework intends to offer insight in the most appropriate strategies and approaches needed to assess the constituent elements of each learning outcome.

Competence

The European Qualifications Framework (EQF) defines a competence as ‘the ability to use knowledge, skills and personal, social and/or methodological abilities, in work or study situations and in professional and personal development’. In the context of the EQF, a competence is described in terms of responsibility and autonomy.

Fostering competences is the goal of all educational programmes. Competences are developed in all course units and assessed at different stages of a programme. Some competences are subject-specific (related to a specific field of study), others are generic (common to any degree course). It is normally the case that competence development proceeds in an integrated and cyclical manner throughout a programme.

Credit (ECTS)

ECTS credits express the volume of learning based on the defined learning outcomes and their associated workload. 60 ECTS credits are allocated to the learning outcomes and associated workload of a full-time academic year or its equivalent, which normally comprises a number of educational components to which credits (on the basis of the learning outcomes and workload) are allocated. ECTS credits are generally expressed in whole numbers.

Dublin Descriptors

The Dublin Descriptors are the cycle descriptors (or ‘level descriptors’) presented in 2003 and adopted in 2005 as the Qualifications Framework of the European Higher Education Area. They offer generic statements of typical expectations of achievements and abilities associated with awards that represent the end of each of a (Bologna) cycle or level. The descriptors are phrased in terms of competence levels, not learning outcomes, and they enable to distinguish between the different cycles in a broad and general manner. A level descriptor includes the following five components:

- knowledge and understanding;
- applying knowledge and understanding;
- making judgements;
- communication;
- lifelong learning skills.

Employability

Employability can be defined in short as ‘the skills and abilities that allows someone to be employed’. The UK Higher Education Academy/ESECT have come up with the following definition of employability-related competences: ‘A set of skills, knowledge and personal attributes that make an individual more likely to secure and be successful in their chosen occupation(s) to the benefit of themselves, the workforce, the community and the economy.’²

² Mantz Yorke, Employability in higher education: what it is – what it is not. Learning & Employability. Series One. York, 2006: [http://www.employability.ed.ac.uk/documents/Staff/HEA-Employability_in_HE\(Is.IsNot\).pdf](http://www.employability.ed.ac.uk/documents/Staff/HEA-Employability_in_HE(Is.IsNot).pdf).

European Credit Transfer and Accumulation System (ECTS)

A learner-centred system for credit accumulation and transfer, based on the principle of transparency of learning, teaching and assessment processes. Its objective is to facilitate planning, delivery and evaluation of study programmes and student mobility by recognising learning achievements and qualifications and periods of learning.

European Higher Education Area (EHEA)

The European Higher Education Area (EHEA) was launched on the Bologna Process decade anniversary in March 2010, during the Budapest-Vienna Ministerial Conference. Building on the main objectives of the Bologna Process since its inception in 1999, the EHEA is meant to ensure more comparable, compatible, coherent and attractive systems of higher education in Europe.

European Qualifications Framework for Lifelong Learning (EQF)

The European Qualifications Framework for Lifelong Learning is a common European reference framework which enables countries of the European Union to link their qualifications systems to one another. It was adopted by the European Parliament and Council in April 2008. The EQF uses eight reference levels based on learning outcomes that are defined in terms of knowledge, skills and competence. It shifts the focus from input (lengths of a learning experience, type of institution) to what a person holding a particular qualification actually knows and is able to do. It makes qualifications more readable and understandable across different countries and systems in the European Union.

Qualifications Framework of the European Higher Education Area (QF-EHEA)

In the European Higher Education Area, qualifications frameworks are found at two levels. An overarching framework (QF-EHEA) has been adopted in 2005 and all member countries committed themselves to develop national qualifications frameworks that are compatible with this overarching framework.

A national qualifications framework for higher education encompasses all the qualifications in a higher education system. It shows the expected learning outcomes for a given qualification and how learners can move between qualifications.

The aim of QF-EHEA is to organise national higher education qualifications into an overarching European-wide qualifications framework. Within this Framework, qualifications are defined according to levels of complexity and difficulty (Bachelor, Master, Doctor).

The QF-EHEA identifies four main cycles which are described by the 'Dublin Descriptors'. They offer generic statements of typical expectations of achievements and abilities associated with awards that represent the end of each of a cycle. The short, first and second cycles are also characterised by credit ranges.

Knowledge

The body of facts, principles, theories and practices that is related to a field of work or study. In the context of the European Qualifications Framework, knowledge is described as theoretical and/or factual. For the bachelor and master level, knowledge is specified as follows:

Bachelor level: advanced knowledge of a field of work or study, involving a critical understanding of theories and principles.

Master level: highly specialised knowledge, some of which is at the forefront of knowledge in a field of work or study, as the basis for original thinking and/or research. Critical awareness of knowledge issues in a field and at the interface between different fields.

Learning outcome

A statement of what a learner knows, understands and is able to do on completion of a learning process. The achievement of learning outcomes has to be assessed through procedures based on clear and transparent criteria. Learning outcomes are attributed to individual educational components and to programmes at a whole. They are also used in European and national qualifications frameworks to describe the level of the individual qualification.

Lifelong learning

All learning activity undertaken throughout life, with the aim of improving knowledge, skills and competences within a personal, civic, social and/or employment-related perspective.

Programmes and services contributing to lifelong learning within the higher education sector may include mainstream programmes, continuing education, evening classes, specific programmes for part-time learners, access to libraries/higher education institution resources, distance learning, training courses, targeted guidance and counselling services among other actions and initiatives.

Skill

The ability to apply knowledge and use know-how to complete tasks and solve problems.

In the context of the European Qualifications Framework, skills are described as cognitive (involving the use of logical, intuitive and creative thinking) or practical (involving manual dexterity and the use of methods, materials, tools and instruments). For the bachelor and master level, skills are specified as follows:

Bachelor level: advanced skills, demonstrating mastery and innovation, required to solve complex and unpredictable problems in a specialised field of work or study.

Master level: specialised problem-solving skills required in research and/or innovation in order to develop new knowledge and procedures and to integrate knowledge from different fields.

Wider Competences

Operationalisation of knowledge and skills in the world of work: tasks/activities that the graduate is able to perform and responsibilities the he/she is able to take on in the workplace.

They reflect both the parameters 'Employability' and 'Civic, Social and Cultural Engagement'. Fostering competences is the object of a process of learning and of an educational programme. For the bachelor and master level, skills are specified as follows:

Bachelor level: manage complex technical or professional activities or projects, taking responsibility for decision making in unpredictable work or study contexts; take responsibility for managing professional development of individuals and groups.

Master level: manage and transform work or study contexts that are complex, unpredictable and require new strategic approaches; take responsibility for contributing to professional knowledge and practice and/or for reviewing the strategic performance of teams.

Student-Centred Learning

A learning approach characterised by innovative methods of teaching which aim to promote learning in communication with teachers and students and which takes students as active participants in their own learning, fostering transferable skills such as problem-solving, critical and reflective thinking (ESU, 2010).

Appendix - CALOHEE Framework for Civic, Social and Cultural Engagement

	Knowledge	Skills	Autonomy and Responsibility (Wider competences)
1.	Demonstrate critical understanding of similarities and differences in and between <i>societies and cultures</i>	Identify, describe and analyse interaction in and between societies and cultures	Demonstrate engagement <i>in the public and professional domain</i> by developing scenarios and alternatives and/or identifying best practices of interaction between societies and cultures and – if required – interventions in case of tensions and/or conflicts
2.	Demonstrate critical understanding of the processes of <i>information and communication</i>	Review and judge (mis)use of sources, data, evidence, qualities, intentions and transparency and expert opinions	Active contribution <i>in the public and professional domain</i> to societal debates using reliable data and information sources and informed judgements
3.	Demonstrate critical understanding of the processes of <i>governance and decision making</i>	Apply and support agreed governing principles, norms and values regarding fairness, transparency, accountability, democracy and relevance in decision and policy making processes	Active contribution to and with local and (inter)national communities, community groups, (political) organisations and pressure groups respecting agreed principles, norms and values
4.	Demonstrate critical understanding of general ethical principles, norms and values and professional standards	Understand and apply the processes of decision making and the consequences of actions taking into account principles, norms, values and standards both from a personal and a professional standpoint.	Active contribution to upholding, promoting and defending general ethical principles, norms, values and professional standards in governance, communication and cultural

			<i>interaction in the public and professional domain.</i>
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