FACULDADE DE ENGENHARIA DA UNIVERSIDADE DO PORTO

Assessment of soft skills for engineering students and professionals

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Resumo

As competências transversais podem ser definidas como traços de personalidade ou capacidades comportamentais, embora seja difícil obter uma definição precisa. Ao mesmo tempo, saber como avaliar essas competências, tanto num processo de autorreflexão como numa heteroavaliação, é um desafio ainda maior. O aspeto com o qual os autores parecem concordar é o quanto as *soft skills* são essenciais para o desenvolvimento dos alunos do ensino superior e a eficácia com que desempenham a sua profissão no atual mundo do trabalho. Este fator torna o processo de avaliação fundamental para os próprios alunos, para os professores que os acompanham na sua formação em engenharia e para as empresas que os recrutam e querem garantir que contratam os melhores candidatos.

Esta dissertação tem como objetivo ajudar as três partes interessadas, reunindo modelos de ensino relevantes e apresentando um novo modelo de avaliação. Há cinco competências analisadas para este estudo, após extensa pesquisa e revisão de literatura sobre a relevância das mesmas para a prática de engenharia: comunicação, trabalho em equipa, resolução de conflitos, pensamento crítico e resolução de problemas e criatividade. A pesquisa que levou à lista final de competências foi fortemente alinhada com a experiência da autora, e tem dois aspetos principais que devem ser considerados: estas não são as únicas cinco competências transversais que os estudantes de engenharia devem desenvolver como suporte à sua carreira, e existem competências intrínsecas às descritas nesta dissertação, como liderança e facilitação.

Em relação ao ensino de *soft skills*, existem vários modelos que visam fornecer uma compreensão mais aprofundada sobre como interagir com outras pessoas, abordando sentimentos e reconhecendo que uma mensagem pode ser interpretada de maneiras diferentes, aprendendo quais as necessidades de uma equipa e como podem variar com o tempo, resolvendo conflitos recorrendo à facilitação e empatia, sendo capazes de pensar criticamente sobre um tópico e encontrando soluções criativas para novos e desafiantes problemas. O modelo de avaliação foi construído considerando estes modelos de aprendizagem e uma forte influência de modelos de avaliação e acreditação já estabelecidos para o ensino de engenharia na Europa, como o EQF, o EUR-ACE e o Tuning-CALOHEE.

Ao aplicar o modelo de avaliação desenvolvido, os alunos tornam-se mais conscientes das suas necessidades para um carreira como engenheiros, os professores recebem uma ferramenta para os ajudar a desenvolver um planeamento de aulas que capacita as necessidades de seus alunos enquanto avaliam continuamente o seu crescimento, e as empresas podem testar os resultados da educação em engenharia e observar se os candidatos têm as competências esperadas de um finalista de mestrado.

Palavras-chave: Competências Transversais, Educação em Engenharia, Soft Skills

Abstract

Soft skills can be defined as personality traits or behaviours skills, although it is challenging to have a precise definition. At the same time, knowing how to assess said skills, both as self-reflection or while evaluating others, is a greater challenge. The aspect that authors seem to agree on is how essential soft skills are for the development of higher education students and the effectiveness of today's jobs and tasks. This factor makes the assessment process crucial for the students themselves, the professors that help them through the process of becoming engineers and the companies that recruit them and want to make sure they hire the best possible candidates.

This dissertation aims to help these three stakeholders by gathering relevant teaching models and presenting a new assessment model. There are five skills analysed for this study, following extensive research and literature review on relevance to the practice of engineering: communication, teamwork, conflict solving, problem-solving and creativity and critical thinking. The research that led to the final list of competences was strongly aligned with the author's experience, and has two main aspects that should be considered: these are not the only five soft skills that engineering students should develop to support them on their career, and there are competences that are considered to be intrinsic to the ones described in this dissertation, such as leadership and facilitation.

Regarding teaching soft skills, there are multiple models that are meant to give a more in-depth understanding on how to interact with other people by addressing feelings and acknowledging that one message can be interpreted in different ways, by learning what are the needs of a team and how they can vary through time, by resolving conflict through facilitation and applying empathy, by being able to think critically about a topic and by finding creative solutions to ever-changing problems. The assessment model was built on top of these learning models with a strong influence from already established evaluation and accreditation models for engineering education in Europe, such as EQF, EUR-ACE and Tuning-CALOHEE.

By applying the assessment model developed, students become more aware of their performance needs as engineers, professors get a tool to assist them in class design that empowers their students' needs while continually assessing their growth and companies can test the outcomes of the engineering education and observe if the candidates have the expertise expected of engineering master's degree graduates.

Keywords: Soft Skills, Engineering Education, Competences

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Lastly, my family. The four most important people of my life and the ones that never thought twice before giving me their best without asking for nothing in return. My brother and sister, for being my mentors and the people I look up to the most. My parents, for having the ability to give me more love than what I thought possible to fit in one person. There is not one step in my life I could achieve without their support.

Beatriz Neiva

"Engineering is not only study of 45 subjects but it is moral studies of intellectual life."

— Prakhar Srivastav

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Abbreviations and Symbols

AMA	American Management Association
ASEE	American Society for Engineering Education
BEST	Board of European Students of Technology
CALOHEE	Measuring and Comparing Achievements of Learning Outcomes in Higher Education in Europe
CEDEFOP	European Centre for the Development of Vocational Training
CPS	Creative Problem Solving
EAFSG	EUR-ACE® Framework Standards and Guidelines
EHEA	European Higher Education Area
EIQ	Emotional Intelligence Quotient
ENAEE	European Network for Accreditation of Engineering Education
EQF	European Qualifications Framework
EU	European Union
IQ	Intelligence Quotient
L&D	Learning & Development
NGO	Non-governmental Organisation
NVC	Nonviolent Communication
O*NET	Occupational Information Network
SEFI	European Society for Engineering Education
TKI	Thomas-Kilmann Conflict Mode Instrument
US	United States

Chapter 1

Introduction

1.1 Context

The quality of engineering education is a growing concern around the world, as different organisations focus their attention and work around this topic. However, it is not only a matter of a college degree or the quality of the learning process for university students. There is a particular focus on education during an engineer's career.

CALOHEE [1] is an EU funded project that aims to assess higher education in Europe by reviewing the competences developed by students and the programmes offered by European universities. The project's domains are Engineering (Civil Engineering), Health Care (Nursing), Humanities (History), Natural Sciences (Physics) and Social Sciences (Education). One of the main projects from CALOHEE was TUNING [2], a process from universities for universities, that aimed for the development of a methodology for designing and implementing higher degrees' programmes. It was launched in 2000 and now there more than 120 countries involved and 1 000 universities as partners.

ASEE [3], the American Society for Engineering Education, is a non-profit organisation that promotes the engineering profession near students and develops policies and programs that create opportunities for engineering faculty members.

SEFI [4], the European Society for Engineering Education, is the largest network of engineering education players in Europe. Its members are institutions of higher education along with their staff and students. Its goal is to improve engineering education and to enhance the image of the engineering profession.

1.2 Goals and Motivation

The primary motivation to write this thesis comes from various factors: the growing interest of companies on engineering students' soft skills, the involvement of the author in an European NGO, BEST - Board of European Students of Technology, that thrives to develop students through

complementary education and educational involvement and the author's experience in training soft skills via non-formal education for European students of technology.

The goals for the dissertation are strictly connected with the teaching and evaluating of soft skills. It will be studied how engineering students try to develop their skills and how companies can evaluate them in the recruitment process. It is also a goal to apply the developed model to a real-life situation.

1.3 Structure

This dissertation is divided into nine chapters. The first one sums-up the context of the topic and the goals for the dissertation. Chapter 2 defines soft skills, states their importance and creates a list of the top 5 competences for engineers to be studied in the thesis. Chapter 3 is a literature review on assessment and accreditation projects for engineering programmes, and the respective frameworks developed. From Chapter 4 to Chapter 8, there are descriptions of soft skills, teaching models for them and frameworks for assessment to be applied in an evaluation environment. Lastly, conclusions and topics for future works are in Chapter 9.

The goal for this alignment is for the reader to firstly have an overview of soft skills, their definition and importance, then understand how assessment and accreditation are made in Europe and, with this information, get to know the five chosen soft skills and ways to assess them.

Chapter 2

Soft Skills

2.1 Definition

Soft skills, defined as personality traits [5], interpersonal and behavioural skills [6] or even being a term related to one's EIQ (Emotional Intelligence Quotient) [7], have a growing importance for engineers both in the search for employment and in their success in life. They concluded that success in life does not rely only on traits measured by IQ (Intelligence Quotient) or grades since these do not consider many skills necessary in life. Yet, success in life can depend on individual personality traits, that not only predict outcomes but can also cause them. These features are hard to measure since they depend on incentives to apply effort and other attributes that might be necessary to perform specific tasks. Also, what is considered to be a soft skill in a specific context might be a hard skill in a different one [8]. These authors also showed that personality traits develop the acquisition of knowledge, but it does not work the other way around [5]. There is an agreement that they are complementary to hard (or technical) skills and are of growing importance to scientific research and engineering [7, 9, 10].

Esa et al. conducted a study that evaluated the application of soft skills in civil engineering programmes across Malaysia. The conclusion was that the level of communication skills, life-long learning, entrepreneurship skills and moral and professional ethics are at a moderate level, according to both students and lecturers. They also stated that communication skills could not be practised by students if there is no initiative and effort from lecturers [11].

The list of soft skills is a never-ending catalogue of interpersonal skills, that evaluate one's ability to interact with others. Gathering examples of soft skills across literature resulted in Table 2.1. These can be roughly divided into personal qualities and interpersonal skills [8]. It is essential to have in consideration that every competence has a different impact and is needed at a different level on different areas of studies or work.

Category	Name
Interpersonal Skills	Communication
	Teamwork
	Conflict management
	Empathy
	Leadership
Personal Qualities	Problem Solving
	Creativity
	Emotional intelligence
	Decision-making
	Time management
	Project management
	Flexibility
	Resilience
	Change management

Table 2.1: Examples of soft skills.

2.2 Importance of soft skills

The importance of such skills comes from the increase in competitiveness in the job market, being necessary to distinguish oneself from the other candidates. Simultaneously, employers prefer candidates that have higher productivity in diverse tasks, such as making a presentation, working with different people and managing projects. In today's world, excellent hard skills alone are not enough anymore, both for recruiting and promoting employees [7, 9, 10].

The list of the most critical soft skills employees need in the current world of work is not the same for every study in this topic. Even the definition of each competence gains different meanings and aspects depending on who is researching its importance. Nonetheless, some skills appear to be dominant across literature such as communication, teamwork, problem solving and creativity, critical thinking, leadership, decision making and emotional intelligence.

In order to understand what are the competences that employers and managers value the most, it is necessary to grasp how is the world of work changing and what needs are surfacing with the growth of automation and robotics. According to Levy et Al., the economy is shifting from manufacturing towards knowledge-based services, which means that job positions are requiring more complex problem solving and creativity than repetitive work, that is being replaced by machines. In Figure 2.1 [12], it is possible to see the economy evolution curves for manufacturing, knowledge-based services and other services.

At the same time, Ocean Tomo concluded that company values are increasingly becoming intangible rather than tangible, which translates in brand value, intellectual property and other assets (Figure 2.2 [13]). To grow these assets, companies need to have employees working in teams and being highly productive, which leads directly to a growing need for these soft skills.

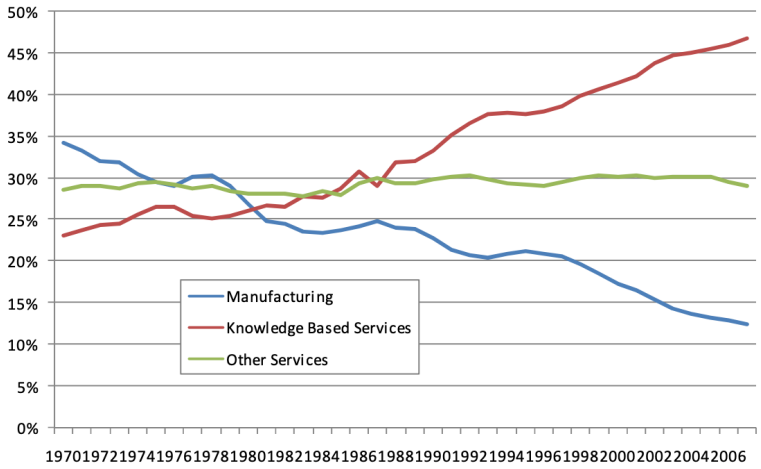

Figure 2.1: Economy restructures towards knowledge-based services (GVA, 1970 - 2007).

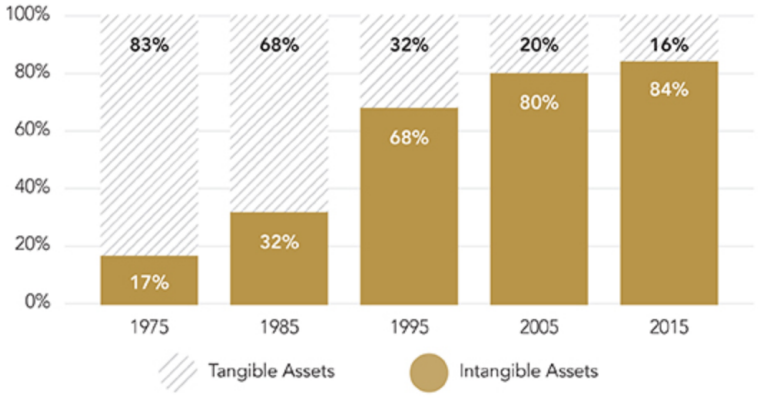

Figure 2.2: Components of S&P 500 market value.

According to research led by LinkedIn, the social network for business and employment, leadership, communication and collaboration are the three most essential skills for employees to learn on L&D programs. The study also came to an important conclusion on why the continuing development of professionals might be lacking: in fact, the number one reason employees do not engage in training is because they do not have the time. This study gathered the input of around 4 000 professionals on the platform and was aim to understand the modern workplace [14].

World Economic Forum, the International Organization for Public-Private Cooperation, presented "The Future of Jobs Report 2018", where it is described how the world of work is evolving, what are the main reasons for that evolution and the consequences it brings. One of the main topics are the skills that employees will need the most shortly. It is said that 54% of all employees will require reskilling and upskilling, meaning that these employees will need additional skills training to excel at their jobs, such as analytical thinking and innovation, active learning and learning strategies, creativity, originality and initiative and critical thinking and analysis. There is also a need for technological skills such as technology design and programming [15]. This particular study follows the Occupational Information Network (O*NET), a database of descriptors of occupations and competences in the US economy, to define the skills that are referred throughout the

report [16].

Another relevant study was the Adecco State of the Economy Survey that evaluated the skills gap of American workers. According to 500 US Senior Executives, 44% of Americans lack soft skills, that in this study were communication, creativity, critical thinking and collaboration [17].

There are also multiple authors, such as Ngang et al. [10], San-Valero et al. [9], Grant and Dickson [18], Schulz [8], Stevenson et al. [19] and Zaharim et al. [20] that believe communication to be one of the main requirements of soft skills in today's workplace, along with critical thinking [10, 8], problem-solving [20] and creativity [8], teamwork [10, 18, 20] and leadership [10, 19].

One other aspect to have in consideration is that soft skills do not work independently from one another. Someone's ability in one specific competence might need other competences. For example, conflict resolution is strongly connected to leadership and emotional intelligence. Solving conflict is an integral part of the role as a leader and calls for the ability to understand what others are feeling and needing [21, 22]. The combination of the analysed literature with the O*NET database resulted in the list of soft skills to be studied in this thesis.

- **Communication:** ability to share clear thoughts both in oral and written forms, both in a close group and in public;
- **Teamwork:** ability to work well in teams as well as understand one's role in said teams, which can be team member or team leader;
- **Conflict solving:** ability to guide a conflict between people to a commonly agreed solution;
- **Critical thinking:** ability to use logic on identifying the strengths and weaknesses of alternative solutions, conclusions or approaches to problems;
- **Problem-solving and creativity:** ability to identify complex problems and create and implement solutions;

Chapter 3

Evaluation and accreditation of engineering programmes

Evaluating and comparing higher education programmes is a concern for multiple organisations and institutions around the world. In Europe alone, there are three primary studies in this area, among others. The current chapter gives an overview of the goals and methods for those studies and finds the connection between them. For this dissertation, two of these three studies are the basis for the descriptors of soft skills, EUR-ACE® and CALOHEE.

3.1 European Qualifications Framework

The first one is the European Qualifications Framework (EQF) from the European Centre for the Development of Vocational Training (CEDEFOP), which aims to create a connection between multiple national qualification systems.

This framework counts with eight reference levels expressed by learning outcomes, defined as what a person should know, understand or be able to do. Each one of the levels has a series of descriptors that indicate the learning outcomes in three areas: knowledge, skills and responsibility and autonomy.

The first one is about theoretical and factual knowledge on a subject. Skills refer to the use of logical, intuitive and creative thinking as well as manual dexterity and the use of methods, materials, tools and instruments. Last but not least, responsibility and autonomy is the ability to apply knowledge and skills autonomously and with responsibility [23].

The levels for first and second cycle degrees (Bachelor's and Master's) are 6 and 7, respectively, and their descriptors are the ones presented in Table 3.1 [23]. The full version of these descriptors can be found in Appendix A.

Level	Knowledge	Skills	Responsibility and Autonomy
6	Advanced knowledge of a field of work or study, involving a critical understanding of theories and principles.	Advanced skills, demonstrating mastery and innovation, required to solve complex and unpredictable problems in a specialised field of work or study.	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.
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.	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.	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.

Table 3.1: Levels 6 and 7 of the European Qualifications Framework.

3.2 EUR-ACE® Framework Standards and Guidelines

The EUR-ACE® Framework Standards and Guidelines (EAFSG) is a project from the European Network for Engineering Accreditation (ENAEE). It strives to define standards for high-quality engineering degree programmes in Europe. The framework was developed with basis on EQF, that was previously discussed, and EHEA, the European Higher Education Area. The last one is a collaboration of 48 countries built to adopt reforms in higher education.

Similarly to EQF, EUR-ACE® has descriptors for learning outcomes for both Bachelor's and Master's degrees. Nevertheless, in this framework, each level has several areas of evaluation more specific for the engineering profession, such as Knowledge and Understanding, Engineering Analysis, Engineering Design, Investigations, Engineering Practice, Making Judgements and Lifelong Learning [24]. The example of Master's Degree outcomes in the learning area of Knowledge and

The learning process should enable **Master Degree graduates to demonstrate:**
• in-depth knowledge and understanding of mathematics and sciences underlying their engineering specialisation, at a level necessary to achieve the other programme outcomes;
• in-depth knowledge and understanding of engineering disciplines underlying their specialisation, at a level necessary to achieve the other programme outcomes;
• critical awareness of the forefront of their specialisation;
• critical awareness of the wider multidisciplinary context of engineering and of knowledge issues at the interface between different fields;

Table 3.2: EUR-ACE® descriptor for Master's Degree programmes, for the learning area of Knowledge and Understanding.

Understanding is presented in Table 3.2 [24]. The descriptors for the master's degree learning outcomes can be found in Appendix B.

3.3 Tuning-CALOHEE Assessment Reference Frameworks

Lastly, the Tuning-CALOHEE Assessment Reference Frameworks for Civil Engineering, Teacher Education, History, Nursing and Physics is an outcome of CALOHEE project funded by the European Commission. This framework shows what competences, expressed in learning outcomes, should be developed in a programme of the areas mentioned above. It is based on and follows a similar structure of EQF, regarding the categories knowledge, skills and autonomy and responsibility, although this last one is described as "wider competences" (Figure 3.1 [25]). According to this project's philosophy, learning, teaching and assessment should be fully aligned. That is why there is also assessment and learning approaches, in addition to the learning outcomes for each dimension.

Specifically for the area of Civil Engineering, multiple dimensions make the descriptors more precise rather than too general, such as knowledge and understanding, analysis and problem-solving, design, investigations, practice, decisions, team working, communication and lifelong learning. It is important to note that these dimensions cover hard skills together with soft skills, already saw as necessary competences for engineering bachelor's and master's. The framework for Civil Engineering in the second cycle (Level 7 of EQF) regarding communication is described in Table 3.3 [25]. The Tuning-CALOHEE descriptors for a master's degree can be found in Appendix C.

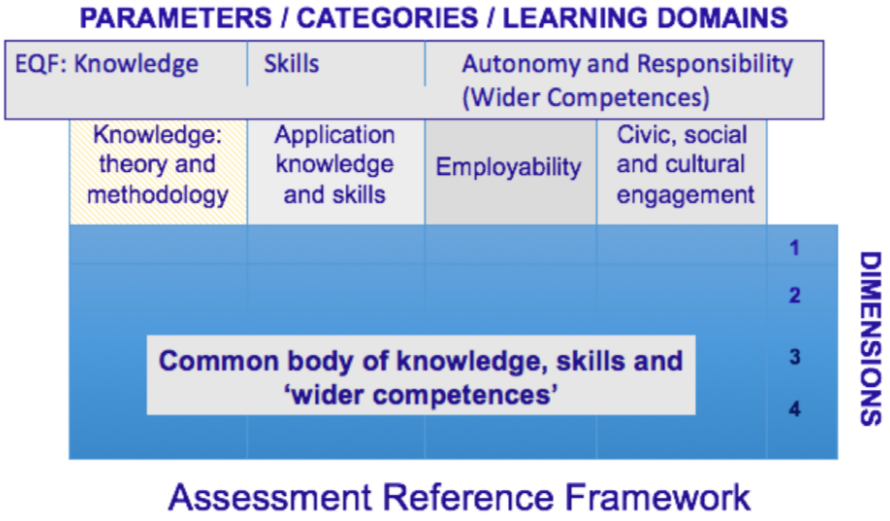

Figure 3.1: Relationship between European Qualifications Framework and Tuning-CALOHEE Assessment Reference Framework.

Dimension 8: Communication			
(Sub) descriptor / TLA approaches	**Knowledge**	**Skills**	**Autonomy and Responsibility (Wider Competences)**
L7_8. Level descriptor	**K7_8 Demonstrate knowledge and understanding of communication strategies, methods and tools, including new and innovative ones, and of their limitations.**	**S7_8 Communicate effectively, clearly and unambiguously information, describe activities and communicate their exits/results – and the knowledge and rationale underpinning these – to specialist and non- specialist audiences in national and international contexts and society at large, using appropriate communication strategies, methods and tools.**	**C7_8 Identify and justify appropriate and relevant communication strategies, methods and tools from established or new and innovative ones.**

Dimension 8: Communication			
(Sub) descriptor / TLA approaches	**Knowledge**	**Skills**	**Autonomy and Responsibility (Wider Competences)**
Subset 1 | L7_8.1 Communication strategies, methods and tools	**K7_8.1** Define and describe communication strategies, methods and tools, the characteristics of effective verbal, written, virtual, and graphical communications and their limitations 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.	**S7_8.1** Plan, compose, integrate and deliver effective verbal, written, virtual and graphical communications for describing activities and communicating 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, by applying rules of grammar and composition in verbal and written communications, properly citing sources, and using appropriate graphical standards in preparing engineering drawings.	**C7_8.1** Identify and justify appropriate and relevant communication strategies, methods and tools among standard and 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.
Assessment approaches	Essays. Problem Solving. Practical Work.	Problem Solving. Practical Work.	Problem Solving. Practical Work. Reflective Practice Assignments.
Learning approaches	Attending lectures. Attending seminars. Attending tutorials. Participating in flipped classroom. Blended learning. Fieldwork.	Problem-based learning. Design-based learning. Practising professional skills. Role play. Peer reviewing.	Problem-based learning. Design-based learning. Practising professional skills. Individual supervision.

Dimension 8: Communication			
(Sub) descriptor / TLA approaches	**Knowledge**	**Skills**	**Autonomy and Responsibility (Wider Competences)**
Teaching approaches	Lectures. Seminars. Tutorials. Flipped classroom. Blended teaching. Fieldwork.	Problem-based classes. Design-based classes. Work-based practice. Role play. Peer reviewing.	Problem-based classes. Design-based classes. Work-based practice. Individual supervision.

Table 3.3: Civil Engineering | Second Cycle | Dimension 8: Communication.

Chapter 4

Communication

This chapter covers different theories that can be used for teaching communication skills and understanding the impact that good or bad communication can have on interpersonal relationships. It also describes the knowledge, skills and responsibility an engineering master's graduate should have regarding communication skills, together with some descriptors that make it easier to assess.

Communication skills are the ability to share clear thoughts in written form as well as verbally, for a close group or in a public presentation.

4.1 Teaching

4.1.1 The Communication Model by Schulz von Thun

Friedemann Schulz von Thun is a German psychologist expert in communication that developed the 4 Sides Model. His theory says that one message can have four different interpretations, both for the sender and the receiver, which means that every conversation has four metaphorical beaks and ears on each side representing interpretations of what is said. These interpretations are factual information, self-statement, relationship indicator and appeal, represented by the colours blue, green, yellow and red, respectively, in Figure 4.1 [26].

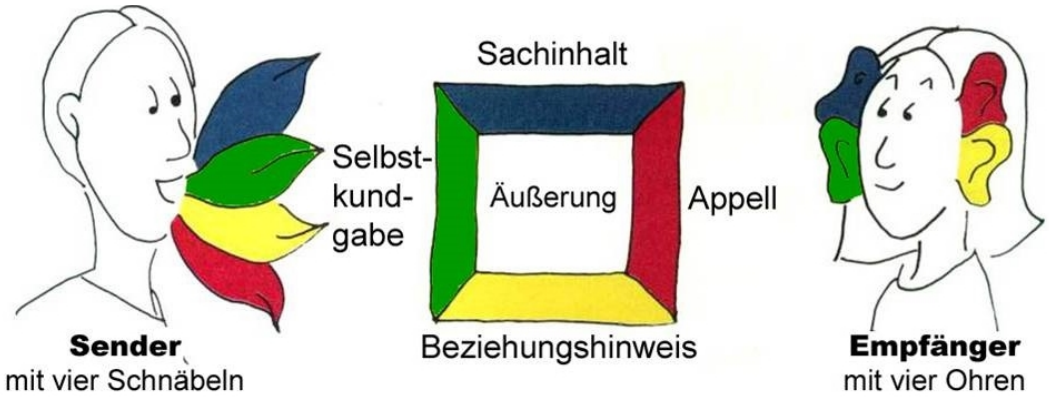

Figure 4.1: Communication Model by Schulz von Thun

On the **factual** level, the focus is on factual content, such as dates, names or data. Facts can be true or false, relevant for the conversation or not and sufficient for the issue or not. In the point of view of the sender, it is vital to communicate clearly, keeping the truth, relevance and sufficiency of the facts shared. The receiver can then follow-up on the topic considering the three aspects mentioned.

On a different level, communicating is almost always a way of providing a **self-statement**. It could be about one's tastes, preferences or dislikes, but it could also be about personality, feelings, or what they stand for. While the sender is providing some information about themselves, the receiver can understand better what they are like, their disposition, and what they defend.

On the **relationship** side of the message, it is clearer what the sender feels about the receiver and what is their opinion on them, based on their intonation, the way they express the message, their body language and even the way they build the sentence. It is common to have an overly sensitive relationship ear on the side of the receiver that tries to answer some questions, such as "what does the other think of me?".

Lastly, there's the possibility of an **appeal**, a request for the other person to do or to think something, creating influence. This level of communication is about requests, instructions and advice. For the receiver, the question that is asked is "what should I do, think or feel?" [26].

This model helps understand that other people might have different views of the same message, and even different than the one intended by the sender. It is crucial to consider that the other person might be interpreting the same information differently, leading to misunderstandings and conflict. One typical example is two people eating a meal together, cooked by one of them. The one that didn't cook says "There is something green in the soup.". Four possible different beaks and ears are described in Table 4.1 [27].

Sender	Receiver
• **Factual information:** There is something green.	• **Factual Information:** There is something green.
• **Self statement:** I don't like greens in my soup.	• **Self statement:** You do not know what the green item is, and that makes you feel uncomfortable.
• **Relationship indicator:** You should know what it is.	• **Relationship indicator:** You think my cooking is questionable.
• **Appeal:** Tell me what it is!	• **Appeal:** I should only cook what you know in the future!

Table 4.1: Example of situation analysed with the 4 Sides Model.

4.1.2 Nonviolent Communication by Rosenberg

Nonviolent communication (NVC) is a theory from Marshall B. Rosenberg, an American psychologist, that "leads us to give from the heart". NVC aims to guide people through a communication process where the focus is on observing, perceiving and expressing feelings and requests.

Even so, before going into the process itself, it is crucial to understand what is violent or "life-alienating" communication. One example is using moralistic judgements to suggest defective traits on people that do not act accordingly to our values. These judgements usually follow the structure "someone is something", for example, "She is stubborn." or "They are irresponsible.". When communicating this way, the focus is on classifying or comparing people, instead of focusing on everyone's needs and feelings. Another form of life-alienating communication is denying responsibility for our actions and feelings, putting it in external factors. It is dangerous not to be aware that every action, thought or feeling is our responsibility. Lastly, communicating in terms of demands or orders also blocks compassion toward others.

The first step of the NVC process is observing without evaluating, which means to be as objective as possible, describing specific situations in time and context, without generalizations. In that sense, we explain what we are seeing, hearing or touching that might be affecting our well-being or is not aligned with our values. If we mix these observations with evaluations, it is more likely that the receiver hears criticism and loses focus on the real intent of the message. The examples in Table 4.2 [28] help to understand the distinction between mixing versus separating observations and evaluations.

Communication	**Example of observation with evaluation mixed in**	**Example of observation separate from evaluation**
1. Use of verb to be without indication that the evaluator responsibility for the evaluation	You are too generous.	When I see you give all your lunch money to others I think you being too generous.
2. Use of verbs with evaluative connotations	Doug procrastinates.	Doug only studies for exams the night before.
3. Implication that one's inferences about another person's thoughts, feelings, intentions, or desires are the only ones possible	She won't get her work in.	I don't think she'll get her work in. *or* She said, "I won't get my work in."
4. Confusion of prediction with certainty	If you don't eat balanced meals, your health will be impaired.	If you don't eat balanced meals, I fear that your health may be impaired.

Communication	**Example of observation with evaluation mixed in**	**Example of observation separate from evaluation**
5. Failure to be specific about referents	Minorities don't take care of their property.	I have not seen the minority family living at 1679 Ross shovel the snow on their sidewalk.
6. Use of words denoting ability without indicating that an evaluation is being made	Hank Smith is a poor soccer player.	Hank Smith has not scored a goal in 20 games.
7. Use of adverb and adjectives in ways that do not signify an evaluation has been made	Jim is ugly.	Jim's looks don't appeal to me.

Table 4.2: Examples of observations with and without evaluations.

After observing the facts without evaluating, comes the identification and expression of feelings. With a complete vocabulary on feelings, it is easier to express more accurately what you are feeling, making it easier to be understood as well. Furthermore, it is common to use the word *feel* without expressing a feeling, so a strong vocabulary can also be helpful to avoid this situation. There is a complete list of feelings in Appendix D.

At this point, it is clear what are we feeling and that we should express it to avoid conflict. Still, to have a better understanding, it is necessary to take responsibility and acknowledge the root. According to NVC, what others say or do may stimulate some feelings, but it is not their cause. When others negatively communicate with us, there are four ways to receive that message. To better understand the alternatives, we can focus on the possible answers to someone saying "You're the most self-centred person I've ever met". The first one is **blaming ourselves** by taking it personally. This option comes at a significant cost on self-esteem, creating a feeling of guilt or shame. The answer in this scenario would be something like "Oh, I should've been more sensitive!". Another option is **blaming others**, which is likely to make us feel angry. Then the answer would be "You have no right to say that! I am always considering your needs. You're the really self-centred one.". The third option would be **sensing our feelings and needs**. In this scenario, we are aware of our emotions and the need for wanting our efforts to be recognised. The answer would be "When I hear you saying that I am the most self-centred person you've ever met, I feel hurt because I need some recognition of my efforts to be considerate of your preferences.". The last option is **sensing others' feelings and needs**, asking "Are you feeling hurt because you need more consideration for your preferences?". One way to acknowledge feelings and take responsibility is to express them from the unmet needs that we might have, which becomes more accessible for

the other person to understand. These needs can be for autonomy, celebration, integrity, physical nurturance and many others.

After addressing what we are observing, feeling and needing, it is time to request others, so our needs can be met. Using a positive language while making the requests clear raises the impact we have on the other person and makes it easier for them to understand and fulfil the need. The request structure should be something like "When I (see, hear) ... I feel ... because I need/value ... . Would you be willing to ... ?".

Although it is crucial to express observations, feelings and needs, it is even more impactful to be able to receive those things from others in an empathetic way. Empathy is listening to others with full attention, really focusing on what is being said and what they feel. It is common to give advice or reassurance in these situations automatically but to be as empathetic as possible, we should ask for permission before. It is more valuable to understand what the other person is feeling truly, and the question we ask in that situation is to become more aware of it. We can also paraphrase what the other person is saying if it contributes to the understanding of it [28].

4.2 Assessment descriptors

After the second cycle of higher education in engineering, being able to communicate effectively is a must. However, there are many factors to determine if someone can do it or not.

Regarding knowledge, a master's graduate in engineering should be able to understand and describe communication models and tools, identify effective written and oral communication and understand their capacities and limitations.

In what skills are concerned, one should be able to plan and compose the communication of a particular topic. It should be done while correctly citing sources and organising thoughts in a logical manner and with correct grammar. After this step, the engineer should effectively deliver this message, both in written and verbal forms. This delivery part of the process has several aspects to take in consideration, such as the ability to share the knowledge on the topic, ideas, problems, their solutions and thought processes and outcomes. Every one of these aspects becomes mandatory, especially for engineering communication, considering the complexity of the problems that may appear. The target group is another factor to consider. It is important to communicate complex content to both engineers and general members of society that have no skill in the area. In the global world of current times, it is also essential to communicate in national and international environments.

Lastly, concerning responsibility and autonomy, it is relevant to identify, chose and justify choices of communication strategies and models for a specific situation. It should always be had in consideration the competences described by the skills section.

In conclusion, the descriptors for communication skills for master's graduates are presented in the Table 4.3.

Communication
• **Knowledge:** Understand and describe communication models and tools, identify effective written and oral communication and understand personal capacities and limitations.
• **Skills:** Outline a communication strategy, cite sources and organise thoughts logically and with correct grammar. Deliver the message in written and oral form, show knowledge on the topic, ideas, problems, solutions, processes and outcomes. Adapt content to skilled engineers and the general public, both national and international.
• **Responsibility and Autonomy:** Identify, chose and justify choices of communication strategies and models for a situation, while covering the skills necessary.

Table 4.3: Communication assessment descriptors for engineering master's graduates.

Chapter 5

Teamwork

The present chapter describes two models for teamwork skills, covering expected behaviours that can bring more awareness to the team, helping people understand their team's needs and predict attitudes. Simultaneously, it describes the knowledge, skills and wider competences expected for an engineer after a master's degree.

Teamwork skills comprise the ability to work well in teams and to understand everyone's role and responsibilities in a specific team.

5.1 Teaching

5.1.1 Teamwork "Big Five" by Salas, Sims and Burke

Eduardo Salas, Dana Sims and Shawn Burke studied teams and teamwork and argue that it can be defined by five components: team leadership, mutual performance monitoring, backup behaviour, adaptability and team orientation. This subsection goes over their research and sums up the main findings, henceforth not referencing the authors that led to the study and only its conclusions. Furthermore, the authors claim that a team that portrays the five aspects mentioned above will have improved performance. Nevertheless, according to this model, there are a few coordinating mechanisms that are needed to assure the team's success, which are shared mental models, closed-loop communication and mutual trust. The complete model is presented in Figure 5.1 [29].

The first coordinating mechanism is **shared mental models**, that can include aligning expectations and predicting each other's needs. Having shared mental models can help the team perform by communicating more effectively, which becomes helpful in stressful situations where communication usually decreases. Another mechanism is **closed-loop communication**. Its importance was already stated in Chapter 4, but this particular type of communication implies that the receiver of a specific message acknowledges its receipt and the sender follows up to make sure the message was received. This model of communication ensures that more complicated messages have higher chances of being understood. **Mutual trust** in a team is also a foundation for its effectiveness because, without it, team members will spend their time doubting each other work, intentions, and deadlines [29].

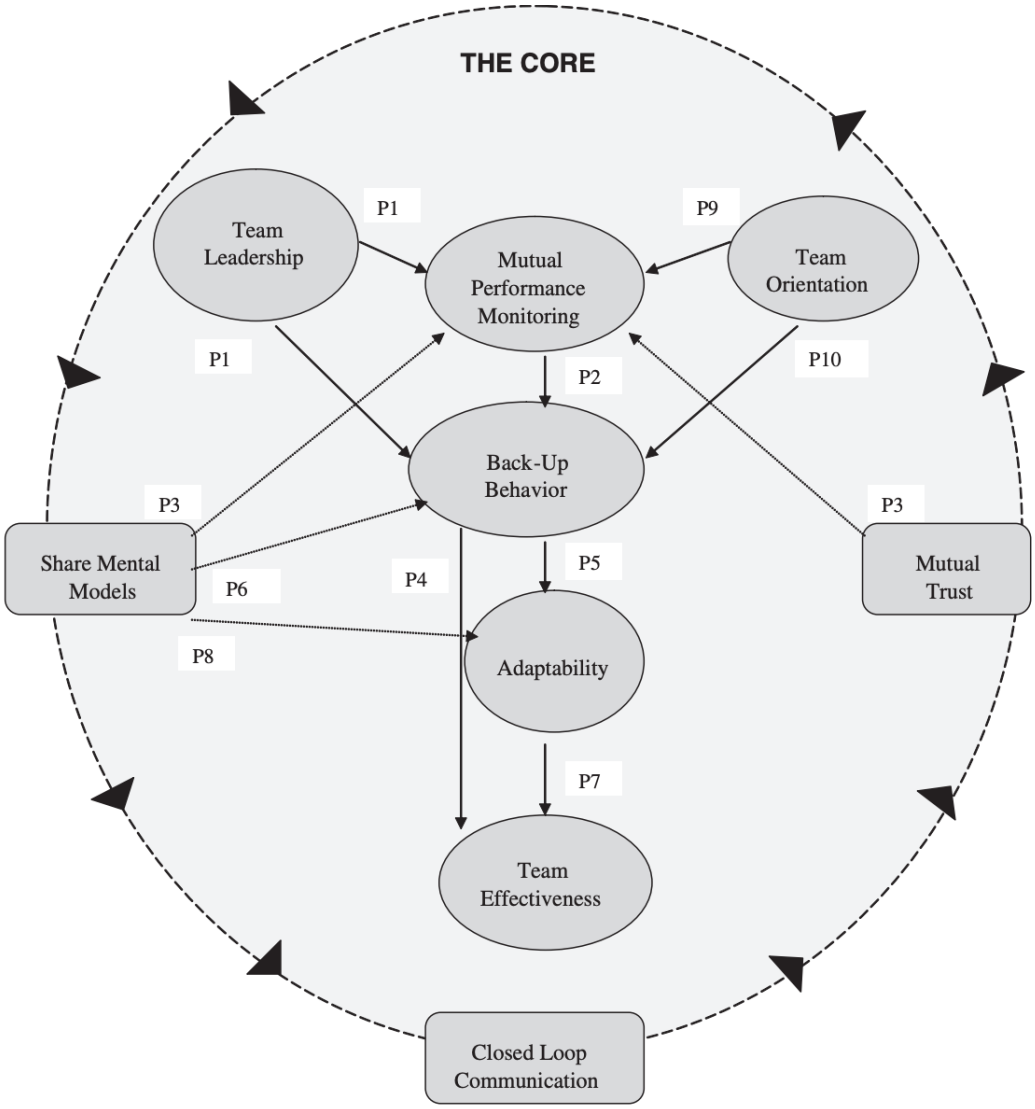

Figure 5.1: Teamwork "Big Five" schematic by Salas, Sims and Burke.

Team leadership is one of the big five because the team leader's inability to facilitate problem solving, goals definition and manage the members' motivation can have a direct impact on team effectiveness. It is the responsibility of the team leader to define and maintain objectives, roles, constraints and resources, to monitor internal and external environments, to facilitate the team's adaptability, to make sure the team has a plan in the case of environmental changes and to establish expectations and track abilities and skills gap of the team members.

The second one is **mutual performance monitoring** that essentially means constant feedback. If every team member is paying attention to how the team works and monitoring the other members' work, they will find improvement points more effectively. In addition, it is needed to have a shared mental model, to understand what the other members are supposed to be doing and to know how the team should be performing while giving feedback accordingly. There is also the

need for a secure and open environment. The goal is to maximise the team's performance and to avoid blaming errors on each other.

The number three is **backup behaviour**, which is an effort to help other team members when it is concluded that the workload is not well-distributed. It can be done in three different ways: giving feedback, assisting the person in need on the task, or directly completing the task for them. This behaviour ensures that all the tasks are completed, but it has prerequisites as well, such as shared mental models and mutual performance monitoring. These factors help to decide between helping the person, who should do it and what is needed.

The fourth aspect is **adaptability**, the capacity to understand if reality was shifted and act accordingly. The main requirement for the team is a global perspective of the task and how changes can affect it and the people involved. Adaptability can have a significant impact of team effectiveness, but for that to happen it is necessary to go through three steps: realise that conditions have changed or are changing, understand what that change implies and develop and apply a new plan.

Last but not least, there is **team orientation**, which is the attitude of preferring to work with others. Team members with team orientation are more likely to consider input from teammates on final decisions and are more open to feedback. This factor is crucial because it causes a deeper task involvement while sharing information, strategies and goals.

The "Big Five" model is a theoretical approach to teamwork that can be taught to team members for them to be more mindful about their actions and relationship with others, making their team more productive and reaching higher goals. However, it is essential to acknowledge that these are not the only aspects to consider when taking a team to its maximum potential.

5.1.2 Stages of Small-Group Development by Tuckman

In 1965 Bruce W. Tuckman developed a model that described the stages that every team goes through, along with the behaviours and feelings associated with each phase. This model is especially useful for teams to become aware of their behaviours and understand why they happen [30, 31]. Initially, there were four stages: forming, storming, norming and performing. Nonetheless, in 1977 Tuckman, together with Mary Jensen, revisited his research and added adjourning, a termination phase [32]. The relationship between the stages and the respective team effectiveness is in Figure 5.2 [33].

During the **forming** stage, team members are focused on creating goals and setting expectations but need orientation from the leader. They are usually as excited to start the project as anxious for not knowing how they will fit in the team. It is common for the team to start to create dependence amongst them and with their leader [30, 31].

After the initial excitement comes **storming**, the stage where interpersonal issues and conflict starts to arise. Behaviour may express frustration towards teammates or the leader, becoming a barrier to productivity, since the focus is on both solving emotional disagreements as well as working on reaching the goals defined. These might be questioned or even changed as well [30, 31].

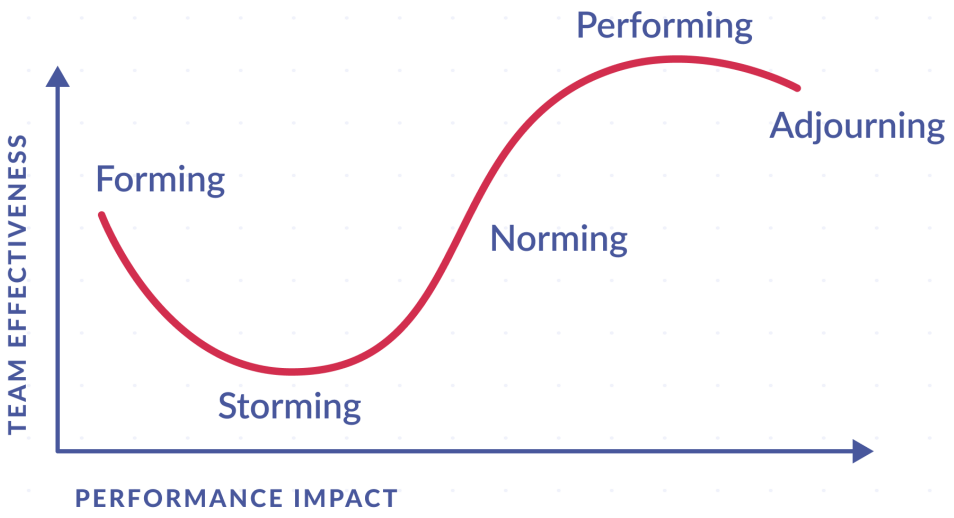

Figure 5.2: Team effectiveness levels for Tuckman's five stages of group development.

The third stage is **norming**, and it is where team members start to resolve the problems and build harmony and cohesion. Usually, teammates feel more comfortable giving their opinions and ideas and ask for help. Since their energy is now more focused on achieving the team's goals and not in resolving conflict, the productivity increases [30, 31].

During the **performing** stage, members finally feel complete comfort and trust in the team and its work. The roles become more fluid and flexible, and people are more willing to offer help to the other members. The team's energy is entirely focused on task performance. Hence its productivity is at its maximum [30, 31].

Lastly, and added only in 1977, there is the **adjourning** stage that happens when the team is finalising their work, and it is time to dissolve it. It is an emotional phase since members can be feeling fulfilled with the work done, anxious because it is coming to an end, and there might be some uncertainty in the future or both. Some members' productivity may drop because of a lack of focus while others' might increase in response to not deal with certain emotions of loss. It is crucial for the team to finish their last tasks, do some evaluation of the whole process and finalise with a celebration, acknowledging everyone's effort and contributions to the team [30, 32].

5.2 Assessment descriptors

Having the ability to work within a team while knowing one's position in it is essential in the contemporary challenges that engineers face. After the second cycle of engineering education and entering the professional world, knowing how to work with others, or even lead them, either on a national or international level, is a requirement for any engineer [25].

An engineering master is expected to know what is their role in the team and understand the working methods, goals and strategies of the team. As a leader, it is required to also know different methods, approaches and possible working methods for the team.

Concerning skills, it is desired that a second cycle finalist works effectively as either a member or a leader in a team, that can be national or international, with different cultures and beliefs, and with multiple disciplines. As a team member, it is also required to meet deliverable deadlines, schedule and budget requirements, while as a leader, the conflict solving skills described in the next chapter.

On responsibility and autonomy, it is necessary to have the capability of choosing while justifying the most appropriate working methods and strategies for the team, having in consideration its nature and needs.

Subset 1: Team member
• **Knowledge:** Understand one's role in the team along with the defined working methods, goals and strategies.
• **Skills:** Work effectively as a member in a team, nationally or internationally, with different cultures and beliefs, and with multiple disciplines. Meet deliverable deadlines, schedule and budget requirements, while following the working methods previously defined.
• **Responsibility and Autonomy:** Chose and justify the most appropriate working methods and strategies for the team, having in consideration its nature and needs.
Subset 2: Team leader
• **Knowledge:** Understand one's role in the team. Be familiar with a collection of possible working methods and approaches for the work to be developed by the team.
• **Skills:** Work effectively as a leader in a team, nationally or internationally, with different cultures and beliefs, and with multiple disciplines. Guide the team members through their tasks and deadlines defined previously.
• **Responsibility and Autonomy:** Chose and justify the most appropriate working methods and strategies for the team, having in consideration its nature and needs.

Table 5.1: Teamwork assessment descriptors for engineering master's graduates.

Chapter 6

Conflict Solving

The present chapter sums-up two possible models for teaching conflict resolution, that go through different styles of conflict handling and steps to resolve a possible interpersonal struggle. There is also a framework for assessing the ability to resolve conflicts in two subcategories: facilitation and empathetic listening.

Conflict solving skills comprise the ability to guide a conflict between people to a common agreed solution.

6.1 Teaching

6.1.1 Conflict and conflict management by Thomas

Multiple models describe different behaviours when dealing with conflict, such as the ones from Follett (1940) [34], Blake and Mouton (1964) [35] and Thomas (1976 and revised in 1992 [36]). Follett started by defining three possible behaviours, followed by Blake and Mouton, that created the first model considering two dimensions [37]. Later, this model was reinterpreted and redefined by Thomas, originating the model in Figure 6.1 [38]. Thomas' version of the model describes the possible behaviours during conflict having in consideration two dimensions. The first one is assertiveness, which is how much an individual is fighting for their concerns and goals. The second one is cooperativeness, which is how much an individual is focusing on other people's concerns and needs [38].

Starting from the left upper corner, **competing** is quite assertive, but uncooperative. Someone acting like this will go after their own agenda with a disregard for the other person's wishes. While keeping assertiveness, but being cooperative, we achieve the **collaborating** mode. Someone behaving this way will try their best to collaborate with the other person and to find a solution that meets everyone's concerns. In the centre there is **compromising**, an intermediate level of assertiveness and cooperativeness, thus a more neutral level. The goal here is to find a middle ground for everyone, where everyone is partially pleased with the solution. Decreasing both on assertiveness and cooperativeness appears the **avoiding** mode. This behaviour leads to not addressing the conflict while postponing it or even sidestepping from it. Last but not least, with

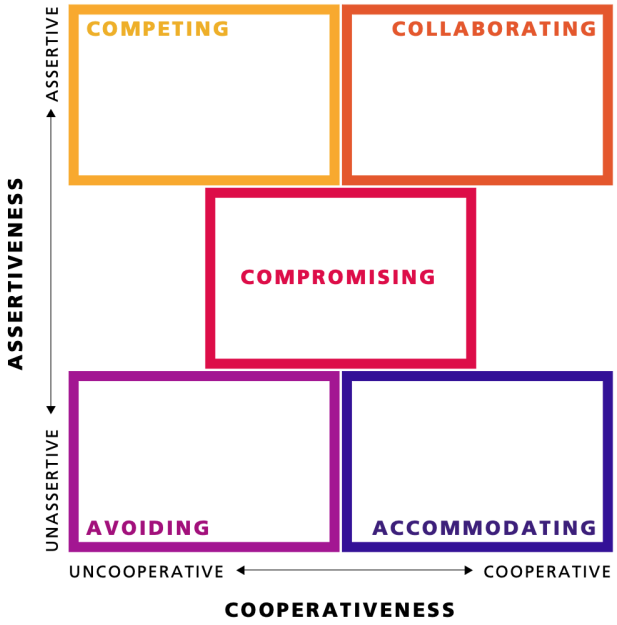

Figure 6.1: Thomas-Kilmann Conflict Modes model.

more cooperativeness, there is **accommodating**. This mode is where someone disregards their feelings and wishes for the satisfaction of someone else's concerns. There are several accommodating behaviours, such as selflessly be more concerned with others', obeying someone's orders against their will or shifting their point of view [38, 39].

It is essential to acknowledge that there is no right or wrong mode or behaviour because all of them can become useful in different situations. However, it is common for people to develop more skills in a particular one and use it more often. Following this model, there is a tool for assessing someone's more likely behaviour in conflicts situations, called the Thomas-Kilmann Conflict Mode Instrument (TKI) [38]. This tool consists of 30 pairs of statements of equal social desirability, where the participants should choose the one that better describes their behaviour. This tool, although widely implemented, has its flaws. The main issue for the participants is frustration coming from the forced answers with no flexibility, causing them to not identify with neither or not knowing which one to chose [39].

6.1.2 The five steps to conflict resolution by the American Management Association

The American Management Association (AMA), an organisation that aims to provide quality management development and training, put conflict resolution in a five-step model for managers in a mediator's point of view [22].

The **first step** is to find the root of the conflict, understanding its causes directly from the people involved in it. The role of the manager is to make everyone feel listened to while getting to know the different versions of the situation [40]. In this step, the communication skills and empathy tackled in Chapter 4 become crucial, mainly when listening to everyone's needs and

feelings. The ability to truly understand the people involved is one big step towards success regarding conflict resolution [41].

Even if the specific situation that triggered the conflict is known, the overview of the intervenients' relationships is critical to understand its origin. That is the **second step**, looking to the forest instead of just the tree. Maybe the current conflict came from a situation in the past, that developed with increasing stress or other external factors.

After understanding the whole background story on a particular conflict, it is time to put everyone in the same room and start coming up with possible solutions. As a **third step**, the mediator should request solutions from each party and carefully listen to everything that is said, while making sure the conversation is not about personal attacks. This way, everyone is focused on finding means of resolving the conflict instead of making it bigger.

The **fourth step** is to find solutions that everyone agrees. The mediator is listening to what everyone finds acceptable and should try to list a few solutions that make everyone happy. The justification part of this step, more than acknowledging that the solutions meet both sides' needs, should show how it affects the organisation in a positive note. This way, people will be more inclined to accept it, because the mediator is not merely trying to make the other side happy.

Lastly, in the **fifth step**, the mediator needs agreement from both parties on at least one of the solutions presented in step four. This agreement could be as formal as a contract, or just a conversation between the parties [40].

6.2 Assessment descriptors

The same way there are multiple theories and models on behaviour towards conflict, there are also several instruments that try to assess someone's preferred style of handling conflict [42]. However, conflict solving skills go beyond the way people manage conflict, and especially for master's graduates and future leaders, the skills essential to assess are the ones that they need to be the facilitator of conflict resolution.

As it was mentioned before, being the third party in a conflict means more than knowing styles and preferred methods of handling it. Focusing on the five-step process by AMA, there is a need to understand the root of conflict and its origin, facilitate a discussion where the involved people come up with possible solutions and make suggestions that make everyone pleased with the final result. The skills present in this model and that can help someone handle conflict between other people are mainly facilitation and empathetic listening [43].

Regarding facilitation, a master's graduate should have enough knowledge on the topic to be able to describe standard facilitation tools, distinguish solid from lousy facilitation practices and pinpoint his or her flaws. In a more practical point of view, a facilitator should have the ability to take a discussion and help the participants to conclude, while keeping as much neutrality as possible. As a wider competence, this person should know if the effectiveness of the discussion needs improvement by adapting methods or encouraging individual participants to be more or less participatory [44].

Regarding empathetic listening, an engineering student at the end of the master's degree should know the differences between empathetic listening and other types of listening and empathetic answers from advice. While listening to someone, there are some necessary skills, such as understanding the other person's needs and feelings by analysing their body language and paraphrasing what they are saying. This way, the facilitator is making sure everything is understood and making the other person feel heard. The master's graduate should also choose the questions and interventions so they can help everyone else understand the person's feelings and needs as well as them [45]. The final descriptors for assessment of conflict solving skills as someone external to the conflict itself are present in Table 6.1.

Subset 1: Facilitation
• **Knowledge:** Describe common facilitation tools, distinguish good from bad facilitation practices and pinpoint personal flaws.
• **Skills:** Take a discussion from the beginning and help participants reach a conclusion, while keeping neutrality.
• **Responsibility and Autonomy:** Evaluate discussion's effectiveness and adapting methods of facilitation in case of need. Balance participants' inputs so everyone has a chance of presenting their point of view.
Subset 2: Empathetic listening
• **Knowledge:** Distinguish between empathetic listening and other types of listening. Distinguish empathetic answers from advice.
• **Skills:** Understand someone's needs and feelings by analysing their body language. Paraphrase to make the other person feel heard.
• **Responsibility and Autonomy:** Chose questions and interventions, helping everyone involved understand better one another.

Table 6.1: Conflict solving assessment descriptors for engineering master's graduates.

Chapter 7

Critical thinking

This chapter goes through on model on critical thinking from Paul and Elder, a framework to help develop critical thinkers. It was also created a framework for assessment of this skill.

Critical thinking comprises the ability to use logic on identifying the strengths and weaknesses of alter-native solutions, conclusions or approaches to problems.

7.1 Teaching

7.1.1 Critical thinking framework by Paul and Elder

Richard Paul was an American philosopher and Linda Elder is an American educational psychologist. The Paul-Elder framework is mainly described with three different components: elements of thought or reasoning, intellectual standards to be applied on the elements of thought and intellectual traits usually linked with a critical thinker and that come from the previous two components [46]. According to these authors, critical thinkers "apply the intellectual standards to the elements of reasoning in order to develop intellectual traits" [47].

The first component is comprised by **elements of reasoning or thought**, that can be seen schematically in Figure 7.1 [47]. There are eight elements that describe the possible ways of thinking when facing a certain topic or argument:

- "All reasoning is done from some **point of view**" [48]. To reason well, it is necessary to identify the most relevant points of view and introduce them empathetically.
- "All reasoning has a **purpose**" [48]. Knowing exactly one's intentions and being as transparent as possible about them allows for good reasoning.
- "All reasoning is an attempt to figure something out, to settle some **question**, to solve some problem" [48]. The question or problem that needs to be answered must be clear and precise, to be possible to solve it.
- "All reasoning is based on data, **information** and evidence" [48]. A strong basis of objective information makes the reasoning around it strong as well.

- "All reasoning contains **inferences or interpretations** by which we draw conclusions and give meaning to data" [48]. There are many possible inferences, but in order to keep a solid reasoning they should be consistent with each other and come only from what evidence implies.
- "All reasoning is expressed through, and shaped by, **concepts** and ideas" [48]. An effective identification and explanation of the key concepts makes for an effective reasoning.
- "All reasoning is based on **assumptions**" [48]. However, the assumptions should be justifiable and there is a need for attention on how they shape the point of view.
- "All reasoning leads somewhere or has **implications and consequences**" [48]. The effect these consequences may have after taking a decision is a factor to have in consideration while reasoning.;

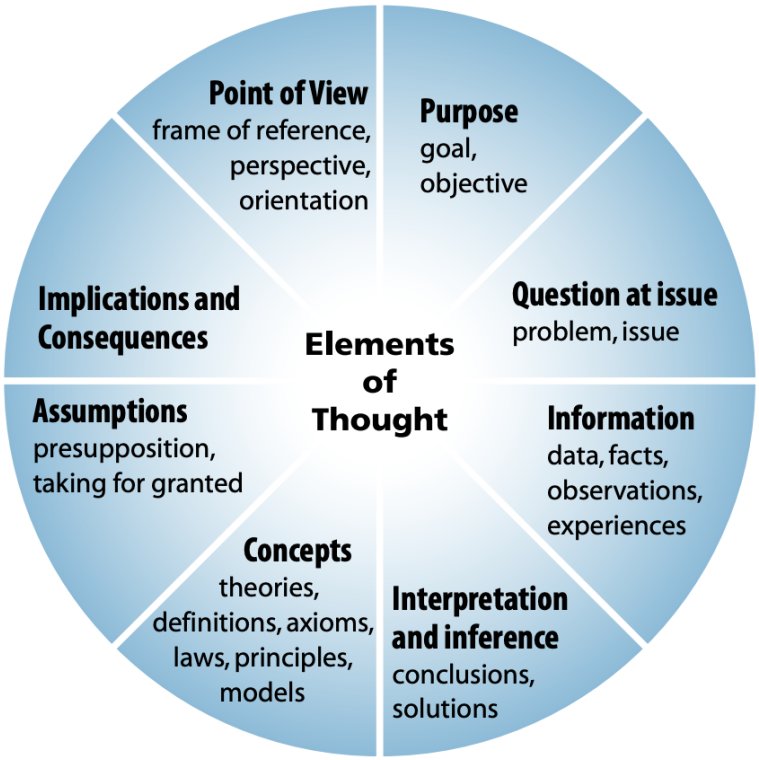

Figure 7.1: Elements of thought of the critical thinking framework.

The second component is a set of **intellectual standards** that are meant to be applied on the elements of thought and that are present in Table 7.1 [47].

Intellectual Standard	
Clarity understandable, the meaning can be grasped	Could you elaborate further? Could you give me an example? Could you illustrate what you mean?

Intellectual Standard	
Accuracy free from errors or distortions, true	How could we check on that? How could we find out if that is true? How could we verify or test that?
Precision exact to the necessary level of detail	Could you be more specific? Could you give me more details? Could you be more exact?
Relevance relating to the matter at hand	How does that relate to the problem? How does that bear on the question? How does that help us with the issue?
Depth containing complexities and multiple interrelationships	What factors make this a difficult problem? What are some of the complexities of this question? What are some of the difficulties we need to deal with?
Breadth encompassing multiple viewpoints	Do we need to look at this from another perspective? Do we need to consider another point of view? Do we need to look at this in other ways?
Logic the parts make sense together, no contradictions	Does all this make sense together? Does your first paragraph fit in with your last? Does what you say follow from the evidence?
Significance focusing on the important, not trivial	Is this the most important problem to consider? Is this the central idea to focus on? Which of these facts are most important?
Fairness Justifiable, not self-serving or one-sided	Do I have any vested interest in this issue? Am I sympathetically representing the viewpoints of others?

Table 7.1: Intellectual standards of Paul-Elder critical thinking framework.

Each element of reasoning has a group of primary intellectual standards [48]. These are considered critical to apply in order to develop intellectual traits.

Lastly there is a collection of intellectual traits, presented in Figure 7.2 [47]. There are seven different characteristics that are expected to be developed with the application of intellectual standards to the elements of reasoning [49]:

- **Intellectual humility:** development of the ability to identify self limitations;
- **Intellectual courage:** development of the ability to evaluate ideas in a neutral way, and address them despite our personal feelings towards them;
- **Intellectual empathy:** development of the ability to see topics in other pointviews and considering other assumptions;

- **Intellectual integrity:** development of the ability to blend with others' reasoning for topic.
- **Intellectual perseverance:** development of the need to have the truth despite obstacles such as difficulties or frustration.
- **Confidence in reason:** development of the ability to build confidence in their reason and think more rationally;
- **Fairmindedness:** development of the ability to look at a certain topic with an objective look, putting aside feelings, raises and interests;

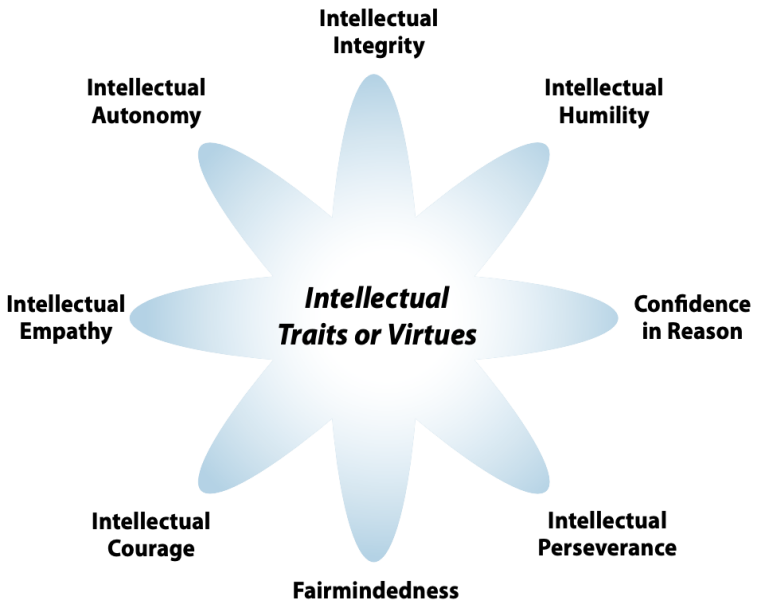

Figure 7.2: Intellectual traits of the critical thinking framework.

7.2 Assessment descriptors

Regarding assessment and according to the Centre for Teaching Excellence from University of Waterloo, there are eight characteristics that may demonstrate critical thinking in someone's work. Interpreting evidence in an accurate way, asking relevant questions, analysing and evaluating information and alternative points, examining beliefs, assumptions and opinions and weighting them against facts in an objective way, drawing reasonable conclusions, justifying opinions, addressing and evaluating alternative points of view and lastly, explaining assumptions and reasons [50].

Watanabe-Crockett also developed a framework for critical thinking assessment based on Bloom's Taxonomy. The six different categories are asking relevant questions about a problem or challenge, finding information that is useful for a problem, remaining open for multiple beliefs and ideas, drawing conclusions, building connections and managing a role in a collaborative group and being aware of self limitations and abilities [51].

With both inputs and following the same structure of the previous chapters, a framework was developed to describe what is expected from engineering master's graduates, which is present in Table 7.2.

Critical thinking
• **Knowledge:** Distinguish information and evidence from points of view, interpretations and ideas. • **Skills:** Find useful information, interpret evidence, examine beliefs, justify opinions, explain assumptions and reasons. • **Responsibility and Autonomy:** Chose the most relevant questions to ask about a topic, evaluate different points of view and draw conclusions.

Table 7.2: Critical thinking assessment descriptors for engineering master's graduates.

Chapter 8

Problem-solving and creativity

The present chapter analyses a model on creative problem solving by Osborn and Parnes, that describes a methodology to follow when trying to solve problems in a creative way. It also presents a proposed framework for evaluating problem-solving and creativity skills, which is ability to identify complex problems and create and implement solutions.

8.1 Teaching

8.1.1 Creative Problem Solving Model by Osborn and Parnes

The Creative Problem Solving (CPS) Model results from an evolution of the Osborn-Parnes creative problem solving process called CPS Learner's Model and was developed by the Creative Education Foundation [52].

This model begins with two important assumptions: "everyone is creative" and "creative skills can be learned and enhanced". Having these assumptions present, there are also four core principles to be taken in consideration through the whole model:

- Divergent and convergent thinking should be done separately, but in a balanced way.
- Problems are easier to solve when presented as open questions, with multiple possibilities.
- Judging an idea in the moment it appears shuts down idea generation. There is a moment for assessing ideas, in the convergent thinking stage.
- Language is an important part of the creative process. "Yes, and" allows for continuation, while the use of the word "but" closes down the conversation and limits idea generation.

In the creative process, Osborn noticed two distinct ways of thinking: divergent thinking, where the generation of ideas happens, and convergent thinking, where the evaluation of the ideas generated happens, as well as decision making. These two modes should be separated and balanced. For each there are some guidelines to a better creative process [52].

8.1.1.1 Divergent thinking guidelines

- **Defer judgement:** it is crucial to apply judgement with the right timing, which is not during a divergent phase.
- **Combine and build:** the combination of ideas or a isolated one can be the starting point for other ideas.
- **Seek wild ideas:** getting outside of the box allows for the appearance of new extraordinary ideas.
- **Go for quantity:** take the time necessary to generate as much ideas as you can.

8.1.1.2 Convergent thinking guidelines

- **Be deliberate:** think about every option fairly, to avoid rush decisions and judgements.
- **Check your objectives:** keep track of your objectives and constantly compare them with the ideas to make sure the choices you make are on track.
- **Improve your ideas:** most of the times, ideas should be improved, worked on and strengthened.
- **Be affirmative:** consider first the strong points and only after that judge with the goal of improving the idea.
- **Consider novelty:** do not dismiss original ideas, but consider them while thinking about ways to rework them.

8.1.1.3 The model

According to the Creative Education Foundation, the last version of the CPS Model has four stages: clarify, ideate, develop and implement (Figure 8.1 [52]). These phases combined have a total of six steps, with divergent and convergent thinking on each one (Table 8.1 [53]).

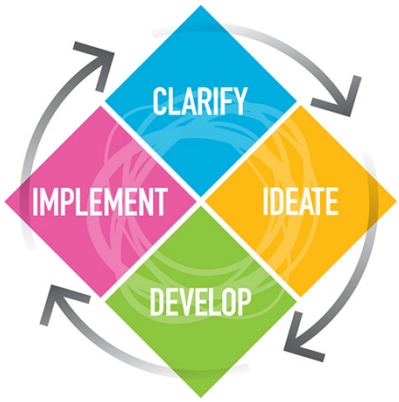

Figure 8.1: Creative Problem Solving (CPS) Model by Osborn and Parnes.

Stage	Step	Purpose
Clarify	Explore the vision	Identify the goal, wish, or challenge.
	Gather Data	Describe and generate data to enable a clear understanding of the challenge.
	Formulate the challenge	Sharpen awareness of the challenge and create challenge questions that invite solutions.
Ideate	Explore ideas	Generate ideas that answer the challenge questions.
Develop	Formulate solutions	To move from ideas to solutions. Evaluate, strengthen, and select solutions for best "fit."
Implement	Formulate a plan	Explore acceptance and identify resources and actions that will support implementation of the selected solution(s).

Table 8.1: Stages, steps and purposes of the CPS Model.

8.2 Assessment descriptors

The assessment reference framework from CALOHEE describes the learning outcomes for analysis and problem solving in the three aspects mentioned before: knowledge, skills and autonomy and responsibility.

Regarding knowledge, in the end of the second cycle of higher education, it is necessary to identify an engineering problem and describe factual information related to it [25]. Having in consideration the model presented in the Section 8.1.1, it is also required to understand how the creative process works, the steps one should go through and the purpose of each step. In respect to the skills expected, applying a problem solving model in a real problem is the central ability, as well as solving it [25]. Lastly, the wider competences needed are justifying the models, tools or methodologies chosen to apply to a certain problem. The final descriptors are in Table 8.2.

Problem solving and creativity
• **Knowledge:** Identify complex problems and describe factual information around the same topic. Understand how the creative process works, the tools available to go through the process and the purpose of each stage.
• **Skills:** Apply models or methodologies to a problem, try different and innovative approaches and solve the complex questions that emerge from it.
• **Responsibility and Autonomy:** Chose the best approach or model to apply to a problem, in an independent way. Justify the choices made according to the problem that is faced.

Table 8.2: Problem solving and creativity assessment descriptors for engineering master's graduates.

Chapter 9

Conclusions

9.1 Final considerations

The initial goal for this dissertation was to create a list of important soft skills for the engineering profession, sum up different ways to teach each one of these skills and develop a set of descriptors for their assessment. Considering the evaluation descriptors, they were meant to describe the knowledge, skill and responsibility and autonomy levels that an engineer is expected to have in the end of their master's degree. Lastly, it was also relevant to develop a practical approach to the theory that showed how the descriptors could be applied and even gather some data on this.

The main outcome of this thesis are the descriptors that are in Tables 4.3, 5.1, 6.1, 7.2 and 8.2. Considering the bibliography consulted and the experience of the author with teaching soft skills and required learning outcomes for engineering students, the goal is considered fulfilled. In relation to the teaching section of the competences, the models presented were the ones found more relevant for an engineering environment.

9.2 Future developments

As mentioned above, one of the goals was to predict how the model could be applied in a real life situation or even to test it and gather results. However, due to a lack of time at the end of the dissertation, this goal was not fulfilled. It is of great interest for future work to apply the descriptors suggested and conclude the impact that they can have both for the person being assessed and a potential company or professor who wants to evaluate one individual.

Appendix A

EQF Descriptors

	Knowledge	Skills	Responsibility and autonomy
Level 1	Basic general knowledge	Basic skills required to carry out simple tasks	Work or study under direct supervision in a structured context
Level 2	Basic factual knowledge of a field of work or study	Basic cognitive and practical skills required to use relevant information in order to carry out tasks and to solve routine problems using simple rules and tools	Work or study under supervision with some autonomy
Level 3	of facts, principles, processes and general concepts, in a field of work or study	A range of cognitive and practical skills required to accomplish tasks and solve problems by selecting and applying basic methods, tools, materials and information	Take responsibility for completion of tasks in work or study; adapt own behaviour to circumstances in solving problems

	Knowledge	**Skills**	**Responsibility and autonomy**
Level 4	Factual and theoretical knowledge in broad contexts within a field of work or study	A range of cognitive and practical skills required to generate solutions to specific problems in a field of work or study.	Exercise self-management within the guidelines of work or study contexts that are usually predictable, but are subject to change; supervise the routine work of others, taking some responsibility for the evaluation and improvement of work or study activities
Level 5 [1]	Comprehensive, specialised, factual and theoretical knowledge within a field of work or study and an awareness of the boundaries of that knowledge	A comprehensive range of cognitive and practical skills required to develop creative solutions to abstract problems	Exercise management and supervision in contexts of work or study activities where there is unpredictable change; review and develop performance of self and others
Level 6 [2]	Advanced knowledge of a field of work or study, involving a critical understanding of theories and principles	Advanced skills, demonstrating mastery and innovation, required to solve complex and unpredictable problems in a specialised field of work or study	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

	Knowledge	**Skills**	**Responsibility and autonomy**
Level 7 [3]	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	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	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
Level 8 [4]	Knowledge at the most advanced frontier of a field of work or study and at the interface between fields	The most advanced and specialised skills and techniques, including synthesis and evaluation, required to solve critical problems in research and/or innovation and to extend and redefine existing knowledge or professional practice	Demonstrate substantial authority, innovation, autonomy, scholarly and professional integrity and sustained commitment to the development of new ideas or processes at the forefront of work or study contexts including research

Table A.1: European Qualifications Frameworks Descriptors.

[1] The descriptor for the short cycle developed by the Joint Quality Initiative as part of the Bologna process, (within or linked to the first cycle), corresponds to the learning outcomes for EQF level 5.

[2] The descriptor for the first cycle corresponds to the learning outcomes for EQF level 6.

[3] The descriptor for the second cycle corresponds to the learning outcomes for EQF level 7.

[4] The descriptor for the third cycle corresponds to the learning outcomes for EQF level 8.

Appendix B

EUR-ACE® Descriptors

Knowledge and Understanding

The learning process should enable **Master Degree graduates to demonstrate:**

• in-depth knowledge and understanding of mathematics and sciences underlying their engineering specialisation, at a level necessary to achieve the other programme outcomes;

• in-depth knowledge and understanding of engineering disciplines underlying their specialisation, at a level necessary to achieve the other programme outcomes;

• critical awareness of the forefront of their specialisation

• critical awareness of the wider multidisciplinary context of engineering and of knowledge issues at the interface between different fields.

Engineering Analysis

The learning process should enable **Master Degree graduates to demonstrate:**

• ability to analyse new and complex engineering products, processes and systems within broader or multidisciplinary contexts; to select and apply the most appropriate and relevant methods from established analytical, computational and experimental methods or new and innovative methods; to critically interpret the outcomes of such analyses;

• ability to conceptualise engineering products, processes and systems;

• ability to identify, formulate and solve unfamiliar complex engineering problems that are incompletely defined, have competing specifications, may involve considerations from outside their field of study and non-technical – societal, health and safety, environmental, economic and industrial – constraints; to select and apply the most appropriate and relevant methods from established analytical, computational and experimental methods or new and innovative methods in problem solving;

• ability to identify, formulate and solve complex problems in new and emerging areas of their specialisation.

Engineering Design

The learning process should enable **Master Degree graduates to demonstrate:**

• ability to develop, to design new and complex products (devices, artefacts, etc.), processes and systems, with specifications incompletely defined and/or competing, that require integration of knowledge from different fields and non-technical - societal, health and safety, environmental, economic and industrial commercial – constraints; to select and apply the most appropriate and relevant design methodologies or to use creativity to develop new and original design methodologies.

• ability to design using knowledge and understanding at the forefront of their engineering specialisation.

Investigations

The learning process should enable **Master Degree graduates to demonstrate:**

• ability to identify, locate and obtain required data;

• ability to conduct searches of literature, to consult and critically use databases and other sources of information, to carry out simulation in order to pursue detailed investigations and research of complex technical issues;

• ability to consult and apply codes of practice and safety regulations;

• advanced laboratory/workshop skills and ability to design and conduct experimental investigations, critically evaluate data and draw conclusions; ability to investigate the application of new and emerging technologies at the forefront of their engineering specialisation.

Engineering Practice

The learning process should enable **Master Degree graduates to demonstrate:**

• comprehensive understanding of applicable techniques and methods of analysis, design and investigation and of their limitations;

• practical skills, including the use of computer tools, for solving complex problems, realising complex engineering design, designing and conducting complex investigations;

• comprehensive understanding of applicable materials, equipment and tools, engineering technologies and processes, and of their limitations;

• ability to apply norms of engineering practice;

• knowledge and understanding of the non-technical – societal, health and safety, environmental, economic and industrial - implications of engineering practice;

• critical awareness of economic, organisational and managerial issues (such as project management, risk and change management)

Making Judgements

The learning process should enable **Master Degree graduates to demonstrate:**

• ability to integrate knowledge and handle complexity, to formulate judgements with incomplete or limited information, that include reflecting on social and ethical responsibilities linked to the application of their knowledge and judgement;

• ability to manage complex technical or professional activities or projects that can require new strategic approaches, taking responsibility for decision making.

Communication and Team-working

The learning process should enable **Master Degree graduates to demonstrate:**

• ability to use diverse methods to communicate clearly and unambiguously their conclusions, and the knowledge and rationale underpinning these, to specialist and non-specialist audiences in national and international contexts;

• ability to function effectively in national and international contexts, as a member or leader of a team, that may be composed of different disciplines and levels, and that may use virtual communication tools.

Lifelong Learning
The learning process should enable **Master Degree graduates to demonstrate:**
• ability to engage in independent life-long learning;
• ability to undertake further study autonomously.

Table B.1: EUR-ACE® Descriptors for Second Cycle of Higher Education.

Appendix C

Tuning-CALOHEE Descriptors

Dimension 1: Knowledge and Understanding			
(Sub) descriptor / TLA approaches	**Knowledge**	**Skills**	**Autonomy and Responsibility (Wider Competences)**
L7_1. Level descriptor	**K7_1 Demonstrate in-depth knowledge and understanding of mathematics as well as sciences and engineering disciplines underlying civil engineering specialisation at a level necessary to achieve the other programme outcomes.**	**S7_1 Apply knowledge and understanding of mathematics as well as sciences and engineering disciplines underlying civil engineering specialisation to solve / design / investigate / conduct very complex civil engineering problems / products, processes and systems / issues / activities**	**C7_1 Identify and justify knowledge and understanding of mathematics as well as sciences and engineering disciplines underlying civil engineering specialisation necessary to solve / design / investigate / conduct very complex civil engineering problems / products, processes and systems / issues / activities.**

Dimension 1: Knowledge and Understanding			
(Sub) descriptor / TLA approaches	**Knowledge**	**Skills**	**Autonomy and Responsibility (Wider Competences)**
Subset 1 | L7_1.1 Mathematics	**K7_1.1** Define and describe key factual information related to mathematics through differential equations and explain key concepts and problem-solving processes.	**S7_1.1** Solve / design / investigate / conduct very complex civil engineering problems / products, processes and systems / issues / activities using and applying knowledge and understanding of mathematics through differential equations.	**C7_1.1** Identify and justify knowledge and understanding of mathematics necessary to solve / design / investigate / conduct very complex civil engineering problems / products, processes and systems / issues / activities through differential equations.
Subset 2 | L7_1.2 Science underlying civil engineering specialisation	**K7_1.2** Define and describe key factual information related to calculus-based physics and chemistry and explain key concepts and problem-solving processes.	**S7_1.2** Solve / design / investigate / conduct very complex civil engineering problems / products, processes and systems / issues / activities using and applying knowledge and understanding of calculus-based physics and chemistry.	**C7_1.2** Identify and justify knowledge and understanding of calculus-based physics and chemistry to solve / design / investigate / conduct very complex civil engineering problems / products, processes and systems / issues / activities.

Dimension 1: Knowledge and Understanding			
(Sub) descriptor / TLA approaches	**Knowledge**	**Skills**	**Autonomy and Responsibility (Wider Competences)**
Subset 3 | L6_1.3 Engineering disciplines underlying civil engineering specialisation	**K7_1.3** Define and describe key factual information related to engineering disciplines underlying civil engineering specialisation and explain key concepts and problem-solving processes having a critical awareness of the forefront of civil engineering specialisation, of the knowledge issues at the interface between different fields and of the wider multidisciplinary context of engineering.	**S7_1.3** Solve / design / investigate / conduct very complex civil engineering problems / products, processes and systems / issues / activities, using and applying knowledge and understanding of engineering disciplines underlying civil engineering specialisation.	**C7_1.3** Identify and justify knowledge and understanding of engineering disciplines underlying civil engineering specialisation necessary to solve / design / investigate / conduct very complex civil engineering problems / products, processes and systems / issues / activities.
Assessment approaches	Short Answer Questions. Multiple Choice Questions. Essays.	Essays. Problem Solving. Practical Work.	Problem Solving. Practical Work. Reflective Practice Assignments
Learning approaches	Attending lectures. Attending seminars. Attending tutorials. Participating in flipped classroom. Blended learning. Preparing and making oral presentations. Researching and writing papers, reports, dissertations.	Participating in exercise courses/ practical classes. Preparing and making oral presentations. Researching and writing papers, reports, dissertations. Problem-based learning. Design-based learning.	Participating in exercise courses/ practical classes. Problem-based learning. Design-based learning.

Dimension 1: Knowledge and Understanding			
(Sub) descriptor / TLA approaches	**Knowledge**	**Skills**	**Autonomy and Responsibility (Wider Competences)**
Teaching approaches	Lectures. Seminars. Tutorials. Flipped classroom. Blended teaching. Oral Assessment. Written assessment.	Exercise courses/ Practical classes. Problem-based classes. Oral Assessment. Written assessment. Problem-based classes. Design-based classes.	Exercise courses/ Practical classes. Problem-based classes. Design-based classes.

Table C.1: Civil Engineering | Second Cycle | Dimension 1: Knowledge and Understanding.

Dimension 2: Analysis and problem solving			
(Sub) descriptor / TLA approaches	**Knowledge**	**Skills**	**Autonomy and Responsibility (Wider Competences)**
L7_2. Level descriptor	**K7_2 Demonstrate comprehensive knowledge and understanding of the processes and methods of analysis / solution of engineering issues (products, processes, systems, situations) / engineering problems in the civil engineering subject area, including new and innovative methods, and of their limitations.**	**S7_2 Analyse / solve very complex engineering issues (products, processes, systems, situations) / engineering problems in civil engineering subject area by applying appropriate and relevant methods of analysis / solution.**	**C7_2 Identify and justify appropriate and relevant methods of analysis / solution of very complex civil engineering issues (products, processes, systems, situations) / engineering problems from established or new and innovative methods.**

Dimension 2: Analysis and problem solving			
(Sub) descriptor / TLA approaches	**Knowledge**	**Skills**	**Autonomy and Responsibility (Wider Competences)**
Subset 1 | L7_2.1 Analysis of civil engineering issues	**K7_2.1** Define and describe key factual information related to civil engineering issues (products, processes, systems, situations), applicable processes and methods of analysis, including new and innovative methods, and their limitations, and explain key concepts related to issue recognition and how analysis methods are applied.	**S7_2.1** Conceptualise and analyse very complex civil engineering issues (products, processes, systems, situations) by applying appropriate and relevant analysis methods and report the results of the analysis process.	**C7_2.1** Identify and justify appropriate and relevant analysis methods of very complex civil engineering issues (products, processes, systems, situations) from established or new and innovative methods, critically interpret the analysis outcomes and present an understanding of the issue and recommendations for necessary measures taking requirements and constraints into account.
Subset 2 | L7_2.2 Solution of civil engineering problems	**K7_2.2** Define and describe key factual information related to civil engineering problem recognition, applicable processes and methods of solution, including new and innovative methods, and their limitations, and explain key concepts related to problem recognition and how solution methods are applied.	**S7_2.2** Identify, formulate and solve very complex civil engineering problems by applying appropriate and relevant solution methods and report the results of the solution process.	**C7_2.2** Identify and justify appropriate and relevant solution methods of very complex civil engineering problems from established or new and innovative methods and present an understanding of the problems and recommendations for necessary measures taking requirements and constraints into account.

Dimension 2: Analysis and problem solving			
(Sub) descriptor / TLA approaches	**Knowledge**	**Skills**	**Autonomy and Responsibility (Wider Competences)**
Subset 3 | L7_2.3 Safe, sustainable and of low impact solutions	**K7_2.3** Define, describe and explain key aspects of safety, sustainability and impact on society and environment related to civil engineering phenomena and to the ethical obligation and social responsibility of professional engineers.	**S7_2.3** Identify, formulate and solve very complex civil engineering problems that may involve nontechnical – societal, health and safety, environmental, economic and industrial – constraints by applying appropriate and relevant solution methods and report the results of the solution process.	**C7_2.3** Identify and justify appropriate and relevant solution methods of very complex civil engineering problems that may involve nontechnical – societal, health and safety, environmental, economic and industrial – constraints from established or new and innovative methods and identify solutions safe, sustainable and of low impact on society and environment.
Assessment approaches	Short Answer Questions. Multiple Choice Questions. Essays.	Essays. Problem Solving.	Problem Solving. Practical Work. Reflective Practice Assignments.
Learning approaches	Attending lectures. Attending seminars. Attending tutorials. Participating in flipped classroom. Blended learning. Problem-based learning.	Participating in exercise courses/ practical classes. Problem-based learning.	Participating in exercise courses/ practical classes. Problem-based learning. Individual supervision.
Teaching approaches	Lectures. Seminars. Tutorials. Flipped classroom. Blended teaching. Problem-based classes.	Exercise courses/ Practical classes. Problem-based classes.	Exercise courses/ Practical classes. Problem-based classes. Individual supervision.

Table C.2: Civil Engineering | Second Cycle | Dimension 2: Analysis and problem solving.

Dimension 3: Design			
(Sub) descriptor / TLA approaches	**Knowledge**	**Skills**	**Autonomy and Responsibility (Wider Competences)**
L7_3. Level descriptor	**K7_3 Demonstrate comprehensive knowledge and understanding of the process and methods of design in civil engineering subject area, including new and original methods, and of their limitations.**	**S7_3 Conceive and design very complex civil engineering products (devices, artefacts, etc.), processes and systems by applying appropriate and relevant design methods.**	**C7_3 Identify and justify appropriate and relevant design methods of very complex civil engineering products (devices, artefacts, etc.), processes and systems from established or new and innovative methods.**
Subset 1 | L7_3.1 Design of civil engineering products, processes and systems	**K7_3.1** Define and describe key factual information related to civil engineering products (devices, artefacts, etc.), processes and systems, applicable processes and methods of design, including new and innovative methods, and their limitations, list major steps in the design process, explain how design methods are applied and define and describe constraints that affect and explain how they affect the process and results of engineering designs.	**S7_3.1** Conceive and design very complex civil engineering products (devices, artefacts, etc.), processes and systems by applying appropriate and relevant design methods and being able to use knowledge and understanding at the forefront of the engineering specialisation, and report the results of the design process.	**C7_3.1** Analyse civil engineering products (devices, artefacts, etc.), processes and systems to determine requirements and constraints, identify and justify appropriate and relevant design methods of very complex civil engineering products, processes and systems from established or new and innovative methods systems and present recommendations for necessary measures taking requirements and constraints into account.

Dimension 3: Design			
(Sub) descriptor / TLA approaches	**Knowledge**	**Skills**	**Autonomy and Responsibility (Wider Competences)**
Subset 2 | L7_3.2 Safe, sustainable and of low impact designs	**K7_3.2** Define, describe and explain key aspects of safety, sustainability and impact on society and environment related to civil engineering phenomena and to the ethical obligation and social responsibility of professional engineers.	**S7_3.2** Conceive and design very complex civil engineering products (devices, artefacts, etc.), processes and systems that may involve non- technical – societal, health and safety, environmental, economic and industrial – constraints by applying appropriate and relevant design methods and report the results of the design process.	**C7_3.2** Identify and justify appropriate and relevant design methods of very complex civil engineering products (devices, artefacts, etc.), processes and systems that may involve non-technical – societal, health and safety, environmental, economic and industrial – constraints from established or new and innovative methods and design safe, sustainable and of low impact on society and environment products, processes and systems and present recommendations for necessary measures taking requirements and constraints into account.
Assessment approaches	Short Answer Questions. Multiple Choice Questions. Essays.	Essays. Problem Solving.	Problem Solving. Reflective Practice Assignments.
Learning approaches	Attending lectures. Attending seminars. Attending tutorials. Participating in flipped classroom. Blended learning. Design-based learning.	Participating in exercise courses/ practical classes. Design-based learning.	Participating in exercise courses/ practical classes. Design-based learning. Individual supervision.

Dimension 3: Design			
(Sub) descriptor / TLA approaches	**Knowledge**	**Skills**	**Autonomy and Responsibility (Wider Competences)**
Teaching approaches	Lectures. Seminars. Tutorials. Flipped classroom. Blended teaching. Design-based classes.	Exercise courses/ Practical classes. Design-based classes.	Exercise courses/ Practical classes. Design-based classes. Individual supervision.

Table C.3: Civil Engineering | Second Cycle | Dimension 3: Design.

Dimension 4: Investigation			
(Sub) descriptor / TLA approaches	**Knowledge**	**Skills**	**Autonomy and Responsibility (Wider Competences)**
L7_4. Level descriptor	**K7_4 Demonstrate comprehensive knowledge and understanding of codes of practice and safety regulations and of investigation methods (consultation of sources of information, simulations, experimental methods) in civil engineering subject area, including new and original emerging methods, and of their limitations.**	**S7_4 Consult and apply codes of practice and safety regulations and conduct investigations (consultation of sources of information, simulations, experimental methods) in civil engineering subject area and within broader or multidisciplinary contexts in order to meet specified needs and report the investigation results.**	**C7_4 Identify and justify appropriate and relevant investigation approaches (among codes of practice and safety regulations, consultation of sources of information, simulations, experimental methods) in civil engineering subject area and within broader or multidisciplinary contexts, and analyse, explain and critically evaluate the investigation results with respect to the needs to be met.**

Dimension 4: Investigation			
(Sub) descriptor / TLA approaches	**Knowledge**	**Skills**	**Autonomy and Responsibility (Wider Competences)**
Subset 1 | L7_4.1 Codes of practice and safety regulations	**K7_4.1** Identify and describe codes of practice and safety regulations in the civil engineering subject area, and explain their purpose, procedures and practical applications, potentialities and limitations, also with respect to other investigation approaches.	**S7_4.1** Consult and apply codes of practice and safety regulations in the civil engineering subject area and within broader or multidisciplinary contexts in order to meet specified needs and report the investigation results.	**C7_4.1** Identify and justify appropriate and relevant codes of practice and safety regulations in the civil engineering subject area and within broader or multidisciplinary contexts to be consulted and applied, analyse, explain and critically evaluate the investigation results with respect to the needs to be met and draw conclusions.
Subset 2 | L7_4.2 Consultation of sources of information	**K7_4.2** Identify and describe literary sources, databases and other sources of information in civil engineering subject area, and explain their purpose, procedures, practical applications, potentialities and limitations, also with respect to other investigation approaches.	**S7_4.2** Conduct searches of literature, consult and critically use databases and other sources of information in civil engineering subject area and within broader or multidisciplinary contexts in order to meet specified needs and report the investigation results.	**C7_4.2** Identify and justify appropriate and relevant source of information (literature sources, databases and other sources of information) in civil engineering subject area and within broader or multidisciplinary contexts to be consulted, analyse, explain and critically evaluate the investigation results with respect to the needs to be met and draw conclusions.
Assessment approaches	Short Answer Questions. Essays. Practical Work.	Essays. Practical Work.	Practical Work. Reflective Practice Assignments.

Dimension 4: Investigation			
(Sub) descriptor / TLA approaches	**Knowledge**	**Skills**	**Autonomy and Responsibility (Wider Competences)**
Learning approaches	Attending lectures. Attending seminars. Attending tutorials. Participating in flipped classroom. Blended learning. Researching and writing papers, reports, dissertations. Carrying out investigation assignments.	Participating in exercise courses/ practical classes. Researching and writing papers, reports, dissertations. Carrying out investigation assignments.	Participating in exercise courses/ practical classes. Practising professional skills. Individual supervision.
Teaching approaches	Lectures. Seminars. Tutorials. Flipped classroom. Blended teaching. Written assignments. Investigation assignments.	Exercise courses/ Practical classes. Written assignments. Investigation assignments.	Exercise courses/ Practical classes. Work-based practice. Individual supervision.
Subset 3 | L7_4.3 Simulations	**K7_4.3** Identify and describe simulation approaches in the civil engineering subject area, and explain their purpose, procedures, practical applications potentialities and limitations, also with respect to other investigation approaches.	**S7_4.3** Conduct simulations in order to pursue detailed investigations and research of technical issues in civil engineering subject area and within broader or multidisciplinary contexts in order to meet specified needs and report the simulation results.	**C7_4.3** Identify and justify appropriate and relevant simulation methods in civil engineering subject are and within broader or multidisciplinary contexts to be conducted, analyse, explain and critically evaluate the investigation results with respect to the needs to be met and draw conclusions.

Dimension 4: Investigation			
(Sub) descriptor / TLA approaches	**Knowledge**	**Skills**	**Autonomy and Responsibility (Wider Competences)**
Subset 4 | L7_4.4 Experimental methods	**K7_4.4** Identify and describe the procedures and equipment necessary to conduct civil engineering experiments in more than one of the technical areas of civil engineering, and explain their purpose, procedures and practical applications, potentialities and limitations, also with respect to other investigation approaches.	**S7_4.4** Provide evidence of advanced laboratory/workshop skills and design and conduct experiments in more than one of the technical areas of civil engineering according to established procedures in order to meet specified needs and report the experiment results.	**C7_4.4** Identify and justify appropriate and relevant experiments to be conducted, analyse, evaluate the accuracy of the results within the known boundaries of the tests, explain and critically evaluate the experiment results according to established procedures with respect to the needs to be met and draw conclusions.
Assessment approaches	Short Answer Questions. Essays. Practical Work.	Essays. Practical Work.	Practical Work. Reflective Practice Assignments.
Learning approaches	Attending lectures. Attending seminars. Attending tutorials. Participating in flipped classroom. Blended learning. Carrying out numerical modelling/laboratory assignments.	Participating in exercise courses/ practical classes. Carrying out numerical modelling/laboratory assignments.	Participating in exercise courses/ practical classes. Practising professional skills. Individual supervision
Teaching approaches	Lectures. Seminars. Tutorials. Flipped classroom. Blended teaching. Problem-based classes.	Exercise courses/ Practical classes. Problem-based classes.	Exercise courses/ Practical classes. Problem-based classes. Individual supervision.

Dimension 4: Investigation			
(Sub) descriptor / TLA approaches	**Knowledge**	**Skills**	**Autonomy and Responsibility (Wider Competences)**
Subset 5 | L7_4.5 New and emerging technologies	**K7_4.5** Identify and describe new and emerging technologies at the forefront of civil engineering specialisation.	**S7_4.5** Investigate the application of new and emerging technologies at the forefront of civil engineering specialisation and their potentialities and limitations, also with respect to technologies already in use.	**C7_4.5** Identify, analyse and explain the impact of new and emerging technologies on society and environment.
Assessment approaches	Short Answer Questions. Essays.	Essays. Problem Solving. Reflective Practice Assignments.	Problem Solving. Reflective Practice Assignments.
Learning approaches	Attending lectures. Attending seminars. Attending tutorials. Participating in flipped classroom. Blended learning.	Participating in exercise courses/ practical classes. Preparing and making oral presentations. Researching and writing papers, reports, dissertations. Individual supervision.	Participating in exercise courses/ practical classes. Individual supervision
Teaching approaches	Lectures. Seminars. Tutorials. Flipped classroom. Blended teaching.	Exercise courses/ Practical classes.Oral Assessment. Written assessment. Individual supervision.	Exercise courses/ Practical classes. Individual supervision.

Table C.4: Civil Engineering | Second Cycle | Dimension 4: Investigation.

Dimension 5: Practice			
(Sub) descriptor / TLA approaches	**Knowledge**	**Skills**	**Autonomy and Responsibility (Wider Competences)**
L7_5. Level descriptor	**K7_5 Demonstrate comprehensive practical knowledge and understanding of materials, equipment and tools, processes and technologies in civil engineering subject area and of their limitations.**	**S7_5 Implement and conduct complex engineering activities in civil engineering subject area and within broader or multidisciplinary contexts, using and applying practical knowledge and understanding of materials, equipment and tools, processes and technologies.**	**C7_5 Identify and justify practical knowledge and understanding of materials, equipment and tools, processes and technologies necessary to conduct complex engineering activities in civil engineering subject area and within broader or multidisciplinary contexts.**
Subset 1 | L7_5.1 Materials, equipment and tools, technologies and processes	**K7_5.1** Define and describe key factual information related to materials, equipment and tools, technologies and processes and explain their practical application in civil engineering subject area.	**S7_5.1** Apply appropriate practical knowledge and understanding on materials, equipment and tools, technologies and processes 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.	**C7_5.1** Analyze existing practices in the use and identify and justify appropriate practical knowledge and understanding of materials, equipment and tools, technologies and processes 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.
Assessment approaches	Short Answer Questions. Essays. Practical Work.	Essays. Problem Solving. Practical Work.	Problem Solving. Practical Work. Reflective Practice Assignments.

Dimension 5: Practice			
(Sub) descriptor / TLA approaches	**Knowledge**	**Skills**	**Autonomy and Responsibility (Wider Competences)**
Learning approaches	Attending lectures. Attending seminars. Attending tutorials. Participating in flipped classroom. Blended learning. Practising professional skills. Fieldwork.	Participating in exercise courses/ practical classes. Preparing and making oral presentations. Researching and writing papers, reports, dissertations. Practising professional skills.	Participating in exercise courses/ practical classes. Practising professional skills.
Teaching approaches	Lectures. Seminars. Tutorials. Flipped classroom. Blended teaching. Work-based practice. Fieldwork.	Exercise courses/ Practical classes. Oral assessment. Written assessment. Work-based practice.	Exercise courses/ Practical classes. Work-based practice.

Table C.5: Civil Engineering | Second Cycle | Dimension 5: Practice.

Dimension 6: Decision making			
(Sub) descriptor / TLA approaches	**Knowledge**	**Skills**	**Autonomy and Responsibility (Wider Competences)**
L7_6. Level descriptor	**K7_6 Demonstrate critical awareness of the key aspects of professional, ethical and social responsibilities linked to management of work contexts, decision-making and judgment formulation in civil engineering subject area.**	**S7_6 Manage work contexts in civil engineering subject area and within broader or multidisciplinary contexts that may be unpredictable and require new strategic approaches, take decisions and formulate judgments.**	**C7_6 Identify and justify appropriate and relevant strategic approaches and analyse professional, ethical and social responsibilities linked to the management of work contexts in civil engineering subject area and within broader or multidisciplinary contexts, taking coherent decisions and formulating coherent judgments.**
Subset 1 | L7_6.1 Managing work contexts, taking decisions and formulating judgments	**K7_6.1** Describe and explain key aspects of professional, ethical and social responsibilities linked to management, decision-making and judgment formulation of work contexts in civil engineering subject area.	**S7_6.1** Manage work contexts in civil engineering subject area and within broader or multidisciplinary contexts that may be unpredictable and require new strategic approaches, identify, locate, obtain, organize and evaluate information and data, take decisions and formulate judgments.	**C7_6.1** Identify and justify appropriate and relevant strategic approaches to manage work contexts in civil engineering subject area and within broader or multidisciplinary contexts, identify and analyse situations involving multiple conflicting professional, ethical and social interests to determine an appropriate course of action, take coherent decisions and formulate coherent judgments also with incomplete or limited information and data.

Dimension 6: Decision making			
(Sub) descriptor / TLA approaches	**Knowledge**	**Skills**	**Autonomy and Responsibility (Wider Competences)**
Assessment approaches	Short Answer Questions. Essays. Practical Work.	Essays. Problem Solving. Practical Work.	Problem Solving. Practical Work. Reflective Practice Assignments.
Learning approaches	Attending lectures. Attending seminars. Attending tutorials. Participating in flipped classroom. Blended learning. Problem-based learning. Design-based learning. Practising professional skills.	Participating in exercise courses/ practical classes. Problem-based learning. Design-based learning. Practising professional skills. Role play. Peer reviewing.	Participating in exercise courses/ practical classes. Problem-based learning. Design-based learning. Practising professional skills. Role play. Peer reviewing.
Teaching approaches	Lectures. Seminars. Tutorials. Flipped classroom. Blended teaching. Problem-based learning. Design-based learning. Practising professional skills.	Exercise courses/ Practical classes. Problem-based learning. Design-based learning. Work-based learning. Role play. Peer reviewing.	Exercise courses/ Practical classes. Problem-based classes. Design-based classes. Work-based practice. Role play. Peer reviewing.

Table C.6: Civil Engineering | Second Cycle | Dimension 6: Decision making.

Dimension 7: Team-working			
(Sub) descriptor / TLA approaches	**Knowledge**	**Skills**	**Autonomy and Responsibility (Wider Competences)**
L7_7. Level descriptor	**K7_7 Demonstrate knowledge and understanding of functioning methods and management strategies of teams that may be composed of different disciplines and levels and awareness of leadership responsibilities.**	**S7_7 Function effectively in national and international contexts as member/leader of teams that may be composed of different disciplines and levels meeting deliverable, schedule and budget requirements.**	**C7_7 Identify and justify appropriate and relevant functioning methods and management strategies of teams that may be composed of different disciplines and levels and elements of successful teamwork.**
Subset 1 | L7_7.1 Team functioning	**K7_7.1** Define and describe key characteristics and functioning methods of effective teams that may be composed of different disciplines and levels.	**S7_7.1** Function effectively as a member of teams that may be composed of different disciplines and levels contributing to meet deliverable, schedule and budget requirements.	**C7_7.1** Identify and justify appropriate and relevant functioning methods of teams that may be composed of different disciplines and levels and analyse factors affecting the ability to function effectively and to meet deliverable, schedule and budget requirements.
Assessment approaches	Essays. Problem Solving. Practical Work.	Problem Solving. Practical Work.	Problem Solving. Practical Work. Reflective Practice Assignments.
Learning approaches	Attending lectures. Attending seminars. Attending tutorials. Participating in flipped classroom. Blended learning. Fieldwork.	Problem-based learning. Design-based learning. Practising professional skills. Role play. Peer reviewing.	Problem-based learning. Design-based learning. Practising professional skills. Role play. Peer reviewing.

Dimension 7: Team-working			
(Sub) descriptor / TLA approaches	**Knowledge**	**Skills**	**Autonomy and Responsibility (Wider Competences)**
Teaching approaches	Lectures. Seminars. Tutorials. Flipped classroom. Blended teaching. Fieldwork.	Problem-based classes. Design-based classes. Work-based practice. Role play. Peer reviewing.	Problem-based classes. Design-based classes. Work-based practice. Role play. Peer reviewing.
Subset 2 | L7_7.2 Team management	**K7_7.2** Define and describe leadership principles and attitudes, role and responsibilities of a leader and management strategies of teams that may be composed of different disciplines and levels.	**S7_7.2** Organize and direct the efforts of teams that may be composed of different disciplines and levels applying leadership principles and meeting deliverable, schedule and budget requirements.	**C7_7.2** Identify and justify appropriate and relevant management strategies of teams that may be composed of different disciplines and levels and possible needs for reviewing the strategic performance, and take responsibility for contributing to professional knowledge and practice of team members.
Assessment approaches	Essays. Problem Solving. Practical work.	Problem Solving. Practical Work.	Problem Solving. Practical Work.
Learning approaches	Attending lectures. Attending seminars. Attending tutorials. Participating in flipped classroom. Blended learning. Problem-based learning. Design-based learning. Practising professional skills.	Problem-based learning. Design-based learning. Practising professional skills. Role play. Peer reviewing.	Problem-based learning. Design-based learning. Practising professional skills.

Dimension 7: Team-working			
(Sub) descriptor / TLA approaches	**Knowledge**	**Skills**	**Autonomy and Responsibility (Wider Competences)**
Teaching approaches	Lectures. Seminars. Tutorials. Flipped classroom. Blended teaching. Problem-based classes. Design-based classes. Work-based practice.	Problem-based classes. Design-based classes. Work-based practice. Role play. Peer reviewing.	Problem-based learning. Design-based learning. Work-based practice.

Table C.7: Civil Engineering | Second Cycle | Dimension 7: Team-working.

Dimension 8: Communication			
(Sub) descriptor / TLA approaches	**Knowledge**	**Skills**	**Autonomy and Responsibility (Wider Competences)**
L7_8. Level descriptor	**K7_8 Demonstrate knowledge and understanding of communication strategies, methods and tools, including new and innovative ones, and of their limitations.**	**S7_8 Communicate effectively, clearly and unambiguously information, describe activities and communicate their exits/results – and the knowledge and rationale underpinning these – to specialist and non- specialist audiences in national and international contexts and society at large, using appropriate communication strategies, methods and tools.**	**C7_8 Identify and justify appropriate and relevant communication strategies, methods and tools from established or new and innovative ones.**

Dimension 8: Communication			
(Sub) descriptor / TLA approaches	**Knowledge**	**Skills**	**Autonomy and Responsibility (Wider Competences)**
Subset 1 | L7_8.1 Communication strategies, methods and tools	**K7_8.1** Define and describe communication strategies, methods and tools, the characteristics of effective verbal, written, virtual, and graphical communications and their limitations 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.	**S7_8.1** Plan, compose, integrate and deliver effective verbal, written, virtual and graphical communications for describing activities and communicating 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, by applying rules of grammar and composition in verbal and written communications, properly citing sources, and using appropriate graphical standards in preparing engineering drawings.	**C7_8.1** Identify and justify appropriate and relevant communication strategies, methods and tools among standard and 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.
Assessment approaches	Essays. Problem Solving. Practical Work.	Problem Solving. Practical Work.	Problem Solving. Practical Work. Reflective Practice Assignments.
Learning approaches	Attending lectures. Attending seminars. Attending tutorials. Participating in flipped classroom. Blended learning. Fieldwork.	Problem-based learning. Design-based learning. Practising professional skills. Role play. Peer reviewing.	Problem-based learning. Design-based learning. Practising professional skills. Individual supervision.

Dimension 8: Communication			
(Sub) descriptor / TLA approaches	**Knowledge**	**Skills**	**Autonomy and Responsibility (Wider Competences)**
Teaching approaches	Lectures. Seminars. Tutorials. Flipped classroom. Blended teaching. Fieldwork.	Problem-based classes. Design-based classes. Work-based practice. Role play. Peer reviewing.	Problem-based classes. Design-based classes. Work-based practice. Individual supervision.

Table C.8: Civil Engineering | Second Cycle | Dimension 8: Communication.

Dimension 9: Lifelong Learning			
(Sub) descriptor / TLA approaches	**Knowledge**	**Skills**	**Autonomy and Responsibility (Wider Competences)**
L7_9. Level descriptor	**K7_9 Demonstrate knowledge and understanding of the learning methods necessary to follow developments in science and technology and undertake further studies in new and emerging technologies in civil engineering subject area and within broader or multidisciplinary contexts.**	**S7_9 Engage in independent lifelong learning and follow developments in science and technology and undertake further studies in new and emerging technologies in civil engineering subject area and within broader or multidisciplinary contexts autonomously.**	**C7_9 Identify and justify appropriate learning strategies and methods in independent lifelong learning to follow developments in science and technology and undertake further studies in new and emerging technologies in civil engineering subject area and within broader or multidisciplinary contexts.**

Dimension 9: Lifelong Learning			
(Sub) descriptor / TLA approaches	**Knowledge**	**Skills**	**Autonomy and Responsibility (Wider Competences)**
Subset 1 | L7_9.1 Learning strategies and methods	**K7_9.1** Define lifelong learning, explain the need for lifelong learning, describe the skills required of a lifelong learner and the learning methods necessary to follow developments in science and technology and undertake further studies in new and emerging technologies in civil engineering subject area and within broader or multidisciplinary contexts.	**S7_9.1** Engage in independent lifelong learning to follow developments in science and technology and undertake further studies in new and emerging technologies in civil engineering subject area and within broader or multidisciplinary contexts autonomously.	**C7_9.1** Identify and justify appropriate learning strategies and methods in independent lifelong learning to follow developments in science and technology and undertake further studies in new and emerging technologies in civil engineering subject area and within broader or multidisciplinary contexts.
Assessment approaches	Essays. Problem Solving. Practical Work. Reflective Practice Assignments.	Problem Solving. Practical Work.	Problem Solving. Practical Work. Reflective Practice Assignments.
Learning approaches	Attending lectures. Attending seminars. Attending tutorials. Problem-based learning. Design-based learning. Work-based practice.	Problem-based learning. Design-based learning. Practising professional skills.	Problem-based learning. Design-based learning. Practising professional skills. Individual supervision.
Teaching approaches	Lectures. Seminars. Tutorials. Problem-based classes. Design-based classes. Work-based practice. Individual supervision.	Problem-based classes. Design-based classes. Work-based practice.	Problem-based classes. Design-based classes. Work-based practice. Individual supervision.

Dimension 9: Lifelong Learning			
(Sub) descriptor / TLA approaches	**Knowledge**	**Skills**	**Autonomy and Responsibility (Wider Competences)**

Table C.9: Civil Engineering | Second Cycle | Dimension 9: Lifelong Learning.

Appendix D

Nonviolent Communication - Feelings vocabulary

How we are likely to feel when our needs "are" being met

absorbed	confident	exultant	involved	relaxed
adventurous	contented	fascinated	joyous, joyful	relieved
affectionate	cool	free	jubilant	satisfied
alert	curious	friendly	keyed-up	secure
alive	dazzled	fulfilled	loving	sensitive
amazed	delighted	glad	mellow	serene
amused	eager	gleeful	merry	spellbound
animated	ebullient	glorious	mirthful	splendid
appreciative	ecstatic	glowing	moved	stimulated
ardent	effervescent	good-humored	optimistic	surprised
aroused	elated	grateful	overjoyed	tender
astonished	enchanted	gratified	overwhelmed	thankful
blissful	encouraged	happy	peaceful	thrilled
breathless	energetic	helpful	perky	touched
buoyant	engrossed	hopeful	pleasant	tranquil

How we are likely to feel when our needs "are" being met

calm	enlivened	inquisitive	pleased	trusting
carefree	enthusiastic	inspired	proud	upbeat
cheerful	excited	intense	quiet	warm
comfortable	exhilarated	interested	radiant	wide-awake
complacent	expansive	intrigued	rapturous	wonderful
composed	expectant	invigorated	refreshed	zestful
concerned				

How we are likely to feel when our needs "are not" being met

afraid	despairing	frustrated	lonely	sleepy
aggravated	despondent	furious	mad	sorrowful
agitated	detached	gloomy	mean	sorry
alarmed	disaffected	guilty	miserable	spiritless
aloof	disaffected	harried	mopey	startled
angry	disappointed	heavy	morose	surprised
anguished	discouraged	helpless	mournful	suspicious
annoyed	disgruntled	hesitant	nervous	tepid
anxious	disgusted	horrified	nettled	terrified
apathetic	disheartened	horrible	numb	tired
apprehensive	dismayed	hostile	overwhelmed	troubled
aroused	displeased	hot	panicky	uncomfortable
ashamed	disquieted	humdrum	passive	unconcerned
beat	distressed	hurt	perplexed	uneasy
bewildered	disturbed	impatient	pessimistic	unglued

How we are likely to feel when our needs "are not" being met

bitter	downcast	indifferent	puzzled	unhappy
blah	downhearted	intense	rancorous	unnerved
blue	dull	irate	reluctant	unsteady
bored	edgy	irked	repelled	upset
brokenhearted	embarrassed	irritated	resentful	uptight
chagrined	embittered	jealous	restless	vexed
cold	exasperated	jittery	sad	weary
concerned	exhausted	keyed-up	scared	wistful
confused	fatigued	lazy	sensitive	withdrawn
cool	fearful	leery	shaky	woeful
cross	fidgety	lethargic	shocked	worried
dejected	forlorn	listless	skeptical	wretched
depressed	frightened			

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