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The Definition of Competency and Skills in an International Context

Sofie Craps[a], Helena Kovacs[b], Roger Hadgraft[c], Roger Penlington[d], and Anette Kolmos[e]

[a] KU Leuven, Belgium, ORCID: 0000-0003-2790-2218;
[b] EPFL, Switzerland, ORCID: 0000-0003-2183-842X;
[c] University of Technology Sydney, Australia, ORCID: 0000-0002-0480-7456;
[d] University of Northumbria, United Kingdom, ORCID: 0000-0002-5928-0145;
[e] Aalborg University, Denmark, ORCID: 0000-0002-0186-2839.

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The concepts of competencies and skills in engineering education are widely used yet inconsistently defined across regions, disciplines, and policy frameworks. This chapter explores the semantic, historical, political, cultural, and research dimensions of competencies, with a particular focus on Europe, while situating developments within a global context. It begins by tracing the utilitarian roots of competencies in psychology and vocational education, followed by an analysis of how supranational initiatives such as the Bologna Process, ENAEE, ABET, and CDIO have shaped their institutionalisation. The chapter then examines the broadening scope of competencies to include transferable skills, driven by globalisation, digitalisation, and pedagogical innovation. Regional and cultural diversity is shown to influence both terminology and enactment, complicating efforts toward harmonisation. Educational research reveals persistent conceptual ambiguity and methodological fragmentation, further challenging coherence. Through critical reflection, the chapter argues that competencies must be understood as a dynamic, context-dependent construct. Rather than seeking uniformity, engineering education should embrace plural definitions and foster reflexivity, transparency, and intercultural sensitivity. In doing so, it can prepare graduates for meaningful engagement in a complex and interconnected world.

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1 Introduction: What's in a name? The semantic puzzle

The meaning of *competencies* and *skills* in engineering education has long been a subject of debate. Terms such as *competence, competency*, *skills*, *attributes*, and *capabilities* are often used interchangeably, yet they are not synonymous. Each term has distinct historical origins, theoretical foundations, and cultural connotations (Guerrero & De los Ríos, 2012; Le Deist & Winterton, 2005; Westera, 2001). Because these differences guide how we design learning outcomes, interpret accreditation expectations, and communicate expectations to students or employers, the terminology we use matters. Ambiguity can create misalignment between what is taught, what is assessed, and what students believe matters for their professional development (Passow & Passow, 2017; Suleman, 2018).

Across Europe, educational systems prioritise different traditions and values, which contributes to variation in how competencies are conceptualised and enacted. While the Bologna Process and the European Qualifications Framework (EQF) provide shared descriptors, countries interpret these in different ways (Europass, n.d.). In German-speaking contexts, *Kompetenz* is often associated with demonstrated performance in authentic situations (Glaesser, 2018), whereas Nordic traditions frame competencies more holistically, integrating knowledge, skills, and attitudes within broader pedagogical models (Crawley et al., 2014; Le Deist & Winterton, 2005). In the UK and Ireland, the discourse of graduate attributes and employability shapes how competencies are described, resulting in a more labour-market oriented vocabulary (Kaasa et al., 2014; Passow & Passow, 2017). These contrasts illustrate that competencies terminology is not neutral: it reflects underlying assumptions about what engineering education is for and what engineers should become. Understanding these differences helps you to make intentional decisions about defining, teaching, and assessing competencies in your own context. Clear terminology strengthens programme coherence, supports collaboration across teaching teams, and helps students articulate their abilities to diverse audiences.

This chapter examines competencies terminology from multiple perspectives. Section 2 traces its historical and conceptual evolution. Section 3 reviews political and policy frameworks shaping contemporary definitions. Section 4 discusses the broadening of competencies from technical to transferable dimensions. Section 5 analyses regional, linguistic, and cultural interpretations. Section 6 examines how competencies terminology is used within engineering education research. Section 7 synthesises these insights and reflects on why definitions matter for educational design and professional practice.

2 A historical and conceptual evolution

Understanding how the concept of competencies has evolved helps you make sense of today's diverse terminology. Although competency as a concept is now widely used across engineering education, its meaning is rooted in different academic traditions that developed over time. These origins continue to influence how competencies are framed in contemporary curricula and research.

Early theoretical work in psychology laid the foundation for the term. White (1959) introduced the notion of competence as an individual's ability to interact effectively with the environment, emphasising intrinsic motivation and adaptation. McClelland (1973) later argued that *competencies* were better predictors of occupational success than intelligence, shifting the focus from innate ability to observable performance in real contexts. These early definitions positioned competencies as something that can be demonstrated through behaviour rather than inferred from abstract measures of ability.

In vocational and professional education, competencies became associated with the ability to perform specific tasks to an expected standard (Eraut, 1994). This tradition, strongly shaped by industrial labour needs, emphasised observable skills, procedural knowledge, and measurable performance, often linked to workplace requirements. While this behaviourist orientation aligned with contemporary needs for efficiency and standardisation, it also contributed to what Westera (2001) later described as a "*confusion of tongues*," as different sectors and disciplines adopted the term in divergent ways.

In its early European form, engineering education emerged with a strongly utilitarian mission. France's *École Nationale des Ponts et Chaussées* (1747) was established to train civil engineers for large-scale infrastructural and urbanisation projects (Miller, 2013). In the United States, the *U.S. Military Academy at West Point* (1802) linked engineering education closely to military and nation-building priorities, preparing engineers for roles in the Army Corps of Engineers (Zelbo, 2023). During the World Wars, engineering expertise became a strategic asset, prompting critical reflections on the risks of producing technically skilled but ethically unreflective professionals; Adorno (1971) famously warned against education that cultivated technical compliance without moral agency. For much of the twentieth century, competencies meant technical mastery, a view reinforced during the Cold War and space race. These examples illustrate how conceptions of competencies have been historically shaped by the socio-political purposes engineering education was expected to serve.

By the late twentieth century, socio-economic and educational changes broadened the concept. Influenced by globalisation, technological change, and lifelong learning agendas, competencies came to include not only knowledge and skills but also attitudes, values, and behaviours (Barrick, 2017; Boyatzis, 1982; Kearns et al., 2016). This more holistic interpretation gained prominence in professional fields, where complex problem solving, ethical judgement, and collaboration became essential expectations for graduates.

Engineering education responded to these broader shifts. The rise of project-based and problem-based learning provided environments in which students could practise collaboration, communication, and reflective judgement alongside technical work (Boelt et al., 2022; Hadgraft & Kolmos, 2020). As engineering roles diversified, competencies expanded to encompass cognitive, interpersonal, and intrapersonal dimensions (Cruz et al., 2020; Male, 2010). Expectations for engineers to address sustainability challenges, digital transformation, and sociotechnical complexity further reinforced this multidimensional understanding (Hadgraft & Kolmos, 2020; Jørgensen & Valderrama, 2016).

This historical layering explains why contemporary frameworks mix behavioural, cognitive, interpersonal, and ethical dimensions. These conceptual trajectories form the backdrop against which policy frameworks and accreditation logics have further institutionalised particular interpretations of competencies — an evolution explored in the next section.

3 Competencies in the political agendas

The conceptual evolution of competencies has increasingly intersected with political agendas and international quality assurance mechanisms. Over the past three decades, policy frameworks and accreditation systems have played a central role in institutionalising competencies, shaping how you are expected to formulate learning outcomes, design curricula, and align programmes with broader policy goals. These frameworks translate broad ideas about competencies into formal descriptors used across higher education systems.

A major turning point was the Bologna Process (1999), which aimed to harmonise degree structures across Europe and placed learning outcomes at the centre of transparency, mobility, and comparability. By requiring qualifications to be expressed in terms of what graduates should know and be able to do, Bologna brought competencies to the foreground of curriculum design (Bologna Declaration, 1999; Maffioli & Augusti, 2003). Building on this foundation, the EQF (Europass, n.d.) introduced a shared structure organised around *knowledge, skills, and competences*, offering a common reference point while still allowing national interpretations.

In engineering education specifically, these policy principles were operationalised through the EUR-ACE Framework Standards and Guidelines, administered by the European Network for Accreditation of Engineering Education (ENAEE). EUR-ACE (2024) defines expected programme outcomes across technical, analytical, interpersonal, and ethical domains, including teamwork, communication, sustainability awareness, and project management — thus influencing how you should describe, teach, practice and assess competencies within your programme.

At the global level, the International Engineering Alliance (IEA) coordinates multilateral agreements — such as the Washington, Sydney, and Dublin Accords — which have contributed to a common vocabulary for describing what engineering graduates should know and be able to do across different education systems. These accords support international comparability of engineering programmes, enabling graduates from accredited programmes to be recognised across participating jurisdictions (IEA, n.d.).

In the United States, ABET's shift in the late 1990s toward outcomes-based accreditation formalised competencies in terms of demonstrable learning outcomes, a movement that influenced global discussions about articulating graduate expectations (Shuman et al., 2005). In Europe, the EUR-ACE Framework — developed within the

Bologna and EQF context — was formulated to be compatible with the IEA Graduate Attributes, ensuring that the competencies language used in European engineering programmes aligns with internationally recognised outcome descriptions.

At roughly the same time as ABET's reform, the CDIO Initiative (Conceive-Design-Implement-Operate), originating at Massachusetts Institute of Technology (MIT) and co-developed with Swedish partner universities, introduced a new engineering curriculum model integrating technical foundations with personal, interpersonal, and professional competencies. CDIO embedded transferable competencies such as teamwork, ethics, communication, and design skills within authentic project-based learning approaches (Crawley et al., 2014). Its influence expanded globally, reinforcing the growing international movement toward competencies-oriented engineering education.

Complementary initiatives outside engineering have further shaped the broader discourse on competencies.

- The OECD's Definition and Selection of Competencies project (DeSeCo), initiated in the late 1990s, introduced influential definitions of *key competencies* for participation in the knowledge society, contributing to the adoption of transversal competencies language in European policy contexts (Rychen, 2019).
- ESCO (European Skills, Competencies, Qualifications and Occupations) (2022), launched in 2010, developed multilingual classifications of skills and competencies to link educational descriptors to labour-market needs, and its taxonomy continues to inform discussions on terminology.
- UNICEF (2019, 2022) highlighted transferable competencies like critical thinking, adaptability, and collaboration, which support civic, social, and professional engagement.
- UNESCO (2021) emphasised core competencies for sustainable development, including systems thinking, anticipatory reasoning, and ethical awareness.

Although these frameworks differ in purpose, scale, and vocabulary, they collectively signal a broadening of competency expectations — from technical proficiency alone to behaviour, judgement, collaboration, and societal responsibility — and influence the broader policy environment in which engineering education operates.

Despite their value, policy-driven frameworks are not without criticism. First, competencies risk being reduced to checklists if adopted superficially, encouraging compliance rather than genuine curricular integration and neglecting their developmental and contextual nature (Cruz et al., 2020). Second, overlapping frameworks can create terminological redundancy or conceptual ambiguity if their conceptual underpinnings are not made explicit (Guerrero & De los Ríos, 2012). Third, an overemphasis on employability risks narrowing the mission of engineering education, sidelining ethical and societal responsibilities (van der Vleuten, 2015). For you, this means you need to engage with frameworks critically to ensure that competencies serve educational purposes rather than bureaucratic ones.

In sum, political frameworks, international agreements, and engineering-specific initiatives have transformed competencies from a loosely defined idea into a formal organising principle of engineering education across Europe and beyond. This institutionalisation has broadened competency expectations from technical expertise to include interpersonal, ethical, and sustainability-related dimensions. The next section explores this widening scope and its implications for teaching and assessment.

4 From technical to transferable: broadening the scope

Engineering education has long been associated with strong foundations in mathematics, physics, and disciplinary knowledge. Historically, competencies were primarily defined in technical terms, emphasising analytical proficiency and the ability to apply scientific principles to well-structured engineering problems. However, as discussed in earlier sections, the scope of competencies has broadened significantly in recent decades, reflecting changes in engineering practice, labour market expectations, and societal priorities.

Several factors have driven this shift. A key driver has been the increasing complexity of engineering work. Globalisation has intensified the need for engineers who can collaborate across cultural, disciplinary, and organisational boundaries, while rapid technological development and digitalisation demand continual learning and adaptation (Hadgraft & Kolmos, 2020; Leslie, 2016; Van Maele et al., 2013). Sustainability challenges call for systems thinking, ethical reasoning, and the capacity to work with multiple stakeholders on value-laden problems (UNESCO, 2021). Together, these developments have reframed engineering competencies as a multidimensional construct that extends beyond technical expertise to include interpersonal, intrapersonal, and societal dimensions.

Importantly, the distinction between technical and transferable competencies is not absolute. Many competencies, such as problem-solving or design thinking, combine disciplinary knowledge with interpersonal, intrapersonal, and contextual dimensions (Hadgraft & Kolmos, 2020; Male, 2010; Passow & Passow, 2017; UNESCO, 2021), making them inseparable from professional practice.

This broadening has significant implications for pedagogy. Technical competencies are typically domain-specific and traditionally assessed through examinations, laboratory work, or design tasks that test students' ability to apply theoretical knowledge. Transferable competencies, by contrast, are cross-cutting and require integrative, experiential, and often collaborative learning approaches. Consequently, traditional lecture-based instruction is increasingly supplemented or replaced by active, student-centred learning approaches such as project-based learning (PjBL), problem-based learning (PBL), and work-integrated learning (WIL). PBL, for example, enables students to collaborate, manage time and resources, communicate with stakeholders, and reflect on their learning — mirroring real-world engineering practice (Boelt et al., 2022).

Despite this progress, challenges persist. Terminological ambiguity continues to exist, with terms such as *generic*, *soft*, *non-technical*, *21st-century*, *professional*, and *transversal* competencies often used interchangeably despite subtle differences (Kearns et al., 2016; Knipprath & De Ryck, 2013; UNICEF, 2019). This ambiguity can complicate communication between educators and between educators and students. Another risk is treating transferable competencies as add-ons or secondary elements rather than integral to engineering curricula. Meaningful integration requires explicit alignment of learning outcomes, teaching strategies, and assessment, ensuring that transferable competencies are developed progressively and intentionally rather than incidentally (Boelt et al., 2022; Cruz et al., 2020; Shuman et al., 2005).

Finally, the growing prominence of transferable competencies raises fundamental questions about the purpose of engineering education. Should its primary aim be to ensure employability, equipping graduates with the competencies demanded by contemporary labour markets? Or should programmes aim to cultivate reflective professionals capable of contributing to sustainable and just societies? This tension echoes broader debates in education (Biesta, 2009). These goals are not mutually exclusive but require careful balancing to avoid narrow interpretations of competencies that prioritise short-term labour-market needs at the expense of broader professional and societal responsibilities. A competency-based approach can support this balance when framed critically and reflexively, moving beyond checklists to embrace the dynamic, developmental, and context-dependent nature of engineering competencies (Craps et al., 2021; Cruz et al., 2020). This handbook provides you with a series of concrete examples on how you can do this.

5 Regional, linguistic, and cultural contexts: a patchwork of terms

Competency terminology does not travel neutrally across regions. Different linguistic traditions, educational histories, and cultural expectations shape how competencies are understood, enacted, and valued (Kaasa et al., 2014; Le Deist & Winterton, 2005). As engineering programmes increasingly operate in international and intercultural environments, understanding these variations becomes essential for curriculum designers and educators supporting diverse student cohorts.

A first source of variation lies in language itself. Multilingual classification systems such as DISCO (European Dictionary of Skills and Competencies) illustrate how several European languages use a single term to refer to *competence*, *competency*, and *skill*, making distinctions less explicit than in English (DISCO, 2022; Guerrero & De los Ríos, 2012). This linguistic overlap means that similar words may refer to broader or narrower constructs depending on local usage.

To illustrate, we briefly explore the terminology in the authors' regions. In French, *compétence* can refer to both jurisdictional authority (e.g., legal competence) and personal or professional ability. However, a distinction exists between *compétence* and *capacité*, reflecting deeper institutional traditions: the former is linked to measurable ability, the latter to potential — differences that influence how transferable and technical competencies are formulated in curricula (Keating, 2004). In German, there is a clearer distinction between *Kompetenz* (integrated competency) and *Fähigkeit* (ability or skill). In Danish, *kompetence* is framed more holistically, integrating knowledge, skills, and attitudes within collaborative and student-centred pedagogies such as CDIO (Crawley et al., 2014), and is contrasted with *dygtighed* or *færdighed* (concrete skills). In Dutch, *bekwaamheid* (a professionally recognised qualification, e.g., a teaching certification) differs from *competentie* (broader educational capability) and *vaardigheid* (concrete skill).

These linguistic subtleties reflect deeper assumptions about learning and professional formation. A competency framed as *habitual* in one linguistic tradition may imply automatic or routine behaviour, whereas in another it may signal adaptive expertise developed through reflective practice. Such nuances influence how educators frame expectations and how students understand what is being assessed.

Cultural norms also shape how competencies are enacted. For example, communication competency varies across cultural settings. In German contexts, engineering communication values precision and explicitness, whereas English-speaking traditions emphasise audience adaptation and clarity of structure, and some Southern European styles place greater emphasis on relational and contextual meaning (Joo, 2024; Kaasa et al., 2014). East Asian teamwork may foreground group harmony and hierarchical sensitivity, with indirect communication strategies and a strong emphasis on cohesion (Hofstede et al., 2010).

As a consequence, a student who appears assertive in one context may be judged as confrontational in another. Similarly, a student who communicates indirectly may be perceived as diplomatic in one culture but insufficiently clear in another. These differences complicate assessment, as criteria developed in one cultural framework may not fully capture competency as enacted elsewhere. Example 1 further illustrates two different ways of looking at teamwork and how these cultural variation show in assessment rubrics.

Example 1. Cultural variation in teamwork and its implications for assessment

Engineering teamwork is universal, but how teamwork is enacted and assessed varies across cultural regions (Hofstede et al., 2010). The following two examples show that understanding these differences helps educators recognise why students may demonstrate competencies differently, and why rubrics need cultural sensitivity.

Nordic countries: teamwork as egalitarian collaboration

- *Nordic cultures place a strong emphasis on equality, low hierarchy, consensus building, and shared responsibility, shaping teamwork as a flat, co-constructed process.*
- *A typical rubric emphasises balanced participation, co-decision making, rotating leadership, consensus orientation.*

German-speaking countries: teamwork as a structured coordination

- *German workplaces value direct, clear, structured communication with strong expectations for punctuality, planning, and accountability — traits that translate into a structured framework.*

- *A typical rubric emphasises role clarity, reliability, advancing planning, task ownership, and explicit documentation.*

Recognising these cultural patterns supports fairer, more informed competency assessment, especially in international classrooms.

A consequence is that graduates trained in one system may struggle to communicate their competencies effectively in another or may find their abilities interpreted differently by employers across cultures (Passow & Passow, 2017). However, at the same time, diversity can be an asset. Exposure to different interpretations of competencies helps students cultivate intercultural adaptability and reflexivity — qualities increasingly valuable in global engineering practice.

Beyond Europe, global variations add further layers. In the United States and Australia, competency is often framed through measurable student outcomes, reflecting accountability cultures in higher education (Passow & Passow, 2017). Beyond the framing and perception of competencies, different competencies are prioritised across other regions. For example, engineering programmes in parts of Latin America foreground social justice and community engagement, while some East Asian systems prioritise technological competitiveness and coordinated industrial advancement, influencing expectations for innovation-oriented and systems-thinking competencies (UNESCO, 2021).

Taken together, these examples show that competencies are both multidimensional and culturally situated. Definitions may appear aligned on paper, yet their meanings, expectations, and behavioural expressions vary widely across linguistic and cultural contexts. This underlines the situated nature of competencies: they cannot be fully divorced from the cultural rules that shape professional interaction. Understanding these variations supports more inclusive curriculum design, more nuanced assessment, and more effective communication with international students and partners. It also prepares graduates to navigate the culturally diverse settings in which contemporary engineering practice unfolds.

6 Terminology in engineering education research

Engineering education research has played a central role in shaping how competencies are understood, investigated, and applied in curriculum and assessment practices. While previous sections traced the historical, political, and regional origins of competency terminology, this section explains how research traditions, methods, and assessment studies shape what we learn about competencies in engineering education. The field has become increasingly interdisciplinary, and over the last decade converges on a view of competencies as integrative, situated, and sociotechnically aligned with the realities of contemporary engineering work.

6.1 Interdisciplinary origins and their impact on terminology

Competency research in engineering education draws on multiple disciplinary traditions, and each brings its own assumptions, constructs, and terminology.

Psychology and learning sciences conceptualised competencies as behavioural effectiveness, with measurable individual attributes (e.g., White's (1959) motivation-based competence and McClelland's (1973) testing "*competence rather than intelligence*"). This tradition informs many measurement instruments and behavioural rubrics used in engineering education.

Vocational and pedagogical traditions introduced holistic and practice-based interpretations, emphasising the integration of knowledge, skills, and values in authentic contexts (Eraut, 1994). The 'competency movement' in HR and management focused on job performance and observable standards with workplace validity (Boyatzis, 1982). More recent policy studies broadened the notion of competencies as societal contributions and key competencies for life and work (e.g., OECD's DeSeCo), a lens that later influenced many engineering education framings of transversal or transferable competencies. The notion of competencies as sociotechnical constructs stems from sociology and science & technology studies.

Because these traditions co-exist, the literature uses the partially overlapping terms *competence, competency, capability*, *readiness,* and *dispositions,* which often carry different meanings across studies, depending on the theoretical lens adopted (Kearns et al., 2016). For example, *capability* is often used in educational contexts to emphasise potential and adaptability, while *readiness* is more common in workforce development literature. The influence of these external disciplines is evident in the way competencies are framed. Some strands present competencies as static lists of attributes, while others view them as dynamic, context-dependent constructs that evolve over time and reflect complex professional judgement (Craps et al., 2021; Cruz et al., 2020; Male, 2010).

These conceptual differences or underlying assumptions are often not fully acknowledged in engineering education research.

6.2 Competency domains in engineering education research

A scan of leading journals in the field, such as the Journal of Engineering Education (JEE), the European Journal of Engineering Education (EJEE), IEEE Transactions on Education (ToE), and the Australasian Journal of Engineering Education (AJEE), shows recurring domains rather than a single definition. Researchers examine competencies in relation to programme aims and study contexts and pedagogy, which explains the diversity but also the fragmentation. For an overview of measurement and definition issues, see the systematic review by Cruz et al., (2020).

A first prominent domain focuses on *generic* or *transferable competencies* — skills that are considered essential across all engineering disciplines and professional contexts. Male (2010, p.41), for example, defines generic engineering competencies as "*knowledge, skills, attitudes and dispositions that are important across all areas of engineering, and facilitate the success of engineers as individuals and their contributions as engineers to a well-functioning society"*. These include communication, teamwork, ethical reasoning, and lifelong learning competencies. Literature increasingly recommends embedding these competencies in disciplinary learning rather than treating them as add-ons (e.g., through design reviews, project reports, or client presentations).

Second, *employability-oriented competencies* are often framed in terms of the transition from education to work. Studies in this area emphasise problem solving, teamwork, communication, and critical thinking as key attributes valued by employers (EbrahimNejad, 2017; Fleming et al., 2024). Passow and Passow (2017) conducted a systematic review of employer surveys and identified problem solving as one of the most frequently cited competencies, particularly when it is integrated with technical knowledge. However, Lutz and Paretti (2021) caution that employability is context-dependent, shaped by organisational cultures and job roles. They argue that it is difficult to define a universal set of employability competencies, and that educational programmes must be responsive to local and sector-specific needs. In line with this, Craps et al. (2021) found that competencies vary according to the job role.

Finally, research also expanded toward *sustainability-related* and *sociotechnical competencies*. Research following frameworks like UNESCO (2021) highlights systems thinking, anticipatory and normative reasoning, stakeholder engagement, and ethical judgement as emerging core expectations. Studies now investigate how to weave these into mainstream engineering modules (e.g., thermodynamics, mechanics) rather than isolating them in electives (Desha et al., 2019; Gonçalves Quelhas et al., 2019). These emerging domains reflect shifting societal expectations of engineers and highlight the increasing need for sociotechnical competencies.

Across these thematic domains, research indicates that competency development benefits from student-centred, practice-based environments, such as problem- and project-based learning, design-implement experiences, and work-integrated learning, because they supply the authentic contexts where integration, judgement, and collaboration are visible (Boelt et al., 2022).

6.3 Methodological challenges in competency research

Terminological inconsistency creates substantial methodological challenges for research. Operationalisation varies widely. A systematic review of competency methods in engineering education found significant inconsistencies in how frameworks were selected, justified, and applied (Cruz et al., 2020). Many studies fail to explain how competency constructs were derived or to justify their alignment with theoretical assumptions, resulting in weak construct specification (Carthy et al., 2019; Suleman, 2018).

A further challenge lies in the overreliance on self-report measures, which are easy to administer but often poor proxies for enacted competency, and restrict comparability across contexts (Carthy et al., 2019). A meta-analysis of professional-skills studies found that many instruments collapse complex constructs into single Likert-scale items (e.g., 'rate your teamwork skills from 1 to 5'), limiting interpretability and making cross-study comparison difficult (Carthy et al., 2019). Such oversimplification reflects deeper divergences between behavioural, holistic, and developmental understandings of competencies and results in inconsistent measurement choices across the literature.

These issues indicate the need for greater conceptual transparency, stronger theoretical justification for operationalisation choices, and multi-method designs that acknowledge the integrative and situated nature of competencies highlighted in contemporary scholarship (Cruz et al., 2020). This call provides the foundation for more coherent, context-sensitive assessment approaches.

6.4 Assessing competencies: persistent challenges and emerging directions

Assessing competencies remains a central difficulty in engineering education research because the complexity and situated nature of competencies are hard to capture with standardised tools. As noted in the previous section, inconsistencies in conceptualisation translate directly into measurement problems. Many studies rely on self-report surveys or analytic rubrics, which offer scalability but often fail to represent how competencies are enacted in authentic settings (Carthy et al., 2019; Suleman, 2018). Simplified indicators, such as single-item ratings of teamwork or communication, are common but restrict comparability across contexts (Lutz & Paretti, 2021). Systematic reviews likewise show that many assessment instruments lack explicit theoretical grounding or justification for operationalisation choices (Cruz et al., 2020).

Qualitative approaches provide richer insight into competencies as situated performance. Interviews, reflective journals, and ethnographic observations reveal how students make decisions, negotiate roles, integrate prior knowledge, and respond to uncertainty. Yet these methods have limitations: they are labour-intensive, difficult to scale, and challenging to standardise without compromising depth (Suleman, 2018). The contrast between scalable but reductive quantitative tools and insightful but resource-intensive qualitative approaches highlights a central methodological tension in competency assessment.

Recent research therefore explores hybrid or innovative approaches. Situational judgement tests (SJTs), for instance, probe professional and sociotechnical reasoning more authentically, though concerns remain regarding contextual validity and transferability (Carthy et al., 2022). Performance-based assessments, such as design reviews or integrated sociotechnical cases, offer higher ecological validity but face challenges of assessor training, reliability, and feasibility at a larger scale.

Across studies, the shared conclusion is that competency assessment requires a multi-method, developmental approach, integrating behavioural evidence, reflective judgement, and performance in authentic tasks (Cruz et al., 2020). Moving forward calls for greater reflexivity, transparency, and interdisciplinary dialogue to build a more coherent and inclusive understanding of competencies and what it means to be a competent engineer in a complex and changing world (Phillips et al., 2024).

7 Why definitions matter: critical reflection and future directions

Competencies are not fixed or universal constructs. Across this chapter, competencies emerged as a historically layered, politically situated, culturally embedded, and research-contested concept. This multiplicity is not a weakness, but a reflection of the many different purposes which competencies serve in engineering education – from curriculum design and assessment to shaping the identities of future engineers and supporting educational and professional mobility. This section synthesises these insights and considers how emerging developments may further shape competency terminology in the years ahead.

7.1 Critical reflection: navigating persistent tensions

A first tension concerns the gap between *formal definitions* and *situated meaning*. While broadly used frameworks, such as the EQF, EUR-ACE, the IEA Graduate Attributes, and ABET's outcomes, provide stability, they inevitably condense complex professional behaviour into simplified descriptors. In practice, however, competencies are enacted through local pedagogical traditions, disciplinary expectations, and cultural norms. You therefore work with definitions that aim for comparability across systems and simultaneously must be interpreted within specific institutional and cultural settings. This duality is not a flaw of competencies frameworks but a reminder that translation is always required.

This tension highlights the importance of making interpretative choices explicit rather than assuming shared understanding, as summarised below.

Uniform definitions of competencies may be neither possible nor desirable. Instead, engineering education benefits from making differences explicit. Transparency supports:

- Clearer communication within teaching teams,
- More consistent assessment practices,
- Reduced confusion for students,
- Improved collaboration across programmes and institutions,
- Greater mobility and mutual understanding across Europe.

Plural interpretations of competencies allow programmes to reflect their missions while still aligning with broader European and global expectations.

A second tension lies in the *risk of misalignment* between what is stated, what is taught, and what is assessed (Kovacs et al., 2023). If competencies are phrased in broad terms, but operationalised through narrow indicators, students receive mixed messages about what matters. Conversely, if competencies are invoked rhetorically without being intentionally embedded in teaching activities, they become disconnected from practice. For instance, if teamwork is valued, but not explicitly taught or assessed, students may not develop the skills needed to collaborate effectively in professional settings. Misalignment does not stem from a lack of frameworks but from insufficient clarity about how local interpretations relate to programme outcomes. Clear internal articulation helps bridge these gaps.

Related to this is the *risk of reductionism*. Competencies can be flattened into checklists when pressure towards accountability outweighs attention to development. For instance, when '*communication*' is reduced to the ability to write reports, this fails to capture the developmental and cultural richness of communicative practice. While structured rubrics support reliability, they cannot fully capture how judgement, uncertainty, or interdisciplinary negotiation unfold in authentic engineering work (Heywood, 2016). Recognising this limitation encourages you to embrace a more balanced approach: using structured indicators where useful, while also allowing space for professional reasoning and contextual decision making.

A third tension concerns *developmental trajectories*. Early-stage demonstrations of competencies differ significantly from the expectations placed on graduating students (Cruz et al., 2020). For example, a first-year engineering student's problem solving typically involves structured tasks with clear parameters, whereas a master student may be expected to work with ill-structured, ambiguous problems that demand creativity, judgement, and autonomy. However, definitions often present them as static end-states. Without recognising gradual progression or levels of proficiency — from novice to expert — assessment risks either underestimating early learning or overestimating what can reasonably be expected. Making developmental expectations explicit at module and programme levels helps students understand how competencies grow and where they are positioned within that trajectory.

Finally, the chapter has shown that *cultural* and *contextual variation* remains unavoidable. Engineering programmes reflect national and cultural traditions regarding what it means to be an engineer (Lucena et al., 2008). Competency terms that appear aligned across countries often differ in connotation, scope, or behavioural expression (Kaasa et al., 2014; Van Maele et al., 2013). Rather than attempting to erase these differences, productive practice requires acknowledging them and making local meanings explicit. This does not undermine international comparability; instead, it strengthens it by clarifying the assumptions that inform your definitions.

Together, these tensions highlight that competencies should not be treated as a finished product to be consumed, but as a language of design. Their usefulness depends on how well you make visible the interpretive choices behind your definitions and how consistently you translate these into teaching, assessment, and programme communication. Example 2 presents concrete strategies that support educators in putting these ideas into practice.

Example 2. From definitions to practice: strategies for aligning competency development

- Make definitions explicit. *Clearly articulate how you understand key competencies such as teamwork, communication, or problem solving.*
- Align outcomes, teaching, and assessment. *Ensure that what you value in your programme is intentionally taught and meaningfully assessed.*
- Use authentic contexts. *Provide opportunities (e.g., PBL, design projects, reflective assignments) for students to enact competencies in realistic settings.*
- Address cultural variation openly. *Discuss with students how competencies can look different across cultural or disciplinary contexts.*
- Encourage reflection. *Support students in developing awareness of how their competencies evolve over time and across situations.*

7.2 Looking ahead: evolving expectations for competencies

The conceptual tensions above become even more pronounced as engineering practice evolves. As an example of this evolution, we discuss two current developments that stand to reshape how you may define and assess competencies in the coming decade.

The first concerns the deepening integration of *artificial intelligence* and *data-driven tools* in engineering work (Schleiss et al., 2022). As computational processes become partially automated, the emphasis shifts from executing analytical procedures to interrogating algorithmic results, validating data sources, and making informed judgements under uncertainty. These shifts invite you to reconsider how analytical, ethical, and communication competencies are defined. The expectation that engineers can explain, question, and justify decisions informed by AI — rather than simply produce correct outputs — suggests that epistemic and value-laden aspects of competencies will become more prominent.

The second development is the gradual adoption of *modular learning* pathways and *micro-credentials* (Ironsi & Ironsi, 2025). These initiatives promise flexibility but challenge programme coherence: competencies that were once embedded across multi-year curricula must now be recognisable in smaller units of learning. For you, this evolution underscores the need for transparent level descriptors, clear evidence requirements, and cross-referencing with qualification frameworks such as the EQF, so that modular recognition does not dilute the meaning of competencies.

These shifts do not replace traditional competency domains; rather, they expose dimensions that may previously have been implicit, such as algorithmic responsibility, systems thinking, or stakeholder negotiation, and bring them more centrally into definitions and assessment.

7.3 Towards reflexivity and shared awareness

Definitions matter because they influence what is taught, what is assessed, and how students understand their own development. Although competency terminology will continue to evolve, especially under the influence of AI and modular learning, its value lies in how explicitly and coherently you choose to use it. By approaching competencies with conceptual clarity, recognising their contextual nature, and designing learning environments that reflect its integrative character, you can navigate the inherent tensions productively and prepare graduates for a profession that increasingly demands both technical sophistication and sociotechnical judgement.

8 Conclusions

This chapter has examined the contested concepts of competencies and skills in engineering education, with a particular emphasis on Europe, situated in a global perspective. It traced the historical and conceptual evolution of competencies, examined the shift from technical to transferable competencies, and analysed their expression across regional, cultural, and research contexts.

Three insights stand out. First, terminological diversity — across languages, cultures, and research traditions — makes it impossible to arrive at a single, universally valid definition of competencies. Second, developmental trajectories remind us that competencies evolve over time and across roles, meaning that assessment must take progression and context into account. Third, cultural variation highlights that competencies such as communication, initiative, or leadership are expressed differently in different societies, requiring adaptability and intercultural sensitivity from graduates.

The challenge for European engineering education is therefore not to eliminate diversity but to engage with it constructively. Harmonisation efforts such as the Bologna Process and EQF remain valuable, but they cannot and should not erase longstanding differences. Instead, the goal should be to cultivate shared awareness: transparency about definitions, reflexivity about applications, and openness to plurality.

By adopting this stance, Europe can model a forward-looking approach to engineering education that values diversity as a source of strength. In doing so, it can prepare engineering graduates not only for professional mobility within Europe but also for meaningful engagement in a complex, interconnected world.

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During the preparation of this work, the authors used Microsoft Copilot to check for spelling and grammar mistakes and improve coherence in text structure. After using this tool, the authors reviewed, edited and made the content their own as needed and take full responsibility for the content of the publication.

Contributor statement

Conceptualisation	Sofie Craps, Helena Kovacs, Roger Hadgraft, Roger Penlington, Anette Kolmos
Data curation	Sofie Craps
Investigation	Sofie Craps, Roger Hadgraft, Roger Penlington
Methodology	Sofie Craps
Project administration	Sofie Craps
Supervision	Sofie Craps
Writing - original draft	Sofie Craps, Helena Kovacs, Roger Hadgraft, Roger Penlington, Anette Kolmos
Writing - reviewing and editing	Sofie Craps, Helena Kovacs, Roger Hadgraft, Roger Penlington, Anette Kolmos