1.3

Competency Frameworks of Use to Engineering Educators

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The competencies engineering students require are changing at a rapid pace due to evolving industry, societal, and technological demands. This has resulted in educators seeking guidance from, and often being overwhelmed by, the fragmented world of competency frameworks, which differ widely in scope, level of detail, and intended purpose. To address this challenge, we begin by contextualising this chapter by asking who would benefit most from reading it, before clarifying the distinction between taxonomies and competency frameworks. We then present three questions that will be used to guide discussion of several contemporary frameworks: what the framework's primary goal is, the areas for which it provides guidance, and how actionable it is. We apply these questions to the diverse frameworks of EntreComp, DigComp, GreenComp, EUR-ACE, CDIO, and UK-SPEC. We believe that our selection of frameworks and subsequent discussions serve as a strong starting point for engineering educators seeking to navigate this landscape with greater confidence.

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1 Who would benefit from reading this chapter?

This chapter is written for practitioners in engineering education who are seeking orientation in the complex landscape of competency frameworks. The primary audience comprises lecturers, programme coordinators, deans, curriculum designers, and teaching and learning support staff working at undergraduate and postgraduate level. Engineering students are an indirect audience. While they are not directly addressed, the frameworks discussed shape the curricula, learning activities and assessments they experience. Throughout this chapter, we have used *competencies* instead of *skills* or similar terminology. When referring to this term, we link our understanding to Chapter 1.2 and the definition by Passow (2012, p. 97): "*competencies are defined as the knowledge, skills, abilities, attitudes, and other characteristics that enable a person to perform skilfully (i.e., to make sound decisions and take effective action) in complex and uncertain situations such as professional work, civic engagement, and personal life"*. Thus, we understand competencies not merely as knowledge or skills, but as dynamic, learnable dispositions that manifest in purposeful and effective performance within complex contexts.

The development of competencies is a lifelong and context-sensitive process, closely tied to performance and evaluative judgement (Rychen & Salganik, 2000; Woollacott, 2009). Against this background, engineering educators are facing increasing pressure to align curricula with rapidly evolving societal, technological, and professional demands. These include sustainability, digitalisation, global collaboration, and artificial intelligence (Hadgraft & Kolmos, 2020; SEFI, 2025).

At the same time, the landscape of competency frameworks is broad and fragmented, with a growing number of overlapping or even conflicting frameworks claiming to define what engineering graduates should be able to do. As noted by Richter and Kjellgren (2025), the abundance of such frameworks can be overwhelming, especially regarding the variety in quality, focus, and practical applicability. Many frameworks provide only vague definitions or lack practical indicators, which makes their application in curricula or teaching strategies challenging. This abundance and vagueness can confuse those at the beginning of their exploration.

Too much detail can result in a framework being inapplicable in another context, whereas too little detail can leave individual educators to make highly subjective decisions. Crossin et al. (2023) emphasise that while competency frameworks provide valuable guidance, their often non-prescriptive nature complicates the task of mapping frameworks onto the varied realities of engineering practice. As Richter and Kjellgren (2025) observe, subjectivity arises when indicators lack specificity in a commonly faced challenge.

This chapter responds to these challenges by presenting a structured and accessible selection of frameworks. It aims to help you gain an initial overview without requiring deep prior knowledge of each. Our focus is not on prescribing a single solution, but rather on offering a guided entry point by providing a comparative and annotated set of frameworks that is indicative of current priorities in engineering education, primarily across Europe. This approach should help educators navigate the field more confidently and help inform decision making when selecting or adapting frameworks for specific institutional or programmatic contexts.

2 Asking the right questions: How to choose a fit-for-purpose resource

Given the large number of competency-related resources available today, engineering educators can justifiably feel uncertain about how to interpret and use them. Many documents are labelled as frameworks, inventories, or similar terms, yet they differ substantially in scope, level of detail, and intended use.

This section aims to address this challenge by first addressing the often-misunderstood distinction between taxonomies and frameworks, and second by offering a set of guiding questions to support fit-for-purpose selection.

Taxonomies primarily classify and organise competencies or skills, while competency frameworks go beyond classification by providing structure, progression, and in some cases guidance for educational action (Child & Shaw, 2020; Wozniak, 2024). Taxonomies and competency frameworks can therefore be considered to form the two ends of a spectrum of utility. It can be helpful for engineering educators to position a given resource along this spectrum.

Examining how a resource is organised — for example, whether it presents simple lists or detailed outcome descriptions — can help to indicate its intended purpose and practical usefulness. At the same time, it is important to recognise that neither taxonomies nor competency frameworks can ever be complete or absolute. Both reflect competencies deemed relevant within a specific time and place, while being applied in different contexts.

In this sense, competency-related resources should be understood as aiming to support more informed professional judgement — being *good enough* to guide decision making, rather than offering definitive solutions. This contextual limitation is further reinforced by the rapidity of societal and technological change. For example, research on skills conducted prior to the widespread impact of GenAI or the COVID-19 pandemic may already be outdated. Similarly, the sources informing skills recommendations have evolved over time.

To support educators in evaluating both taxonomies and competency frameworks, this chapter proposes three guiding questions (see Table 1.3.1). These questions are intentionally generic and can be applied across different types of resources:

1. What is the resource's primary goal (e.g., to define, assess, or develop competencies and skills)?
2. In which areas does it provide guidance (e.g., curriculum or module design, assessment, professional development)?
3. How actionable is it (e.g., does it include performance indicators, progression levels, or sample rubrics)?

An example of a resource whose utility aligns more closely with a taxonomy than with a competency framework is the World Economic Forum's 21st-century skills (2015). It comprises 16 skills grouped into three categories: foundational literacies (core skills), competencies (skills for solving challenges), and character qualities (skills for navigating change). If we analyse the skills taxonomy of the World Economic Forum (WEF) using our three questions, a clear profile emerges:

- Its primary goal is to define and classify competencies and skills, rather than to specify how they should be assessed or developed.
- The guidance it provides is primarily for high-level curriculum considerations, helping educators identify which skills to include in a programme.
- Its actionability is limited; as a descriptive list of topics, it typically lacks the concrete performance indicators or progression levels needed to design specific teaching activities or assessment rubrics.

This is largely continued in the WEF's 2025 Future of Jobs Report (World Economic Forum, 2025), though the guidance provided is primarily industry related.

In addition, many widely used resources in engineering education, such as EUR-ACE or ABET, function as accreditation standards rather than taxonomies, while UK Standard for Professional Engineering Competence and Commitment (UK-SPEC) also operates as a regulatory standard for professional registration. They share the prescriptive qualities of competency frameworks, providing clear pathways to specific educational outcomes, but carry additional regulatory force in defining what accredited programmes or registrants must demonstrate.

An example of such a framework is the European Entrepreneurship Competence Framework (EntreComp), which offers a set of scaffolding elements that educators can draw on when designing for entrepreneurial competency development (Bacigalupo et al., 2016). EntreComp organises 15 competencies into a hierarchy of three categories, namely Ideas and Opportunities, Resources, and Into Action, and supplements these with a progression model of eight proficiency levels articulated through 442 learning outcomes. Unlike a simple taxonomy, these elements give educators concrete material to work with when sequencing learning, defining outcomes, and designing assessment.

Accordingly, a competency framework yields different answers to our guiding questions than a taxonomy does:

- Its primary goal goes beyond just defining competencies and skills to actively guiding how they can be developed and assessed.
- It therefore provides guidance in more detailed areas of curriculum design and student professional development, showing how competencies can be progressed over time.
- This makes a competency framework typically more actionable, as it typically includes the specific performance indicators and progression levels that educators need to design meaningful learning activities and assessment rubrics.

Now that we have a clear method for identifying and understanding different resources, the following section provides an overview of selected competency frameworks used in engineering education today.

3 A selection of diverse frameworks for engineering education practitioners

Having provided background context regarding frameworks and the questions to be asked when working with them, we present below the frameworks we have selected to expand on in this chapter. Our aim is to furnish the above discussion with concrete examples, while also linking you to other sections of this handbook to dive deeper.

The selection was guided by four considerations: (1) relevance to current engineering education challenges (e.g., sustainability, digitalisation, employability), (2) diversity of framework types (e.g., geographical scope, accreditation standards, engineering education approaches), (3) variation in intended application level (e.g. curriculum, programme, professional, or module level), and (4) their influence within engineering education practice. The guiding questions introduced in Section 2 are then used to analyse and compare these selected examples.

The six frameworks discussed in Table 1.3.1 serve different functions, and it is useful to distinguish three broad categories before examining each in turn. The first comprises European Union-level competence frameworks, namely EntreComp (Bacigalupo et al., 2016), DigComp (Vuorikari et al., 2022), and GreenComp (Bianchi et al., 2022), all developed by the European Commission's Joint Research Centre as non-prescriptive reference models intended to provide a shared conceptual vocabulary for lifelong learning across sectors and educational levels. Their function is orientational: they describe what competent action in a given domain looks like, but they neither prescribe curricula nor certify programmes.

The second category consists of regulatory and accreditation standards, namely UK-SPEC (Engineering Council, 2020) and EUR-ACE (ENAEE, 2021). Both define minimum outcomes that engineering graduates or registrants must demonstrate and carry formal consequences, though they differ in mechanism: EUR-ACE accredits programmes directly, whereas UK-SPEC sets the standard for professional registration and shapes education indirectly through the AHEP accreditation standard.

The third category is community-driven engineering education frameworks, of which the CDIO syllabus (Crawley et al., 2011) is the principal example in this chapter. These emerge from networks of engineering educators rather than from regulatory or policy bodies, and their function is to support curriculum and module design through detailed, practice-oriented educational goals.

These distinctions matter because each type answers a different question for the educator: EU frameworks help articulate which competencies to develop, while regulatory and accreditation standards specify what a programme or registrant must demonstrate.

Table 1.3.1: Overview of selected competency frameworks with guiding questions.

	What is the framework's primary goal?	*In which areas does it provide guidance?*	*How actionable is it?*
EntreComp	Foster a value-creation mindset (Bacigalupo et al., 2016)	Programme design; competency assessment; learning activity design	Model with eight proficiency levels to help learning and assessment design
DigComp	Develop digital competencies and skills (Vuorikari et al., 2022)	Labour market skill requirements; education and training curricula	List of 21 skills with examples of knowledge, skills, and attitudes
GreenComp	Develop sustainability competencies across Europe (Bianchi et al., 2022)	Education at all levels; learner development	List of 12 competencies across four areas and 40 learning outcomes
EUR-ACE	Define minimum outcomes and quality standards for engineering programmes	Programme design; accreditation; quality assurance	Eight learning areas with clear cycle-level expectations
CDIO Syllabus	Define and structure practice-oriented engineering competencies to guide curriculum development	Curriculum and module design; systematic curriculum development; alignment with engineering practice	A structure with multiple levels of detail for curriculum development and outcome definition
UK-SPEC	Define and assess the standards for professional engineering and technician registration in the UK	Professional assessment and registration; professional and ethical standards; curriculum and module design	Five performance indicators, progressional levels and examples of evidence

These six frameworks were developed with different audiences in mind. Recognising this matters when translating them into engineering education contexts. EntreComp, DigComp, and GreenComp are not engineering-specific, which means engineering educators using them must do additional work to translate generic competence descriptors into discipline-relevant learning outcomes. EUR-ACE and the CDIO Syllabus were developed specifically for engineering programmes and educators, so the translation effort is smaller, although institutional adaptation is still required. UK-SPEC sits apart: it was written for individual engineers seeking professional registration, and its influence on engineering education is indirect, mediated through the AHEP accreditation standard.

The citizen-oriented frameworks offer transversal orientation that requires substantial adaptation, the engineering-specific frameworks offer closer-to-ready scaffolding, and the regulatory standards set the required outcome for programmes. These six frameworks will be discussed in more detail below.

3.1 EntreComp

The European Entrepreneurship Competence Framework, EntreComp, was published by the European Commission in 2016. It was developed by the EC's Joint Research Centre (JRC) feeding into *A New Skills Agenda for Europe* (European Commission, 2016), a communication from the European Commission to address the skills gap detected in the EU, which was considered a threat to stability and social cohesion. The agenda lays out three strategic pillars. The first — "*Improving the quality and relevance of skills formation*" — includes the action area "*Building resilience: key competences and higher, more complex skills*", which places a special focus on promoting entrepreneurial mindsets. EntreComp has since been reaffirmed by the Union of Skills strategy, as it includes an explicit undertaking for higher education to integrate entrepreneurship training across all disciplines (European Commission, 2025).

Introduced in Section 2 as one of the most comprehensive models of its type, the European Entrepreneurship Competence Framework, EntreComp defines 15 entrepreneurial competencies across three areas and a progression model of eight proficiency levels defined by 442 learning outcomes (Bacigalupo et al., 2016). On first impression, it appears highly actionable for practitioners, with progressive learning outcomes helping educators better design learning activities and assessment rubrics. However, its complexity presents challenges to its use. The EntreComp areas and competencies are:

- *Area 1.* Ideas and opportunities, consisting of spotting opportunities, creativity, vision, valuing ideas, and ethical and sustainable thinking.
- *Area 2.* Resources, consisting of self-awareness and self-efficacy, motivation and perseverance, mobilising resources, financial and economic literacy, and mobilising others.

- *Area 3.* Into action, consisting of taking the initiative, planning and management, coping with uncertainty, ambiguity and risk, and working with others.

EntreComp illustrates how a competency framework can provide engineering educators with ready-made scaffolding, in the form of competence areas, progression levels, and learning outcomes, that can be adapted into competency development scripts for specific curricular or modular contexts.

Like many competency frameworks, EntreComp uses a specific lexicon that may not align with common usage. Its definition of entrepreneurship is: *"[T]he capacity to act upon opportunities and ideas to create value for others. The value created can be social, cultural, or financial, recognising social value, cultural capital, as well as money"* (McCallum et al., 2018). This is markedly broader than the dictionary sense of someone *"who owns and manages a business, bearing the financial risks of the enterprise"* (Oxford English Dictionary, n.d.). This gap matters for practitioners: a quick reading of the framework's headline diagrams, interpreted through prior assumptions, can obscure its intent and how its competencies are defined and measured. Recognising EntreComp's expansive view of entrepreneurship, from business creator to transferable competency, also has practical consequences. In an engineering education setting, it implies that entrepreneurship should not be taught as a niche subject outsourced to business schools but integrated into mainstream engineering modules. Therefore, one major criticism of EntreComp for engineering educators is its size and complexity.

Additionally, practitioners might find curriculum design and assessment through separate learning outcomes for each competency and/or area a flawed approach. This is supported by a study conducted by Joensuu-Salo et al. (2022), who questioned the theoretical validity of the framework’s proposed multidimensional structure of three areas of entrepreneurial competency. They found a high correlation between assessments targeted at different areas of the framework. For example, a student who scores well in one area will likely score well in all others.

EntreComp's aim of fostering a value-creating mindset is ambitious, but the framework does not itself develop these competencies in learners. Used alongside this handbook, practitioners can draw selectively on its elements to design learning activities and assessments, while remaining alert to its complexity and to the assumptions embedded in its lexicon.

3.2 DigComp

The impact of digital technologies and how we respond to them is significant (Draghi, 2024; European Commission, 2026). DigComp, the European Digital Competence Framework for Citizens, is a research-driven framework developed by the European Union to provide a common understanding of digital competency to aid in the development of digital literacy (Vuorikari et al., 2022).

The primary function of DigComp is to provide a standardised language to describe digital skills and competencies, creating a standardised reference point for diverse stakeholders (Ikanos, n.d.; Vuorikari et al., 2022). This aids policymakers to formulate strategies, educators to design curricula, employers to define job requirements, and citizens to self-assess their skills. Although DigComp was developed for citizens rather than engineering professionals, its relevance to engineering education is twofold.

First, contemporary engineering graduates operate as digital citizens as well as technical practitioners: they are expected to communicate responsibly online, evaluate digital information critically, safeguard data, and engage with emerging technologies such as artificial intelligence in their interactions with colleagues, clients, and the public. Digital citizenship in this sense functions as a transversal graduate attribute that complements, rather than competes with, discipline-specific technical competencies.

Second, DigComp provides a common vocabulary that engineering programmes can use to articulate the digital dimensions of generic graduate outcomes (communication, lifelong learning, professional responsibility) which already appear in accreditation standards such as EUR-ACE and UK-SPEC. For engineering educators, then, DigComp is useful less as a substitute for discipline-specific digital skills frameworks and more as an orientation tool for the transversal, citizenship-oriented dimensions of digital literacy that engineering graduates carry into professional practice.

DigComp is structured around five core competence areas: information and data literacy; communication and collaboration; digital content creation; safety; and problem solving. These are broken down further into 21 specific skills and competencies (Vuorikari et al., 2022, p. 4). For assessment purposes, DigComp introduces a progression model of eight proficiency levels for each competency, grouped into four main stages, namely Foundation, Intermediate, Advanced, and Highly Specialised. This progression maps to increasing levels of cognitive complexity and learner autonomy, from requiring guidance for simple tasks (Level 1) to creating new ideas and resolving complex problems (Level 8) (Vuorikari et al., 2022). In addition to the levels, throughout the DigComp publications, examples of knowledge, skills, and attitudes are provided.

The framework has been regularly updated to keep up with technological development. The latest version, DigComp 2.2, was released in 2022 to address emerging technologies like artificial intelligence and new societal trends such as remote work (Vuorikari et al., 2022). There are also multiple spin-offs, such as the Digital Competence Framework for Educators (DigCompEdu) which focuses specifically on the pedagogical use of digital technologies (Redecker, 2017). This specialised framework has spurred a rich ecosystem of teacher training programmes and self-reflection tools, such as SELFIEforTEACHERS, which helps educators at pre-tertiary level assess their own digital skills (Redecker, 2017), promoting a pedagogical shift from teaching isolated 'computer skills' to embedding digital competency development across the entire curriculum. An additional example is the CRISS project, which developed a competency-based assessment model where students apply digital skills to solve problems within their regular subjects (Guitert et al., 2021). A notable use of DigComp in the engineering field comes from the Visual Literacy in Engineering

Education (VLEE) project (Różewski et al., 2021), in which visual literacy skills were aligned with DigComp (Martín Erro et al., 2022).

A large amount of literature has been written on the framework and its derived assessment instruments. These include studies that have used quantitative methods to confirm the framework's five-area structure in diverse cultural and educational settings (Abubakari et al., 2025; Gómez-Trigueros et al., 2025), as well as practical accounts where researchers have used DigComp to assess the competency levels of various populations, such as university students and educators (Saltos-Rivas et al., 2022). Studies often find that while basic skills are common, proficiency in more complex areas like *Digital Problem Solving* and *Digital Content Creation* is lacking (Abubakari et al., 2025).

Beyond academia, DigComp is a useful tool for policy and employment, as it serves as a key reference for national and regional governments in designing digital skills strategies that align with EU-wide goals (Kluzer & Pujol Priego, 2018). For the labour market, the framework provides a standard for defining digital skill requirements in job roles, assessing candidates, and identifying training needs (Kluzer et al., 2020). This practical application is supported by an ecosystem of assessment and certification, ranging from free self-assessment tools that let individuals benchmark themselves against the standard to formal certifications offering verifiable credentials for the labour market, such as the ICDL, which has aligned its modules with DigComp (ICDL Foundation, n.d.).

3.3 GreenComp

The European Sustainability Competence Framework, GreenComp, is one of the policy actions in the European Green Deal, which aims to develop sustainability competencies within the European Union and its citizens. Within GreenComp, sustainability competencies are understood as empowering "*learners to embody sustainability values, and embrace complex systems, in order to take or request action that restores and maintains ecosystem health and enhances justice, generating visions for sustainable futures"* (Bianchi et al., 2022, p. 12).

GreenComp identifies four areas — embodying sustainability values; embracing complexity in sustainability; envisioning sustainable futures; and acting for sustainability — and 12 competencies to support the development of knowledge, skills, and attitudes that prioritise care and respect for the environment.

Like other European Commission competency frameworks, such as EntreComp and DigComp, GreenComp is designed as a non-prescriptive reference model. Its role is to provide a shared conceptual foundation that can be applied flexibly across a wide range of lifelong learning contexts and purposes (Bianchi et al., 2022). Although GreenComp was not developed specifically for engineering education and addresses learners across all educational levels, it is included here because sustainability has become a central expectation for engineering graduates and curricula (e.g., Royal Academy of Engineering, 2025). For engineering educators, GreenComp can therefore serve as an orientation framework for identifying sustainability-related competencies, while requiring translation into engineering-specific learning outcomes and contexts.

Unlike EntreComp and DigComp, GreenComp does not provide proficiency levels or assessment guidance that can be applied directly in educational and training programmes. It nonetheless remains a competency framework rather than a taxonomy: it organises sustainability competencies into four interrelated areas with embedded progression logic, articulates the underpinning knowledge, skills, and attitudes, and was designed to guide curriculum and programme development across lifelong learning contexts (Bianchi et al., 2022). Where proficiency-level scaffolding is required for educational application, derivative works fill the gap. The most developed example is the OpenPass4Climate project (Martín-Ramos et al., 2025), a university consortium funded by the EU, which produced a set of 40 learning outcomes distributed across GreenComp's four areas and 12 competencies, translating its abstract concepts into actionable and measurable form.

Below is an excerpt of the learning outcomes proposed for competence Area 1 (sustainability values) and competence 1.1 (valuing sustainability):

1. Critique sustainability arguments, policies, and actions by analysing their underlying values and principles, including cultural and generational differences.
2. Negotiate solutions that reach a consensus aligned with specific sustainability principles while respecting diverse stakeholder perspectives.
3. Design and implement a personal action plan, applying concrete sustainability principles to daily choices.
4. Analyse how consumption drivers impact resource demand and environmental and social sustainability.

The 40 learning outcomes are comprehensive enough to adapt to all levels in education, whether in a formal or informal context. They have been designed to encourage behavioural change and emotional engagement as well as knowledge and understanding. This promotes learner transformation rather than focusing on skills attainment, as is the case with EntreComp and DigComp.

3.4 EUR-ACE framework standards and guidelines

The EUR-ACE label, awarded by the European Network for Accreditation of Engineering Education (ENAEE), is a Europe-wide quality mark for engineering degree programmes at both bachelor and master levels (see Chapter 1.4 for further information). Compliant with the European Qualification Framework (EQF), ENAEE defines a set of programme outcomes and quality standards that describe the knowledge, skills, and abilities engineering graduates from an accredited degree programme are expected to demonstrate. Europe’s EUR-ACE system, like America’s ABET, abides by international accreditation agreements, e.g., the Washington Accord, which is discussed in more detail in Chapter 1.4.

The mission of ENAEE “*is to serve the public and society through the promotion and advancement of engineering education in Europe and abroad. ENAEE aims at building* *a pan-European framework for the accreditation of engineering education programmes, to enhance the quality of engineering graduates, to facilitate the mobility of professional engineers and to promote quality and innovation in engineering education"* (ENAEE, 2021, p. 3). Since 2006, over 3,800 engineering programmes at more than 680 universities in 30 countries (in Europe and beyond) have received the EUR-ACE label, showing reliability and adaptability to different national contexts.

The EUR-ACE Framework Standards and Guidelines (EAFSG) include eight learning areas, each with specified learning outcomes that apply to bachelor (first-degree cycle, FCD) and master, (second-degree cycle, FCD): knowledge and understanding, engineering analysis, engineering design, investigations, engineering practice, making judgements, communication and teamworking, and lifelong learning. Both cycles address the same core competencies, but the expected depth and autonomy differ.

Bachelor's programmes focus on building a solid foundation of scientific and technical knowledge alongside practical problem solving skills, while master programmes expect graduates to work more independently, manage complex projects, and tackle open-ended or unpredictable engineering challenges. Importantly, the programme outcomes present the *minimum threshold* for engineering degrees. Table 1.3.2 shows an excerpt regarding the learning areas Communication and Team-working and Lifelong Learning, (ENAEE, 2021 p. 11).

Table 1.3.2: EUR-ACE Framework Standards and Guidelines for communication and teamworking in EUR-ACE (adapted from ENAEE, 2021)

The learning process should enable bachelor degree graduates to demonstrate:	*The learning process should enable master degree graduates to demonstrate:*
Ability to effectively communicate information, ideas, problems and solutions with the engineering community and society at large;	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 a national and international context, as an individual and as a member of a team, and to cooperate effectively with engineers and non-engineers.	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.

These outcomes serve as a reference for practitioners both for developing engineering programmes and for evaluating these during accreditation, across all engineering disciplines and profiles (ENAEE, 2021). It is important to note that the standards describe the programme outcomes that accredited programmes must achieve, but they do not prescribe *how* these outcomes are achieved, as they do not represent didactic guides. Thus, higher education institutions remain free to develop programmes with their own focus and identity, including innovative formats, and to set their own admission requirements.

Beyond graduate competencies, the EUR-ACE framework also sets requirements for programme design and quality assurance. Accredited programmes must demonstrate that their intended outcomes are clearly formulated, aligned with stakeholder and labour-market needs, and supported by appropriate teaching methods, staffing, resources, and internal evaluation processes. In doing so, the label not only signals technical quality but also confirms that programmes are systematically organised to produce capable, adaptable engineers.

3.5 CDIO Syllabus

The CDIO (Conceive–Design–Implement–Operate) initiative is a global educational framework for engineering education with the goal of preparing graduates for real-world engineering practice. Originating in the early 2000s, the initiative was driven by the question of which knowledge, skills, and attitudes engineering students need in order to be prepared for professional practice, in response to a perceived gap between education and real-world demands (Crawley et al., 2011; Crawley et al., 2014).

CDIO builds on the premise that the lifecycle of products, processes, or systems defines the context of engineering education, as these stages represent the authentic contribution of engineers to society (Crawley et al., 2011). This vision was summarized in the following statement: "*Graduating engineers should be able to conceive-design-implement-operate complex value-added engineering systems in a modern team-based environment*" (Crawley et al., 2011, p. 3).

Besides the CDIO Standards, which provide an overview of principles for implementing CDIO, the key outcome of the initiative was the CDIO Syllabus, which is a structured reference framework of topics indicating desirable competencies of engineering graduates. Instead of providing another list of graduate attributes, the syllabus provides detailed and actionable educational goals to support curriculum and module development (Crawley et al., 2011; Edström & Kolmos 2014).

The CDIO syllabus has been shown to align well with national and international accreditation requirements such as ABET, EUR-ACE, and UK-SPEC (Crawley et al., 2011; Malmqvist 2009). Comparative analyses show that graduate attributes across Washington Accord organisations are also reflected in the CDIO Syllabus (Paul et al., 2015). However, since accreditation standards evolve continuously, maintaining an up-to-date alignment remains an ongoing task (Malmqvist et al., 2022).

The syllabus is designed to be comprehensive yet non-prescriptive (Crawley et al., 2011; Malmqvist et al., 2022). It serves as a flexible reference to support curriculum design, benchmarking and accreditation, while requiring adaptation to specific institutional contexts and stakeholder needs (Malmqvist et al., 2022).

The CDIO Syllabus 3.0, the latest version, is structured into five main areas (Malmqvist et al., 2022):

1. *Fundamental Knowledge and Reasoning.* Covers core scientific and engineering knowledge, now expanded to include social sciences and humanities, acknowledging the broader context of engineering work.
2. *Personal and Professional Skills and Attributes.* Encompasses problem solving, experimentation, systems thinking, ethical reasoning, lifelong learning, and adaptability, among others.
3. *Interpersonal Skills.* Focuses on teamwork, collaboration, and communication.
4. *Conceive–Design–Implement–Operate (CDIO) Skills.* The ability to conceive, design, implement, and operate products, processes, and systems within enterprise and societal contexts.
5. *Expansion.* A new section addressing competencies such as leadership, entrepreneurship, and research, which are essential for some but not all graduates.

Each area is broken down into subcategories and multiple levels of detail, allowing educators to engage at different depths, depending on whether they focus on programme-level design or individual modules. This flexible structure aims to avoid overwhelming new users while still supporting curriculum mapping when needed.

Currently, the CDIO initiative is a worldwide community, yet its participation and research output are strongly concentrated in Europe, particularly in Nordic countries (Malmqvist et al. 2019; O'Connor et al., 2023). A systematic review of CDIO knowledge library publications (2010–2020) by O'Connor et al. (2023) shows that most work focuses on implementation, with comparatively few evidence-based studies. The authors call for more evidence-based research and cross-institutional collaboration to strengthen CDIO's long-term impact. Regarding impact, Pick et al. (2021) examined alumni who graduated before and after CDIO implementation. Their study found perceived improvements in teamwork, communication and design skills, while also noting that further development is needed in other competencies. Implementing CDIO at the programme level requires significant effort, coordination among stakeholders and often involves curricular restructuring (González et al., 2019).

Taken together, the CDIO Syllabus serves both as an orientation tool and a design resource. For institutions beginning to engage with competency-based engineering education, it offers a coherent, structured overview of the full landscape of skills 21st-century engineers require.

3.6 UK-SPEC

In the United Kingdom, public, employers, and government trust in the engineering profession is formally upheld by a key regulatory standard: *The Standard for Professional Engineering Competence and Commitment* (UK-SPEC) (Engineering Council, 2020). Published by the Engineering Council (EC), which operates under a Royal Charter conferring it legal jurisdiction, the standard proposes a benchmark of competency against which professional engineers are formally assessed. The

Engineering Council maintains a national register of these engineers and technicians and is active in international agreements such as the Washington Accord to ensure that UK engineers are recognised globally.

The process for attaining professional registration involves a peer review consisting of a portfolio of evidence and interviews. This is undertaken by Professional Engineering Institutions (PEIs) licensed by the Engineering Council, such as the Institution of Mechanical Engineers (IMechE) and the Institution of Engineering and Technology (IET). Successful professional registration entitles engineers to use one of three protected titles that signify their level of competency and responsibility: the first tier consists of Engineering Technicians (EngTech), the middle tier consists of Incorporated Engineers (IEng), and the highest tier is the Chartered Engineer (CEng).

The UK-SPEC framework itself is defined by five broad competency areas that applicants must demonstrate. These are: Knowledge and Understanding; Design, Development and Solving Engineering Problems; Responsibility, Management and Leadership; Communication and Interpersonal Skills, and Professional Commitment. Each registration level requires the applicant to meet specific sub-competencies under each area.

The influence of UK-SPEC includes this handbook's structure. The book's three themes, Responsibility, Project Management and Leadership; Communication and Interpersonal Skills; and Professional Commitment and Lifelong Learning, are developed from the Chartered Engineer Standard listed in the UK-SPEC.

As a regulatory standard, a key distinction of UK-SPEC is that it is not expected to directly shape learning processes, in contrast to educational frameworks such as CDIO. Primarily, it serves as a mechanism via which engineers demonstrate that they are worthy of the trust that society places in the engineering profession to regulate itself.

Despite this apparent distinction, UK-SPEC in fact strongly influences and shapes engineering education via the Accreditation of Higher Education Programmes (AHEP) standard (currently AHEP4) (Engineering Council, 2020), which is published by the EC in tandem with UK-SPEC. This translates the competency requirements defined in UK-SPEC into a set of criteria that engineering programmes should meet, akin to EUR-ACE accreditation standards. For more information on accreditation, see Chapter 1.4.

Viewed in a wider context, as observed by Gonzalez (2025), UK-SPEC exemplifies a regulatory philosophy rooted in the UK's historical traditions of standards and external accountability. From this perspective, UK-SPEC can be envisioned as an example of how a national regulatory framework might shape its country's engineering education and distinguishes it from other countries.

4 Summary

This chapter offers engineering education practitioners an entry point into the vast landscape of competency frameworks. We began by distinguishing taxonomies, which classify and organise competencies, from competency frameworks, which add structure, progression, and guidance for educational action, positioning the two as ends of a spectrum of utility rather than discrete categories.

Three guiding questions were proposed to help you evaluate any given resource: what its primary goal is, the areas in which it provides guidance, and how actionable it is. These questions were then applied to six contemporary frameworks of relevance to engineering education in Europe and beyond: EntreComp, DigComp, GreenComp, EUR-ACE, the CDIO Syllabus, and UK-SPEC. The selected examples therefore represent different purposes and levels of application, ranging from broad European competency frameworks to accreditation standards and engineering-specific educational approaches. The chapter does not prescribe a single solution but instead emphasises that frameworks should be understood as orientation tools whose effective use is frequently enhanced through derivative works that provide contextual adaptation, critical reflection on purpose, and alignment with institutional needs.

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