ENHANCE

European Universities of Technology Alliance

Work Package 4
Future Skills for Engineers and Scientists

SUMMARY SHORT- AND LONG-TERM STRATEGIES FOR FUTURE SKILLS

Written by ENHANCE Work Package 4 Members

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ENHANCE Deliverable 4.1 Summary: Short- and long-term strategies for Future Skills

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Introduction: The Case for a Pedagogical Paradigm Shift

The ENHANCE WP4 Delierable "Short- and Long-Term Strategies for Future Skills" presents a timely and important framework for reconfiguring higher education in engineering and the sciences. Developed by the ENHANCE Alliance and led by TU Delft, this deliverable focuses on defining, evaluating, and operationalising 'future skills'. These are the capacities students must cultivate to act effectively across complex, interdisciplinary, and technology-driven environments.

The premise of the report is rooted in the understanding that engineering education must move beyond technical mastery. As engineers are increasingly expected to engage with systemic sustainability challenges, ethical dilemmas, and digital disruption, higher education institutions must prepare students not merely to adapt to the future, but to shape it. The deliverable argues for a transition from a discipline-centric pedagogical model to one grounded in context, collaboration, and societal engagement.

To this end, the report synthesises a large body of research that includes student and alumni, surveys, expert interviews, and research literature. Based on these, 1) an Emerging Competence Requirements Framework as the basis for rethinking curricular design was produced, as well as 2) a roadmap for institutional change, organised across short- and long-term priorities.

The findings hold significant implications for curriculum leaders, rectors, and other university management seeking to align educational offerings with global and European societal needs.

Defining Future Transferable Competencies

At the core of the report is a conceptualisation of 'future skills'. ENHANCE WP4 group adopts the term "transferable competencies" to reflect abilities that transcend disciplinary boundaries and allow learners to act proficiently in real-world, often uncertain, contexts. These competencies are grouped into four domains: subject-specific, method-specific, social, and personal. However, based on the research findings, the report also integrates the ETH Zurich framework to explicitly address competencies in sustainability and digitalisation, areas increasingly central to engineering practice (see Appendix 1).

Competencies are not framed as isolated skills, but as dynamic and integrative capabilities. Definitions draw from established educational theory (Weinert, Nägele & Stalder, La Cara et al.), and from interviews with thought leaders in engineering education and policy. The resulting framework does not propose a static checklist, but rather a flexible, adaptable structure for embedding meaningful learning into diverse educational environments.

Research Findings: Validation from Stakeholders

The report triangulates findings from three key research groups: current students, recent alumni, and external stakeholders (including industry and academic leadership).

Student surveys from across the Alliance revealed a strong prioritisation of personal and social competencies. Respondents repeatedly emphasised motivation, communication, teamwork, and problem-solving as essential for their future professional lives. These competencies were not perceived as peripheral, but as fundamental tools for leveraging technical expertise within collaborative and adaptive work environments. This insight reflects an emerging student expectation that universities support not only technical formation, but also personal development and self-efficacy.

Through analysis of alumni surveys, we identified significant gaps between their university preparation and the demands of their current roles. Among the most critical gaps were competencies in ethical reasoning, sustainability thinking, and digital fluency. This includes AI awareness and computational modelling. These findings were echoed in industry reports which highlighted the need for transdisciplinary approaches and emphasised systems thinking, circular economy awareness, and digital integration as essential for addressing 'wicked problems' such as climate change, economic transition, and societal resilience.

Finally, semi-structured interviews with European education and industry experts added further qualitative considerations. Interviewees emphasised collaboration, critical thinking, adaptability, and empathy as distinctly human competencies that must be prioritised in curricula, especially as automation and AI alter the landscape of knowledge work. The recurring concern was that while universities often succeed in transmitting knowledge, they fall short in fostering the holistic competencies needed to work across disciplines, cultures, and systems.

Current Practices and Institutional Gaps

The second phase of the report maps current teaching practices within the ENHANCE universities against the ETH Competence Framework. While the analysis reveals a strong tradition of technical education, it also identifies significant shortcomings in the systematic development of transferable competencies.

Subject-specific and method-specific competencies are well covered across the Alliance. Curricula tend to offer robust training in foundational STEM knowledge and analytical methodologies. However, the integration of sustainability and digital literacy remains inconsistent. Most institutions treat these as elective or extracurricular components, rather than embedding them throughout core curricula. Similarly, transdisciplinary learning is often confined to optional projects or short-term initiatives rather than serving as a central organising principle for academic programs.

Social and personal competencies are underrepresented in formal instruction. Although students may acquire such competencies through student organisations, internships, or group work, these experiences are rarely structured or assessed systematically. The report finds that reliance on informal learning not only limits inclusivity (as not all students participate in extracurriculars), but also weakens the ability to monitor and support competency development at scale.

Assessment practices are a further point of concern. Traditional exams continue to dominate, particularly in large foundational courses, even where more authentic assessment (e.g. portfolios, peer review, reflective writing) would be more suitable for measuring competencies like collaboration, ethical reasoning, or leadership. Moreover, academic staff often lack both the training and institutional incentives to innovate pedagogically in these domains.

Challenges at Multiple Scales

The report's interview analysis reveals a complex landscape of structural, cultural, and political challenges that constrain educational reform. These are grouped into three interconnected levels: the educational system, European-level, and global-level.

At the educational level, university systems are described as siloed, slow to change, and constrained by entrenched assessment models and funding regimes. Faculty workloads, reward structures, and governance practices often discourage innovation in teaching, particularly when it concerns competencies perceived as "soft" or outside one's disciplinary expertise. The lack of mechanisms for faculty development in pedagogy further limits progress.

At the European level, the report identifies regulatory divergence, degree recognition challenges, and political uncertainty as major obstacles to cross-border collaboration and mobility. Fragmented policies on digital education, data privacy (e.g., GDPR), and AI regulation were repeatedly cited as barriers to both innovation and institutional partnership. Broader geopolitical instability, including populism and rising nationalism, threatens the collaborative ethos on which alliances like ENHANCE depend.

Globally, interviewees drew attention to AI and automation, climate change, economic inequality, and demographic shifts (e.g., aging populations, migration patterns) as drivers of transformation that universities must urgently address. These "wicked problems" require not just technical solutions, but graduates capable of acting with agility, ethics, and collaborative intelligence across sectors and scales.

Strategic Planning and Institutional Recommendations

In response to the evidence gathered, the WP4 team conducted a SWOT analysis and co-created four institutional strategies via a structured workshop and writing process. These strategies are grouped into short-term and long-term phases.

In the short term (2025–2027), the focus will be on developing flexible, accessible tools to support competency integration. This includes online training programs for both students and teachers covering the human, ecological, and economic dimensions of technology. A modular toolbox of classroom activities ('snippets') will be developed to support in-class development of transversal competencies. These efforts are designed to lower the barrier to entry for educators and provide practical resources that can be easily adapted across contexts.

In the long term (post-2027), the focus shifts to structural curriculum reform and institutional capacity-building. Key initiatives include embedding challenge-based, transdisciplinary, and multicultural learning experiences into core programs. Teacher training will be expanded, with a focus on sustainable entrepreneurship and pedagogies of co-construction and reflexivity. The aim is to create learning ecosystems in which knowledge is not only transmitted but created collaboratively in response to societal needs.

Conclusion: Toward a Future-Ready University

The WP4 report represents an effort to align science and engineering education with the ethical, technological, and ecological imperatives of the 21st century. It argues that transferable competencies are not ancillary to technical knowledge but are central to its effective application. For university leadership, the report issues a call to action: to foster institutions that are not only centers of knowledge production, but also laboratories of democratic practice, sustainable innovation, and collective intelligence.

To realise this vision, universities must invest in faculty development, curricular redesign, and institutional infrastructure that supports interdisciplinary, inclusive, and reflective learning. Competency frameworks, assessment tools, and teaching strategies must be co-developed with students, communities, and industry. And importantly, academic leadership must model the values it seeks to instill: adaptability, collaboration, critical thinking, and a deep sense of social responsibility.

Bibliography

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Weinert, F. E. (2001). Concept of competence: A conceptual clarification. In *Defining and selecting key competencies*. Hogrefe & Huber Publishers.

For the list of sources use in the full D4.1 report, please contact g.penny@tudelft.nl.

Appendix 1

A language comparison between the ETH Competence Framework and Feedback from Alumni, Literature, and Industry Reports.

Table 1

Emerging Competence Requirements Framework.

Competence domains	ETH Competence Framework (La Cara et al., 2023)	Sustainability competencies (Brundiers et al., 2021; Waltner et al., 2019)	Computational and digital competencies (Bocconi et al., 2022; Raspberry Pi, 2020)
Subject-specific competencies Knowledge of theories, concepts, and techniques and its application to specific fields	**Concepts and theories** (ability to understand and apply the basic concepts and definitions that are relevant for a scientific subject or a field)	**Cross-sectoral concepts and theories:** green chemical engineering, sustainable finance and accounting, climate science, circular economy, sustainable procurement, etc.	**Algorithmic thinking** (ability of reaching a solution through a clear definition of steps by breaking a problem into pieces) **Computational modelling** (knowledge of and ability to use Boolean logic)
	Techniques and technologies(ability to understand and apply techniques and technologies in use within a specific scientific subject or field)	**Cross-sectoral techniques and technologies:** Advanced quantitative data analysis, environmental impact assessment, sustainability disclosure and reporting, climate risk modelling, etc.	**Algorithms/programming/automation** (ability to increase human labour efficiency through programmes and machines) **Data and data analysis** (ability to plan data analysis process and store data) **Computing systems and networks** (knowledge and

			practice with hard- and software, cybersecurity, network communication and organisation)
Method-specific competencies Knowledge and application of methods to make sense of, and operate in, any context	**Analytical competencies** (ability to break down processes and systems into parts while understanding their interaction)		**Patterns and generalisation** (ability to identify patterns, similarities and connections) **Abstraction** (ability to choose the right detail to hide so that the problem becomes easier, without losing anything that is important, e.g., by using the right representation system) **Debugging or evaluation** (ability to systematically apply analysis and evaluation to predict and verify outcomes)
	Media and Digital Technologies (ability to access, evaluate, and use media and digital technology)		
	Decision-making (ability to define a decision and a set of alternative actions from which to choose)	**Integrated problem-solving** (ability to combine steps of the sustainability problem-solving process, while drawing on interdisciplinary knowledge)	
	Problem-solving (ability to define a problem and find solutions for it)	**Implementation competency** (ability to realise a planned solution towards a sustainability-informed vision).	**Decomposition** (ability to think about artefacts or problems in terms of their component parts that can be solved, developed, and

			evaluated separately)
	Project Management (ability to manage projects and produce results)		
Social competencies Competencies applied in the interaction with others	**Communication** (ability to communicate with others in different contexts and forms, including languages)	**Interpersonal competency** (ability to apply concepts and methods in ways that engage and motivate diverse stakeholders and empathically work with collaborators' and citizens' different ways of knowing and communication)	
	Cooperation and Teamwork (ability to build relationships with others to pursue common goals and achieve results in a constructive atmosphere)		**Impact of computing – culture and societal interactions** (knowledge of and ability to work with programmes and machines by considering the social and ethical issues around the creation and use of computational products)
	Sensitivity to Diversity (ability to recognise differences among people and work with them)		
	Self-presentation and Social Influence (ability to present an authentic and professional image of self to others and motivate others to the adoption of a specific behaviour)		

	Leadership and Responsibility (ability to motivate and inspire others and support others' achievements)		
	Customer Orientation (ability to approach relationships with others and society in terms of what you have to offer to meet their needs rather than what you need or want)	**Values thinking** (ability to differentiate between intrinsic and extrinsic values in the social and natural world and critically evaluate how particular stated values align with agreed-upon sustainability values)	
	Negotiation (ability to advocate positions with an open mind and try to synthesise ideas from all viewpoints best)		
Personal competencies Competencies concerning self-management in the context of own work	**Adaptability and Flexibility** (ability to adjust effectively to a changing environment and deal well with changes)	**Future thinking** (ability to iterate and continuously refine one's own futures in productive and explicit tension to the status quo, while critically reflecting how assumptions on how society works might influence these future scenarios)	
	Critical Thinking (ability to analyse and evaluate situations and recommend courses of action)	**System thinking** (ability to collectively analyse complex systems across different domains and scales in relation to sustainability issues and problem-solving frameworks)	

	Creative Thinking (ability to produce and implement novel and useful ideas)	**Strategic thinking** (ability to recognize resilience and barriers to change and creatively plan innovative experiments to test strategies)	
	Integrity and Work Ethics (adherence to moral and ethical principles in the conduct of own work and in the relationship with others)		**Impact of computing – culture and social interactions** (knowledge of and ability to work with programmes and machines by considering the social and ethical issues around the creation and use of computational products)
	Self-awareness and Self-reflection (ability to understand own strengths and weaknesses and enhance self-development)		
	Self-direction and Self-management (ability to motivate oneself and organise own work in order to achieve results)		