TUNING

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

Civil Engineering

Edition 2018

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Tuning Educational Structures in Europe

The name Tuning was chosen for the project to reflect the idea that universities do not look for uniformity in their degree programmes or any sort of unified, prescriptive or definitive European curricula but simply for points of reference, convergence and common understanding. The protection of the rich diversity of European education has been paramount in the Tuning Project from the very start and the project 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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For more information about the CALOHEE project:

CALOHEE website:

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

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1. 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 framework', a 'skills framework' and a 'competency framework', linked by level. The last column, the 'competency 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 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 brochure 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. The outcomes are presented in a template to facilitate readability and rapid comparison across the subject areas. The summary aims to provide, in a very 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.

The Tuning-CALOHEE Management Team

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3. 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 frameworks proposed in paragraphs 5 and 6.

1.1 Engineering and Civil Engineering

Clarification: *In this chapter the main characteristics of the academic sector and the field of study are outlined for an audience that is informed but not specialized in the discipline involved. This is done by defining and describing the subject area, which is also positioned in the wider context of the academic domain / sector. If relevant, information is offered about its development over time. Also attention can be drawn to work established in the past in the framework of Tuning, Thematic Network Programmes or other initiatives.*

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 suchas 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. Also sustainability calls for civil engineers to be leaders.

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

Clarification: *The chapter departs from the description offered in chapter 1. An overview is offered of the theoretical and methodological approaches applied as well as the topics covered by the field. It also distinguishes between more theoretical orientations and applied orientations. In other words, what is the typical degree profile of an intensive research institution and programme versus a more applied one and different variations in between. Furthermore, a general overview is offered of the main sub-fields and/or specialisations. Information can also be offered about the different lengths of study programmes that exist in the EHEA. If the discipline is regulated, a description is expected of the existing framework and the regulations defined. For preparing of the chapter the outcomes of the CALOHEE questionnaire on typical degrees can be used, which was distributed in April 2016.*

Engineering education basically deals with the transfer or theoretically 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 product 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.

5. Typical occupations and Tasks of Graduates

Clarification: *To obtain a reliable picture of the employability field, information has been collected through the CALOHEE questionnaire. This questionnaire does not only ask for typical occupations obtained by graduates with first and second cycle degrees (BA and MA) but also about the tasks that are performed in those occupations. In a number of sectors – in particular the not regulated ones – study programmes do not prepare for particular jobs but for a set of tasks which are perceived as very useful for a range of jobs. As a consequence, these programmes should develop the knowledge and skills which allow for implementing these tasks successfully. The intention of this chapter is to offer an overview of typical occupations and tasks which graduates are expected to perform in the jobs obtained.*

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.

6. Rational, Process and Methodology applied to develop the sectoral and subject area frameworks

Clarification: *The chapter allows for offering the arguments and procedure (steps) applied to prepare the frameworks. The SAGs are asked to include the list of subject specific and generic 'competences' (according to the TUNING definition) which are perceived as the core of the academic field involved. Background information is required how these competences were selected. The choice can be based on previous TUNING and other surveys and on the outcomes of the CALOHEE questionnaires. Furthermore, the SAGs are asked to identify and motivate the dimensions which have been applied for constructing the frameworks.*

In order to develop the sectoral and the subject area frameworks, the SAG started from the EUR-ACE programme (learning) outcomes recently re-defined by the European Network for Accreditation of Engineering Education (ENAEE) 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 (ENAEE) on March 2016.

The EUR-ACE programme outcomes (POs) are the basis for a European mutual recognition agreement, currently developed under the framework of ENAEE.

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.

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

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].

Table 4.1 (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 6.1 – 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. The ability to demonstrate a systematic understanding of the key aspects and concepts of their branch of engineering. The ability to demonstrate comprehensive knowledge of their branch of engineering including emerging issues. The ability to demonstrate awareness of the wider multidisciplinary context of engineering.	An ability to apply knowledge of mathematics and other basic subjects. An ability to use knowledge of mechanics, applied mechanics and of other core subjects relevant to civil engineering. An ability to apply knowledge in a specialized area related to civil engineering.	**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 ((j) a knowledge of contemporary issues) **	1.1 KNOWLEDGE OF UNDERLYING MATHEMATICS AND SCIENCE 1.2 CORE FUNDAMENTAL KNOWLEDGE OF ENGINEERING *1.3 ADVANCED ENGINEERING FUNDAMENTAL KNOWLEDGE, METHODS AND TOOLS* ***	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.)

							5 Materials science. **Use** knowledge of materials science to **solve** problems appropriate to civil engineering. 6 Mechanics. **Analyse** and solve problems in solid and fluid mechanics.
Analysis and problem Solving	The ability to apply their knowledge and understanding to identify, formulate and solve engineering problems using established methods. The ability to apply knowledge and understanding to analyse engineering products, processes and methods.	An ability to identify, formulate and solve civil engineering problems.	**Problem Analysis**: Complexity of analysis. **WA2:** Identify, formulate, research literature and analyse *complex* engineering problems reaching substantiated conclusions using first principles of mathematics, natural sciences and engineering sciences. (WK1 to WK4)	(e) an ability to identify, formulate, and solve engineering problems	2.1 ANALYTICAL REASONING AND PROBLEM SOLVING (11. Quality Control and Quality Assurance)	10. Problem Recognition and Solving	8 Problem recognition and solving. **Formulate** and solve an ill-defined engineering problem appropriate to civil engineering by **selecting** and applying appropriate techniques and tools. 14 Breadth in civil engineering areas. **Analyse** and solve well-defined engineering problems in at least four technical areas appropriate to civil engineering. *15 Technical specialization.* ***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. 19 Globalization. **Analyse** engineering works and services in order to function at a basic level in a global context.
Design	The ability to apply their knowledge and understanding to develop designs to meet defined and specified requirements. The ability to demonstrate an understanding of design methodologies, and be able to use them.	An ability to design a system or a component to meet desired needs. *An understanding of the interaction between technical and environmental issues and ability to design and construct environmentally friendly civil engineering works.*	**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. **WA3:** Design solutions for *complex* engineering problems and design systems, components or processes that meet specified needs with appropriate consideration for public health and safety, cultural, societal, and environmental	(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.	2.3 SYSTEM THINKING 4.3 CONCEIVING, SYSTEMS ENGINEERING AND MANAGEMENT 4.4 DESIGNING	5. Design	9 Design. **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. *15 Technical specialization.* ***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.*

			considerations. (WK5)				
Investigations	The ability to conduct literature searches, use databases and other sources of information. The ability to design and conduct appropriate experiments, interpret the data and draw conclusions. The ability to demonstrate workshop and laboratory skills.	An ability to design and conduct experiments, as well as analyse and interpret data. An ability to identify research needs and necessary resources.	**Investigation**: Breadth and depth of investigation and experimentation. **WA4:** Conduct investigations of *complex* 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.	(b) an ability to design and conduct experiments, as well as to analyse and interpret data.	2.2 EXPERIMEN-TATION, INVESTIGATION AND KNOWLEDGE DISCOVERY	9. Experiments	7 Experiments. **Specify** an experiment to meet a need, conduct the experiment, and analyse and **explain** the resulting data.
Practice	The ability to select and apply relevant analytic and modelling methods. The ability to select and use appropriate equipment, tools and methods.	An ability to use the techniques, skills and modern engineering tools, including IT, necessary for engineering practice.	**Modern Tool Usage**: Level of understanding of the appropriateness of the tool. **WA5:** Create, select and apply appropriate techniques, resources, and modern engineering	(h) the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental , and societal	*1.3 ADVANCED ENGINEERING FUNDAMENTAL KNOWLEDGE, METHODS AND TOOLS* 4.1 EXTERNAL, SOCIETAL AND ENVIRONMENT	(4. Manufacturing / Construction) 6. Engineering Economics 8. Engineering Tools	10 Sustainability. **Analyse** systems of engineered works, whether traditional or emergent, for sustainable performance. 11 Contemporary issues and historical perspectives. **Analyse** the impact of historical and

	The ability to combine theory and practice to solve engineering problems. The ability to demonstrate understanding of applicable techniques and methods, and their limitations. The ability to demonstrate understanding of the non-technical implications of engineering practice. *The ability to demonstrate understanding of the health, safety and legal issues and responsibilities* *of engineering practice, the impact of engineering solutions within a societal and*	An understanding of the elements of project and construction management. *An understanding of the interaction between technical and environmental issues and ability to design and construct environmentally friendly civil engineering works.* An understanding of the impact of solutions for civil engineering works in a global and societal context.	and IT tools, including prediction and modelling, to complex engineering problems, with an understanding of the limitations. (WK6) **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) **Project Management and Finance**: Level of management	context. (k) an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice.	AL CONTEXT 4.2 ENTERPRISE AND BUSINESS CONTEXT (4.5 IMPLEMEN-TING) (4.6 OPERATING)	12. Risk, Reliability, and Uncertainty 13. Safety 14. Societal Impact 15. Systems Engineering (16. Operations and Maintenance) 17. Sustainability and Environmental Impact 18. Technical Breadth 19. Technical Depth 20. Business Aspects of Engineering	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. 12 Risk and uncertainty. **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. 13 Project management. **Formulate** documents to be incorporated into the project plan. (17 Public policy. **Apply** public policy process techniques to simple public policy problems related to civil engineering works.) (18 Business and public

	*environmental context, and commitment to professional ethics, responsibilities and norms of engineering practice. ** The ability to demonstrate knowledge of project management and business practices, such as risk and change management, and awareness of their limitations.		required for differing types of activity. **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.			25. Legal Aspects of Engineering (27. Professional Attitudes) 28. Project Management (29. Public Policy and Engineering)	administration. **Apply** business and public administration concepts and processes.) (22 Attitudes. **Demonstrate** attitudes supportive of the professional practice of civil engineering.)
Decision Making	*The ability to demonstrate understanding of the health, safety and legal issues and responsibilities of engineering practice, the impact of engineering solutions within a societal and environmental context, and*	An understanding of ethical commitment and professional responsibility of civil engineers.	**Ethics**: Understanding and level of practice. **WA8:** Apply ethical principles and commit to professional ethics and responsibilities and norms of engineering practice. (WK7)	(f) an understanding of professional and ethical responsibility.	2.5 ETHICS, EQUITY AND OTHER RESPONSIBILI-TIES	22. Ethical Responsibility	24 Professional and ethical responsibility. **Justify** a solution to an engineering problem based on professional and ethical standards and **assess** personal professional and ethical development.

	commitment to professional ethics, responsibilities and norms of engineering practice.						
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 multidisciplina ry 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 *complex* engineering activities with the engineering community and with	(g) an ability to communicate effectively.	3.2 COMMUNICA-TIONS 3.3 COMMUNICA-TIONS IN FOREIGN LANGUAGES	21. Communication	16 Communication. **Plan, compose,** and **integrate** the verbal, written, virtual, and graphical communication of a project to technical and non-technical audiences.

			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.				
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

7. Sectoral Qualifications Framework of General Descriptors for Engineering

Clarification: *A short introduction to the grid presented, followed by the actual table. It is suggested that information is also included about the construction of the table, such as it being based on a merger of the two European overarching qualification frameworks.*

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), 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 5.1 shows the correspondence between the QF dimensions and the identified dimensions of the SQF for the engineering domain.

Table 7.1 – 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.ieagreements.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 7.2 – TUNING Sectoral Qualifications Framework of General Descriptors at Master level for ENGINEERING (Level 7)

QF EHEA 2nd 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 Wider Competences (Responsibility and Autonomy) 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 complex engineering problems / products, processes and systems / issues / activities* in the field of study 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.	Apply knowledge and understanding to solve / design / investigate / conduct complex engineering problems / products, processes and systems / issues / activities in the field of study 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.	Select the most appropriate and relevant established method or new and innovative methods to solve / design / investigate / conduct complex engineering problems / products, processes and systems / issues / activities in the field of study 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, reflecting on ethical and social responsibilities linked to the carrying out of engineering activities.
I. *have demonstrated knowledge and understanding that is founded upon and extends and/or enhances that typically associated with Bachelor's level, and*	**Knowledge and Understanding**	• Demonstrate in-depth knowledge and understanding of mathematics and sciences underlying engineering specialisation, at a level necessary to achieve the other programme outcomes. • In-depth knowledge and understanding of engineering disciplines underlying	• Apply knowledge and understanding of mathematics and sciences and engineering disciplines underlying specialisation to solve / design / investigate / conduct complex engineering problems / products, processes and systems / issues / activities	• Identify knowledge and understanding necessary to solve / design / investigate / conduct complex engineering problems / products, processes and systems / issues / activities in the field of study that may be new or unfamiliar, involve considerations from outside the field of study,

that provides a basis or opportunity for originality in developing and/or applying ideas, often within a research context		specialisation, at a level necessary to achieve the other programme outcomes. • Critical awareness of the forefront of engineering specialisation. • Critical awareness of the wider multidisciplinary context of engineering and of knowledge issues at the interface between different fields.	in the field of study 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.	incompletely defined and /or conflicting issues and non-technical constraints, and require original/innovative thinking.
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	**Analysis and Problem Solving**	• Demonstrate comprehensive knowledge and understanding of methods of analysis of engineering issues (products, processes, systems, situations) in the field of study, including new and innovative methods, and of their limitations. • Demonstrate comprehensive knowledge and understanding of methods of problem solving in the field of study, including new and innovative methods, and of their limitations. • Demonstrate critical awareness of the need of solutions of engineering problems in the field of study safe, sustainable and of low impact on society and environment.	• Conceptualise and analyse new and complex engineering issues (products, processes, systems, situations) in the field of study and within broader or multidisciplinary contexts, to critically interpret the outcomes of such analyses and to present an understanding of the issue and recommendations for necessary measures taking requirements and constraints into account. • Identify, formulate and solve complex engineering problems in the field of study that may be unfamiliar or in new and emerging areas of the specialisation, involve considerations from outside the field of study, incompletely defined and /or conflicting issues and non-technical – societal, health and safety, environmental, economic and industrial – constraints.	• Identify the most appropriate and relevant method of analysis of engineering issues (products, processes, systems, situations) in the field of study from established or new and innovative methods. • Identify the most appropriate and relevant method of problem solving in the field of study from established methods or new and innovative methods. • Identify solutions of engineering problems in the field of study and within broader or multidisciplinary contexts and to present recommendations for necessary measures safe, sustainable and of low impact on society and environment.
	Design	• Demonstrate comprehensive knowledge and understanding of design methods in the field of study, including new and original methods, and of their limitations. • Demonstrate critical awareness of the	• Conceive and design complex engineering products (devices, artefacts, etc.), processes and systems in the field of study that may be new or unfamiliar, involve considerations from outside the	• Identify the most appropriate and relevant design method in the field of study area from established or new and innovative methods. • Conceive and design safe and sustainable

		need for sustainable development in the field of study.	field of study, incompletely defined and /or competing specifications and non-technical – societal, health and safety, environmental, economic and industrial – constraints. • Design using knowledge and understanding at the forefront of the engineering specialisation.	engineering products, processes and systems in the field of study.
	Investigations	• Demonstrate comprehensive knowledge and understanding of investigation methods in the field of study, including new and original emerging methods, and of their limitations. • Demonstrate knowledge and understanding of new and emerging technologies at the forefront of engineering specialisation.	• Conduct searches of literature, to consult and critically use databases and other sources of information in the field of study and within broader or multidisciplinary contexts. • Consult and apply codes of practice and safety regulations in the field of study and within broader or multidisciplinary contexts. • Carry out simulation in order to pursue detailed investigations and research of complex engineering issues in the field of study and within broader or multidisciplinary contexts, critically evaluate results and draw conclusions. • Design and conduct experimental investigations in the field of study, critically evaluate data and draw conclusions. • Investigate the application of new and emerging technologies at the forefront of engineering specialisation.	• Identify the most appropriate and relevant investigation method in the field of study, including new and original emerging methods. • Identify the potential impact of new and emerging technologies at the forefront of engineering specialisation on society and environment.
	Practice	• Demonstrate comprehensive and understanding of materials, equipment and tools, technologies and processes in	• Use and apply practical knowledge and understanding to solve / design / investigate / conduct complex	• Identify practical knowledge and understanding necessary to solve / design / investigate / conduct complex

		the field of study and of their limitations. • Demonstrate critical awareness of the societal, health and safety, environmental impact and risks of engineering activities in the field of study. • Demonstrate critical awareness of economic, industrial and managerial implications (such as project management) of engineering activities in the field of study.	engineering problems / products, processes and systems / issues / activities in the field of study and within broader or multidisciplinary contexts, integrating theory and practice. • Implement and conduct complex engineering activities in the field of study and within broader or multidisciplinary contexts by identifying societal, health and safety, environmental impact and risks and economic, industrial and managerial implications and acting appropriately, and to meet deliverable, schedule and budget requirements, while fulfilling all legal and regulatory requirements.	engineering problems / products, processes and systems / issues / activities in the field of study and within broader or multidisciplinary contexts. • Identify safe and sustainable implementation and conduction processes of engineering activities in the field of study and within broader or multidisciplinary contexts • Evaluate and mitigate/minimize societal, health and safety, environmental impact and risks and to optimize economic, industrial and managerial implications of engineering activities in the field of study and within broader or multidisciplinary contexts.
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*	**Decisions making**	• Demonstrate critical awareness of the ethical and social responsibilities linked to the management of engineering work contexts in the field of study.	• Identify, locate, obtain, organize and evaluate information and data in the field of study and within broader or multidisciplinary contexts. • Manage complex engineering work contexts in the field of study and within broader or multidisciplinary contexts that may be unpredictable and require new strategic approaches, and to take decisions and formulate judgments with incomplete or limited information and data.	• Reflect on ethical and social responsibilities linked to the management of complex work contexts in the field of study and within broader or multidisciplinary contexts, taking decisions and formulating judgments.
IV. *can communicate their conclusions, and the knowledge and rationale underpinning these, to*	**Team-working**	• Demonstrate knowledge and understanding of the strategies and methods of management of teams composed of different disciplines and	• Function effectively in national and international contexts as leader of a team that may be composed of different disciplines and levels. • Manage teams and resources meeting	• Identify the most appropriate and relevant method of team management and to identify elements of successful teamwork. • Take responsibility for contributing to

specialist and non-specialist audiences clearly and unambiguously		levels. • Demonstrate awareness of leadership responsibilities.	deliverable, schedule and budget requirements.	professional knowledge and practice and/or for reviewing the strategic performance of teams.
	Communication	• Demonstrate knowledge and understanding of the communication strategies and of the diverse methods and tools of communication, including new and innovative ones, and of their limitations.	• Apply knowledge and understanding of communication strategies and to use diverse method and tool of communication, including new and innovative ones, to 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.	• Identify the most appropriate and relevant strategy, method and tool of communication.
V. *have the learning skills to allow them to continue to study in a manner that may be largely self-directed or autonomous*	**Lifelong Learning**	• Demonstrate knowledge and understanding of one's personal strengths and weaknesses and of the learning methods 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.	• Engage in independent lifelong learning and 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 autonomously.	• Identify the most appropriate learning strategy and method in independent lifelong learning and 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.

* **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 engineering activities and/or
- knowledge and understanding of engineering practice.

Table 7.3 – TUNING Sectoral Qualifications Framework of General Descriptors at Bachelor level for ENGINEERING (Level 6)

QF EHEA 1st cycle descriptors	SQF domain dimensions Level 6 (BACHELOR)	EQF descriptor Knowledge Level 6 *Advanced knowledge of a field of work or study, involving a critical understanding of theories and principles*	EQF descriptor Skills Level 6 *Advanced skills, demonstrating mastery and innovation, required to solve complex and unpredictable problems in a specialised field of work or study*	EQF descriptor Wider Competences (Responsibility and Autonomy) Level 6 - *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*
Special feature degree programme		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.	Apply knowledge and understanding to solve / design / investigate / conduct complex engineering problems / products, processes and systems / issues / activities in the field of study.	Select the most appropriate and relevant established method to solve / design / investigate / conduct complex engineering problems / products, processes and systems / issues / activities in the field of study, being aware of ethical and social responsibilities linked to the management of engineering activities.
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 forefront of their field*	**Knowledge and Understanding**	• Demonstrate knowledge and understanding of mathematics and sciences underlying engineering specialisation, at a level necessary to achieve the other programme outcomes. • Demonstrate knowledge and understanding of engineering disciplines underlying specialisation, at a level necessary to achieve the other programme outcomes, including some awareness at their forefront. • Demonstrate awareness of the wider	• Apply knowledge and understanding of mathematics and sciences and engineering disciplines underlying specialisation to solve / design / investigate / conduct complex engineering problems / products, processes and systems / issues / activities in the field of study.	• Identify knowledge and understanding necessary to solve / design / investigate / conduct complex engineering problems / products, processes and systems / issues / activities in the field of study.

of study		multidisciplinary context of engineering.		
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;*	**Analysis and Problem Solving**	• Demonstrate knowledge and understanding of established methods of analysis of engineering issues (products, processes, systems, situations) in the field of study and of their limitations. • Demonstrate knowledge and understanding of established methods of problem solving in the field of study and of their limitations. • Demonstrate awareness of the importance of non-technical – societal, health and safety, environmental, economic and industrial – considerations in solving engineering problems in the field of study.	• Analyse complex engineering issues (products, processes, systems, situations) in the field of study, to correctly interpret the outcomes of such analyses and to present an understanding of the issue and recommendations for necessary measures taking requirements and constraints into account. • Identify, formulate and solve complex engineering problems in the field of study having awareness of non-technical – societal, health and safety, environmental, economic and industrial – implications.	• Identify appropriate and relevant established methods of analysis of engineering issues (products, processes, systems, situations) in the field of study. • Identify appropriate and relevant established methods of problem solving in the field of study. • Reflect on non-technical – societal, health and safety, environmental, economic and industrial – implications in solving engineering problems in the field of study and in formulating recommendations for necessary measures.
	Design	• Demonstrate knowledge and understanding of established design methods in the field of study and of their limitations. • Demonstrate awareness of the importance of non-technical – societal, health and safety, environmental, economic and industrial – considerations in designing engineering products, processes and systems in the field of study.	• Develop and design complex engineering products (devices, artefacts, etc.), processes and systems in the field of study to meet established requirements having awareness of non-technical – societal, health and safety, environmental, economic and industrial – implications.	• Identify appropriate and relevant established design methods in the field of study. • Reflect on non-technical – societal, health and safety, environmental, economic and industrial – implications in designing engineering products, processes and systems in the field of study.
	Investigations	• Demonstrate knowledge and understanding of established investigation methods in the field of study and of their limitations.	• Conduct searches of literature, to consult and use scientific databases and other appropriate sources of information in the field of study. • Consult and apply codes of practice and safety regulations in the field of study. • Carry out simulation in order to pursue	• Identify appropriate and relevant established investigation methods in the field of study.

			detailed investigations and research of technical issues in the field of study, interpret results and draw conclusions. • Design and conduct experimental investigations in the field of study, interpret data and draw conclusions.	
	Practice	• Demonstrate knowledge and understanding of materials, equipment and tools, engineering technologies and processes in the field of study and of their limitations. • Demonstrate awareness of the societal, health and safety, environmental impact and risks of engineering activities in the field of study. • Demonstrate awareness of economic, industrial and managerial implications (such as project management) of engineering activities in the field of study.	• Use and apply practical knowledge and understanding to solve / design / investigate / conduct complex engineering problems / products, processes and systems / issues / activities in the field of study. • Implement and conduct complex engineering activities in the field of study having awareness of societal, health and safety, environmental impact and risks and economic, industrial and managerial implications and acting appropriately, and to meet deliverable, schedule and budget requirements, while fulfilling all legal and regulatory requirements.	• Identify practical knowledge and understanding necessary to solve / design / investigate / conduct complex engineering problems / products, processes and systems / issues / activities. in the field of study. • Reflect on societal, health and safety, environmental impact and risks and on economic, industrial and managerial implications of engineering activities in the field of study.
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*	**Decision making**	• Demonstrate awareness of the ethical and social responsibilities linked to the management of engineering activities in the field of study.	• Gather and interpret information and data. • Manage complex engineering activities in the field of study and to take decisions and formulate judgments based on available data.	• Reflect on ethical and social responsibilities linked to the management of engineering activities in the field of study, taking decisions and formulating judgments.
IV. *can communicate information, ideas, problems and solutions to*	**Team-working**	• Demonstrate knowledge and understanding of the working methods of teams.	• Function effectively in national and international contexts as a member of a team that may be composed of engineers	• Take responsibility for managing professional development of individuals and groups.

both specialist and non-specialist audiences			and non-engineers.	
	Communication	• Demonstrate knowledge and understanding of the diverse methods and tools of communication and of their limitations.	• Use diverse method and tool of communication to communicate effectively information, describe activities and communicate their exits/results with engineering community in national and international context and society at large.	• Identify appropriate and relevant methods and tools of communication.
V. *have developed those learning skills that are necessary for them to continue to undertake further study with a high degree of autonomy*	**Lifelong Learning**	• Demonstrate knowledge and understanding of one's personal strengths and weaknesses and of the learning methods necessary to follow developments in science and technology in the field of study.	• Engage in independent life-long learning and to follow developments in science and technology in the field of study.	• Identify appropriate learning strategies and methods in independent lifelong learning and 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.

8. Subject Area Qualifications Framework of General Descriptors for Civil Engineering

Clarification: *A short introduction to the grid presented, followed by the actual table. It is suggested to explain how the outcomes of this table are aligned with the Sectoral Framework.*

The SAG shared the opinion that normally a subject area qualifications 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 6.1 and 6.2 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 8.1 – TUNING Qualifications Framework General Descriptors of a Master Course in the Subject Area of CIVIL ENGINEERING (LEVEL 7)

QF EHEA 2nd 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 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 complex civil engineering problems / products, processes and systems / issues / activities*/** 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.	Apply knowledge and understanding to solve / design / investigate / conduct complex civil engineering problems / products, processes and systems / issues / activities 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.	Select the most appropriate and relevant established method or new and innovative methods to solve / design / investigate / conduct complex civil engineering problems / products, processes and systems / issues / activities 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, reflecting on ethical and social responsibilities linked to the carrying out of engineering activities.
I. *have demonstrated knowledge and understanding that is founded upon and extends and/or*	**Knowledge and Understanding**	• Demonstrate in-depth knowledge and understanding of mathematics and sciences*** underlying civil engineering specialisation, at a level necessary to achieve the other programme outcomes.	• Apply knowledge and understanding of mathematics and sciences and engineering disciplines underlying civil engineering specialisation to solve / design / investigate / conduct complex	• Identify knowledge and understanding necessary to solve / design / investigate / conduct complex civil engineering problems / products, processes and systems / issues / activities that may be

enhances that typically associated with Bachelor's level, and that provides a basis or opportunity for originality in developing and/or applying ideas, often within a research context		• Demonstrate in-depth knowledge and understanding of engineering disciplines underlying civil engineering specialisation****, at a level necessary to achieve the other programme outcomes. • Demonstrate critical awareness of the forefront of civil engineering specialisation. • Demonstrate critical awareness of the wider multidisciplinary context of engineering and of knowledge issues at the interface between different fields.	civil engineering problems / products, processes and systems / issues / activities 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.	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.
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	**Analysis and Problem Solving**	• Demonstrate comprehensive knowledge and understanding of methods of analysis of engineering issues (products, processes, systems, situations) in civil engineering subject area, including new and innovative methods, and of their limitations. • Demonstrate comprehensive knowledge and understanding of methods of solving civil engineering problems, including new and innovative methods, and of their limitations. • Demonstrate critical awareness of the need of solutions of civil engineering problems safe, sustainable and of low impact on society and environment.	• Conceptualise and analyse new and complex engineering issues (products, processes, systems, situations) in civil engineering subject area and within broader or multidisciplinary contexts, to critically interpret the outcomes of such analyses and to present an understanding of the issue and recommendations for necessary measures taking requirements and constraints into account. • Identify, formulate and solve complex civil engineering problems that may be unfamiliar or in new and emerging areas of the specialisation, involve considerations from outside the field of study, incompletely defined and /or conflicting issues and non-technical – societal, health and safety, environmental, economic and industrial – constraints.	• Identify the most appropriate and relevant method of analysis of engineering issues (products, processes, systems, situations) in civil engineering subject area from established or new and innovative methods. • Identify the most appropriate and relevant method of solving civil engineering problems from established or new and innovative methods. • Identify solutions of engineering problems in civil engineering subject area and within broader or multidisciplinary contexts and to present recommendations for necessary measures safe, sustainable and of low impact on society and environment.

	Design	• Demonstrate comprehensive knowledge and understanding of methods of design in civil engineering subject area, including new and original methods, and of their limitations. • Demonstrate critical awareness of the need for sustainable development in civil engineering subject area.	• Conceive and design complex civil engineering products (devices, artefacts, etc.), processes and systems that may be new or unfamiliar, involve considerations from outside the field of study, incompletely defined and /or competing specifications and non-technical – societal, health and safety, environmental, economic and industrial – constraints. • Design using knowledge and understanding at the forefront of the engineering specialisation.	• Identify the most appropriate and relevant method of design in civil engineering subject area from established or new and innovative methods. • Conceive and design sustainable engineering products, processes and systems in civil engineering subject area.
	Investigations	• Demonstrate comprehensive knowledge and understanding of investigation methods in civil engineering subject area, including new and original emerging methods, and of their limitations. • Demonstrate knowledge and understanding of new and emerging technologies at the forefront of civil engineering specialisation.	• Conduct searches of literature, to consult and critically use databases and other sources of information in civil engineering subject area and within broader or multidisciplinary contexts. • Consult and apply codes of practice and safety regulations in civil engineering subject area and within broader or multidisciplinary contexts. • Carry out simulation in order to pursue detailed investigations and research of complex technical issues in civil engineering subject area and within broader or multidisciplinary contexts, critically evaluate results and draw conclusions. • Design and conduct experimental investigations in civil engineering subject area, critically evaluate data and draw conclusions.	• Identify the most appropriate and relevant investigation method in civil engineering subject area, including new and original emerging methods. • Identify the potential impact of new and emerging technologies at the forefront of civil engineering specialisation on society and environment.

			• Investigate the application of new and emerging technologies at the forefront of civil engineering specialisation.	
	Practice	• Demonstrate comprehensive knowledge and understanding of materials, equipment and tools, technologies and processes in civil engineering subject area and of their limitations. • Demonstrate critical awareness of the societal, health and safety, environmental impact and risks of civil engineering activities. • Demonstrate critical awareness of economic, industrial and managerial implications (such as project management) of civil engineering activities.	• Use and apply practical knowledge and understanding to solve / design / investigate / conduct complex engineering problems / products, processes and systems / issues / activities in civil engineering subject area and within broader or multidisciplinary contexts, integrating theory and practice. • Implement and conduct complex engineering activities in civil engineering subject area and within broader or multidisciplinary contexts by identifying societal, health and safety, environmental impact and risks and economic, industrial and managerial implications and acting appropriately, and to meet deliverable, schedule and budget requirements, while fulfilling all legal and regulatory requirements.	• Identify practical knowledge and understanding necessary to solve / design / investigate / conduct complex engineering problems / products, processes and systems / issues / activities in civil engineering subject area and within broader or multidisciplinary contexts. • Identify safe and sustainable implementation and conduction processes of engineering activities in civil engineering subject area and within broader or multidisciplinary contexts. • Evaluate and mitigate/minimize societal, health and safety, environmental impact and risks and to optimize economic, industrial and managerial implications of engineering activities in civil engineering subject area and within broader or multidisciplinary contexts.
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*	**Decisions making**	• Demonstrate critical awareness of the ethical and social responsibilities linked to the management of work contexts in civil engineering subject area.	• Identify, locate, obtain, organize and evaluate information and data in civil engineering subject area and within broader or multidisciplinary contexts. • Manage complex work contexts in civil engineering subject area and within broader or multidisciplinary contexts that may be unpredictable and require new strategic approaches, and to take decisions and formulate judgments with	• Reflect on ethical and social responsibilities linked to the management of complex work contexts in civil engineering subject area and within broader or multidisciplinary contexts, taking decisions and formulating judgments.

responsibilities linked to the application of their knowledge and judgements			incomplete or limited information and data.	
IV. *can communicate their conclusions, and the knowledge and rationale underpinning these, to specialist and non-specialist audiences clearly and unambiguously*	**Team-working**	• Demonstrate knowledge and understanding of the strategies and methods of management of teams composed of different disciplines and levels. • Demonstrate awareness of leadership responsibilities.	• Function effectively in national and international contexts as leader of a team that may be composed of different disciplines and levels. • Manage teams and resources meeting deliverable, schedule and budget requirements.	• Identify the most appropriate and relevant strategy and method of team management and to identify elements of successful teamwork. • Take responsibility for contributing to professional knowledge and practice and/or for reviewing the strategic performance of teams.
	Communication	• Demonstrate knowledge and understanding of the communication strategies and of the diverse methods and tools of communication, including new and innovative ones, and of their limitations.	• Apply knowledge and understanding of communication strategies and to use diverse methods and tools of communication, including new and innovative ones, to 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.	• Identify the most appropriate and relevant strategy, method and tool of communication.
V. *have the learning skills to allow them to continue to study in a manner that may be largely self-directed or autonomous*	**Lifelong Learning**	• Demonstrate knowledge and understanding of one's personal strengths and weaknesses and of the learning methods necessary to follow developments in science and technology and undertake further studies in new and emerging in civil engineering subject area and within broader or multidisciplinary	• Engage in independent lifelong learning and 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 autonomously.	• Identify the most appropriate learning strategy and method in independent lifelong learning and 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.

		contexts.		

* **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; Traffic Engineering;
- Environmental Engineering; Safety Engineering; Sanitary Engineering;
- Economics and Management.

Table 8.2 – TUNING Qualifications Framework General Descriptors of a Bachelor Course in the Subject Area of CIVIL ENGINEERING (LEVEL 6)

QF EHEA 1st cycle descriptors	SQF domain dimensions Level 6 (BACHELOR)	EQF descriptor Knowledge Level 6 *Advanced knowledge of a field of work or study, involving a critical understanding of theories and principles*	EQF descriptor Skills Level 6 *Advanced skills, demonstrating mastery and innovation, required to solve complex and unpredictable problems in a specialised field of work or study*	EQF descriptor Wider Competences Level 6 - *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*
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.	Select the most appropriate and relevant established method to solve / design / investigate / conduct complex civil engineering problems / products, processes and systems / issues / activities, being aware of ethical and social responsibilities linked to the management of engineering activities.
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 forefront of their field*	**Knowledge and Understanding**	• Demonstrate knowledge and understanding of mathematics and sciences*** underlying civil engineering specialisation, at a level necessary to achieve the other programme outcomes. • Demonstrate knowledge and understanding of engineering disciplines**** underlying civil engineering specialisation, at a level necessary to achieve the other programme outcomes, including some awareness at their forefront.	• Apply knowledge and understanding of mathematics and 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 necessary to solve / design / investigate / conduct complex civil engineering problems / products, processes and systems / issues / activities.

of study		• Demonstrate awareness of the wider multidisciplinary context of engineering.		
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;*	**Analysis and Problem Solving**	• Demonstrate knowledge and understanding of established methods of analysis of engineering issues (products, processes, systems, situations) in civil engineering subject area and of their limitations. • Demonstrate knowledge and understanding of established methods of solving civil engineering problems and of their limitations. • Demonstrate awareness of the importance of non-technical – societal, health and safety, environmental, economic and industrial – considerations in solving civil engineering problems.	• Analyse complex civil engineering issues (products, processes, systems, situations), to correctly interpret the outcomes of such analyses and to present an understanding of the issue and recommendations for necessary measures taking requirements and constraints into account. • Identify, formulate and solve complex civil engineering problems having awareness of non-technical – societal, health and safety, environmental, economic and industrial – implications.	• Identify appropriate and relevant established methods of analysis of engineering issues (products, processes, systems, situations) in civil engineering subject area. • Identify appropriate and relevant established methods of solving civil engineering problems. • Reflect on non-technical – societal, health and safety, environmental, economic and industrial – implications in solving civil engineering problems and in formulating recommendations for necessary measures.
	Design	• Demonstrate knowledge and understanding of established design methods in civil engineering subject area and of their limitations. • Demonstrate awareness of the importance of non-technical – societal, health and safety, environmental, economic and industrial – considerations in designing civil engineering products, processes and systems.	• Develop and design complex civil engineering products (devices, artefacts, etc.), processes and systems to meet established requirements having awareness of non-technical – societal, health and safety, environmental, economic and industrial – implications.	• Identify appropriate and relevant established design methods in civil engineering subject area. • Reflect on non-technical – societal, health and safety, environmental, economic and industrial – implications in designing civil engineering products, processes and systems.
	Investigations	• Demonstrate knowledge and understanding of established investigation methods in civil engineering subject area and of their limitations.	• Conduct searches of literature, to consult and use scientific databases and other appropriate sources of information in civil engineering subject area. • Consult and apply codes of practice and	• Identify appropriate and relevant established investigation methods in civil engineering subject area.

			safety regulations in civil engineering subject area. • Carry out simulation in order to pursue detailed investigations and research of technical issues in civil engineering subject area, interpret results and draw conclusions. • Design and conduct experimental investigations in civil engineering subject area, interpret data and draw conclusions.	
	Practice	• Demonstrate knowledge and understanding of materials, equipment and tools, technologies and processes in civil engineering subject area and of their limitations. • Demonstrate awareness of the societal, health and safety, environmental impact and risks of civil engineering activities. • Demonstrate awareness of economic, industrial and managerial implications (such as project management) of civil engineering activities.	• Use and apply practical knowledge and understanding to solve / design / investigate / conduct complex civil engineering problems / products, processes and systems / issues / activities. • Implement and conduct complex civil engineering activities having awareness of societal, health and safety, environmental impact and risks and economic, industrial and managerial implications and acting appropriately, and to meet deliverable, schedule and budget requirements, while fulfilling all legal and regulatory requirements.	• Identify practical knowledge and understanding necessary to solve / design / investigate / conduct complex civil engineering problems / products, processes and systems / issues / activities. • Reflect on societal, health and safety, environmental impact and risks and on economic, industrial and managerial implications of civil engineering activities.
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*	**Decision making**	• Demonstrate awareness of the ethical and social responsibilities linked to the management of civil engineering activities.	• Gather and interpret information and data. • Manage complex civil engineering activities and to take decisions and formulate judgments based on available data.	• Reflect on ethical and social responsibilities linked to the management of civil engineering activities, taking decisions and formulating judgments.

IV. *can communicate information, ideas, problems and solutions to both specialist and non-specialist audiences*	**Team-working**	• Demonstrate knowledge and understanding of the working methods of teams.	• Function effectively in national and international contexts as a member of a team that may be composed of engineers and non-engineers.	• Take responsibility for managing professional development of individuals and groups.
	Communication	• Demonstrate knowledge and understanding of the diverse methods and tools of communication and of their limitations.	• Use diverse methods and tools of communication to communicate effectively information, describe activities and communicate their exits/results with engineering community in national and international context and society at large.	• Identify appropriate and relevant methods and tools of communication.
V. *have developed those learning skills that are necessary for them to continue to undertake further study with a high degree of autonomy*	**Lifelong Learning**	• Demonstrate knowledge and understanding of one's personal strengths and weaknesses and of the learning methods necessary to follow developments in science and technology in civil engineering subject area.	• Engage in independent lifelong learning and to follow developments in science and technology in civil engineering subject area.	• Identify appropriate learning strategies and methods in independent lifelong learning and 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.

9. Learning, Teaching and Assessment

Clarification: *This chapter should include information about learning, teaching and assessment strategies and approaches which are relevant for achieving the learning outcomes as included in the table presented in the previous chapter. The utility value of the framework is highly furthered if applicable approaches can be offered per dimension, taking into account the categories 'knowledge', 'skills' but in particular 'wider competences'. These can be phrased as examples of good practice. It is advised to make use of previous documents as well as the CALOHEE questionnaire taking into account, in particular the identified 'tasks' which graduates are expected to apply in a work situation.*

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 7.1.

Table 9.1 – 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 *(combination of Internet instruction and classes)*	1	Flipped classroom *(combination of Internet instruction and classes)*	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 7.2 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 9.2 - 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 6.1 and 6.2 are defined in the document *Assessment 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 9.3.

Table 9.3 - 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 3.3. Essay – Assertion 3.4. Essay – Write on 3.5. Essay – Describe/Explain 3.6. Essay – Discuss 3.7. Essay – Compare 3.8. Essay – Evaluate 3.9. Essay – Problem
Problem solving	4.1. Problem solving – Routines 4.2. Problem solving – Diagnosis 4.3. Problem solving – Strategy 4.4. Problem solving – Interpretation 4.5. Problem solving – Generation
Practical work	5.1. Practical work – Demonstration 5.2. Practical work – Exercise 5.3. Practical work – Structured enquiry 5.4. Practical work – Open ended enquiry 5.5. Practical work – Project
Short-answer questions (SAQ)	6.1. SAQ – Select crucial evidence 6.2. SAQ – Explain methods, procedures and relationships

	6.3. SAQ – Present arguments 6.4. SAQ – Describe limitations of data 6.5. SAQ – Formulate valid conclusions 6.6. SAQ – Identify assumptions 6.7. SAQ – Formulate hypothesis 6.8. SAQ – Formulate action plans
Reflective Practice Assignments	7.1. Reflective practice assignments – Concrete experience 7.2. Reflective practice assignments – Reflective observation 7.3. Reflective practice assignments – Abstract conceptualization 7.4. Reflective practice assignments – Active experimentation

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 8.1 and 8.2, shown in the document *Assessment 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.

10. 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 whole 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 not only.

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12. Contacts

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