ENGINEERS 4 EUROPE

E4E

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Results of the 3rd Primary and Secondary Research Round: Inputs to the E4E Skill Strategy

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For more information about the E4E project: E4E website: www.engineers4europe.eu

Contents

1. Introduction.

Digital skills are essential for access to employment and participation in today's society. The European Union has recognized their importance since 2006, including them among the key competencies for lifelong learning. Later, the Digital Competence Framework (DigComp) established five fundamental areas: data literacy, communication and collaboration, content creation, safety, and problem-solving **[Fernandez2025]**.

In 2018, the Council of the European Union's Recommendation expanded the concept of digital competence, defining it as the safe and responsible use of technology in work and education. These skills are becoming increasingly relevant due to digital transformation and labour market automation.

The 2020 European Skills Agenda highlights that more than 90% of jobs require digital skills. In this context, it is crucial that digital competencies be accessible to the entire population, with an emphasis on vocational training and workforce reskilling. Digital transformation demands continuous training, ensuring that professionals can remain competitive in the evolving job market.

2. Situation in Spain and Eur27 (2021-2025)

In the field of digital skills, although Spain started from a relatively advanced position in 2021 within the Digital Economy and Society Index (DESI)—ranking 11th out of the 28 EU countries at the time—it still faced significant challenges in human capital and ICT training, including:

Nearly half of the Spanish population (43%) lacked basic digital skills, and 8% had never used the internet.

The proportion of ICT graduates accounted for only 4% of total graduates, while ICT specialists made up just 3.2% of total employment.

The participation of women specialists in ICT remained stagnant between 2017 and 2021 at around 1% of total female employment.

To address these challenges, Spain has implemented strategies such as *España Digital 2025* and the *National Digital Skills Plan*, aiming to improve the training of citizens and workers. Digital education is key to ensuring employability and adaptation to technological changes.

The *Digital Spain* strategy, established in 2020, identifies four types of digital skills, each targeting a different population group:

- **Basic digital skills**, aimed at the general public.
- **Advanced digital skills**, focused on the active workforce.
- **Specialized digital skills**, designed for professionals in the digital sector.
- **Digital skills in education**, directed at primary, secondary, and non-specialized vocational education students.

The key aspects of each of these four types are detailed in the mind map in Annex I.

To promote the acquisition and improvement of digital skills, the *National Digital Skills Plan* (*PNCD2021*) was adopted in 2021. This plan outlines six strategic objectives:

1. Ensuring digital inclusion.
2. Reducing the digital gender gap by increasing the number of women specialists in ICT.
3. Guaranteeing the digitalization of education and the acquisition of digital skills for teachers and students at all levels of the education system.
4. Ensuring the acquisition of advanced digital skills for both unemployed individuals—improving their employability—and active workers.
5. Ensuring that Spain has enough ICT specialists.
6. Ensuring that Spanish companies, especially SMEs, possess the necessary digital skills for their digital transformation.

To achieve these objectives, seven action lines and sixteen measures have been defined, as outlined in **[PNCD2021]**. Among these, the most relevant for the *Engineers 4. Europe* project are:

Measure 3: Digitalization of education and the development of digital skills for learning.

Measure 4: Training in digital skills throughout working life.

The results of the implementation of this National Digital Skills Plan are shown in Table 1a for Spain and for Eur 27 (average) on table 1b. It can be observed that Spain started from a reasonably good position in all the analysed indicators, which are sourced from Eurostat, specifically from the DESI (Digital Economy and Society Index) reports between 2021 and 2024 **[EUROSTAT2024]**. Note that, from a methodological standpoint, data on various indicators are not collected every year. Table 1.c provides information on the date of data collection for each indicator. When Eurostat does not provide data for a specific year, it is marked as NA (Not available).

In Table 1.a, indicators where Spain is above the European average are highlighted in green, while those below the average are shown in red. Notably, out of the 14 indicators analyzed, Spain is above the average in 9 of them (64%) by the end of the period (2023 or 2024, depending on the indicator).

Table 1a: Digital competences indicators evolution for Spain in period 2021-2024. Source: Own elaboration based on Eurostat

	Spain			
Digital Skills (%)	**2021**	**2022**	**2023**	**2024**
ICT Graduates	4.2	4	4.8	5.2
ICT Specialist	3.9	4.1	4.3	4.4

Entreprises Providing ICT Training	20.1	20.1	20.7	NA
At least Basic Digital Skills	NA	64.16	64.16	66.18
Above Digitl Skills	NA	38.06	38.06	38.65
	Spain			
Digital Transformation of Business (%)	**2021**	**2022**	**2023**	**2024**
SMEs with at least a basic level of digital intensity	NA	59.7	67.5	60.5
Electronic information sharing	41.9	48.2	48.2	53.6
Social Media Ue	28.5	28.5	28.5	37.1
Big Data/ in SME	9	9	9	NA
Data Analytics All	NA	NA	NA	38
Cloud	NA	27	27	26
AI	NA	7.7	7.7	9.2
e-Invoices	32.8	32.8	32.8	40
e-Commerce turnover	11.7	11.5	11.5	9.6

Table 1b: Digital competences indicators evolution for Eur27 in period 2021-2024. Source: Own elaboration based on Eurostat

	EU 27 Average			
Digital Skills (%)	**2021**	**2022**	**2023**	**2024**
ICT Graduates	3.9	3.9	4.2	4.5
ICT Specialist	4.3	4.5	4.6	4.8
Entreprises Providing ICT Training	19.7	19.7	22.4	
At least Basic Digital Skills	NA	53.92	53.92	55.56
Above Digitl Skills	NA	26.46	26.46	27.32
	EU 27 Average			
Digital Transformation of Business (%)	**2021**	**2022**	**2023**	**2024**
SMEs with at least a basic level of digital intensity	NA	54.8	69.1	57.7
Electronic information sharing	34.6	36.7	36.7	42
Social Media Ue	22.4	28.4	28.4	30.6
Big Data/ in SME	14.2	14.2	14.2	NA
Data Analytics All	NA	NA	NA	33.2
Cloud	NA	34	34	37.9
AI	NA	7.6	7.6	8
e-Invoices	33.2	33.2	33.2	38.6
e-Commerce turnover	9.6	9.1	10.2	11.9

Table 1c: Year in which data has been obtained. Source: Own elaboration based on Eurostat

	DESI			
Indicator	**2021**	**2022**	**2023**	**2024**
ICT Graduates	2019	2020	2021	2022
ICT Specialist	2020	2021	2022	2023
Entreprises Providing ICT Training	2020	2020	2022	NA
At least Basic Digital Skills	NA	2021	2021	2023
Above Digitl Skills	NA	2021	2021	2023
SMEs with at least a basic level of digital intensity	NA	2021	2022	2023
Electronic information sharing	2019	2021	2021	2023
Social Media Ue	2019	2021	2021	2023
Big Data/ in SME	2020	2020	2020	NA
Data Analytics All	NA	NA	NA	2023
Cloud	NA	2021	2021	2023
AI	NA	2021	2021	2023
e-Invoices	2020	2020	2020	2023
e-Commerce turnover	2020	2021	2022	2023

3. Digital Skills Demanded by Professional Sector in Spain 2025

In this section, we analyse the most in-demand digital competencies in the business sector. By linking this with the previous section, we can observe whether:

a) The measurements made by administrative entities are aligned with market demands.
b) The degree to which the digital competencies requested by companies are being achieved.

For this study, we have considered the following 12 representative entities that regularly publish reports and white papers on labour market-related topics:

- LinkedIn (Professional social network) **[Linkedin 2024]]**
- Nascor Formación (Lifelong learning) **[Nascor 2023]**
- InfoJobs (Job board company) **[Infojobs2025]**
- Universae (Higher education and lifelong learning) **[Universiae2022]**
- ISDI (Higher education business school) **[ISDI2023]**
- Telefónica (Large tech company) **[Telefónica 2023]**
- Technical and Scientific Park, Castilla-La Mancha (Promoting entity) **[PCyTCLM2025]**
- Asociación para el Progreso de la Dirección (Association) **[APD2020]**
- Universidad Nacional de Educación a Distancia (UNED) (Higher education and lifelong learning**) [UNED 2025]**
- Iberdrola (Large energy and engineering company) **[Iberdrola 2024]**

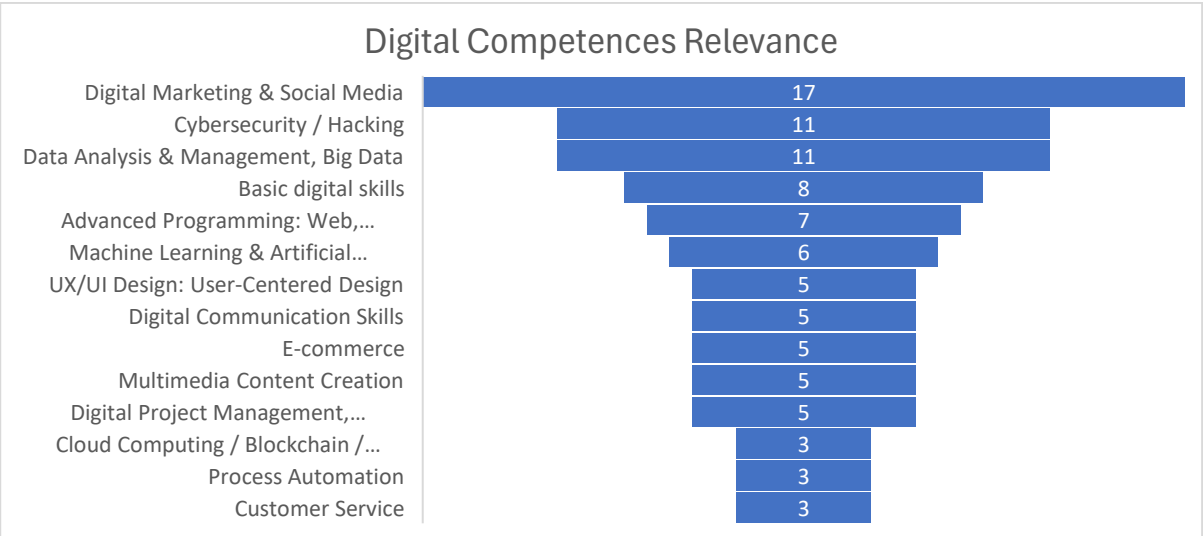
- ESIC (Higher education and lifelong learning) **[MillwardBrow2017]**
- SAGE (Large tech company) **[SAGE2023]**

We collected a total of 94 digital competency records, which were analysed to identify key groupings (clusters)and detect the most relevant ones (the complete set of competences is available on Annex II). Table 2 presents the 14 grouping results, including the number of elements in each group (cluster size), that is, the number of times a specific concept appeared in the total list of 94 competencies.

Table 2: Resulting digital competences grouping.

Cluster ranking	Digital Competence Cluster	Cluster size
1	Digital Marketing & Social Media	17
2	Cybersecurity / Hacking	11
3	Data Analysis & Management, Big Data	11
4	Basic digital competences	8
5	Advanced Programming: Web, Software, VR/AR/XR	7
6	Machine Learning & Artificial Intelligence	6
7	UX/UI Design: User-Centred Design	5
8	Digital Communication Skills	5
9	E-commerce	5
10	Multimedia Content Creation	5
11	Digital Project Management, Innovation, Decision-Making, Information Management	5
12	Cloud Computing / Blockchain / Cryptocurrencies	3
13	Process Automation	3
14	Customer Service	3

Figure 1: Digital competences clustered ordered by cluster size



In the table we have highlighted in green those competencies that may have a high degree of equivalence with those defined by EuroStat and that are presented in Table XX. Setting aside those more related to the level of education or the intensity of use in companies and focusing on specific technological competencies, it can be observed that there is a high degree of similarity. In other words, the information and indicators analysed by EuroStat are relevant and reasonably aligned with the demands of the sector. However, it is worth noting that some of the most in-demand digital competencies in the business sector, such as cybersecurity (ranked 2nd out of 14) or advanced programming (ranked 5th out of 14), are not considered beyond the category of "Above Basic Digital Skills."

Regarding the situation of Spain and Euro 27 in relation to the digital competencies required by companies, Table 3 shows the indicator values for the year 2024.

Table 3: Values from selected indicators from EuroStat for Spain and Eur27

Cluster ID	Digital Competence Cluster	Spain	Eur27
1	Digital Marketing & Social Media	37.1	30.6
3	Data Analysis & Management, Big Data	38	33.2
4	Basic Digital Skills	66.18	55.56
6	Machine Learning & Artificial Intelligence	9.2	8
9	E-commerce	9.6	11.9
12	Cloud Computing / Blockchain / Cryptocurrencies	26	37.9

In general, the acquisition of digital competencies is reasonably good in Digital Marketing & Social Media (Cluster 1), Data Analysis (Cluster 3), and Basic Competencies (Cluster 4). However, it falls far short of adequate levels in key future competencies such as AI, e-commerce, and cloud technologies

4. Conclusions

In this work, we have detailed the main measures taken in Spain for digital training and analyzed the evolution of the digital skills acquisition indicators provided by EuroStat in the period 2021-2024 (post-COVID-19 pandemic period), both for Spain and for the European Union average (EU-27). A survey of 12 entities has also been conducted regarding the most demanded digital skills in the professional sector, and these were compared with those provided by EuroStat. The main conclusions are as follows:

1. The digital training plans in Spain seem to have had a limited impact, considering the evolution of the EuroStat indicators, with positive increases but within a range of 2-5 percentage points over 4 years in most of them.

2. There is a strong correlation between the indicators offered by EuroStat and the skills demanded by companies, which makes these indicators useful when measuring the degree of digitalization of society. However, some indicators related to advanced programming and cybersecurity are missing.
3. It can be observed that in different versions of the DESI documents provided by EuroStat, the date of obtaining the indicators remains unchanged in several of them. For example, the "Big Data" indicator is dated 2020 in the DESI reports for 2021, 2022, and 2023, and has not been updated beyond that year. This limits the ability to draw conclusions for the future.
4. The indicators reflect a positive situation for Spain in most of the indicators, in line with the European situation, but with values above the European average.
5. The indicators related to certain high-impact technologies, both currently and in the near future, such as AI and cloud technologies, show alarmingly low values.

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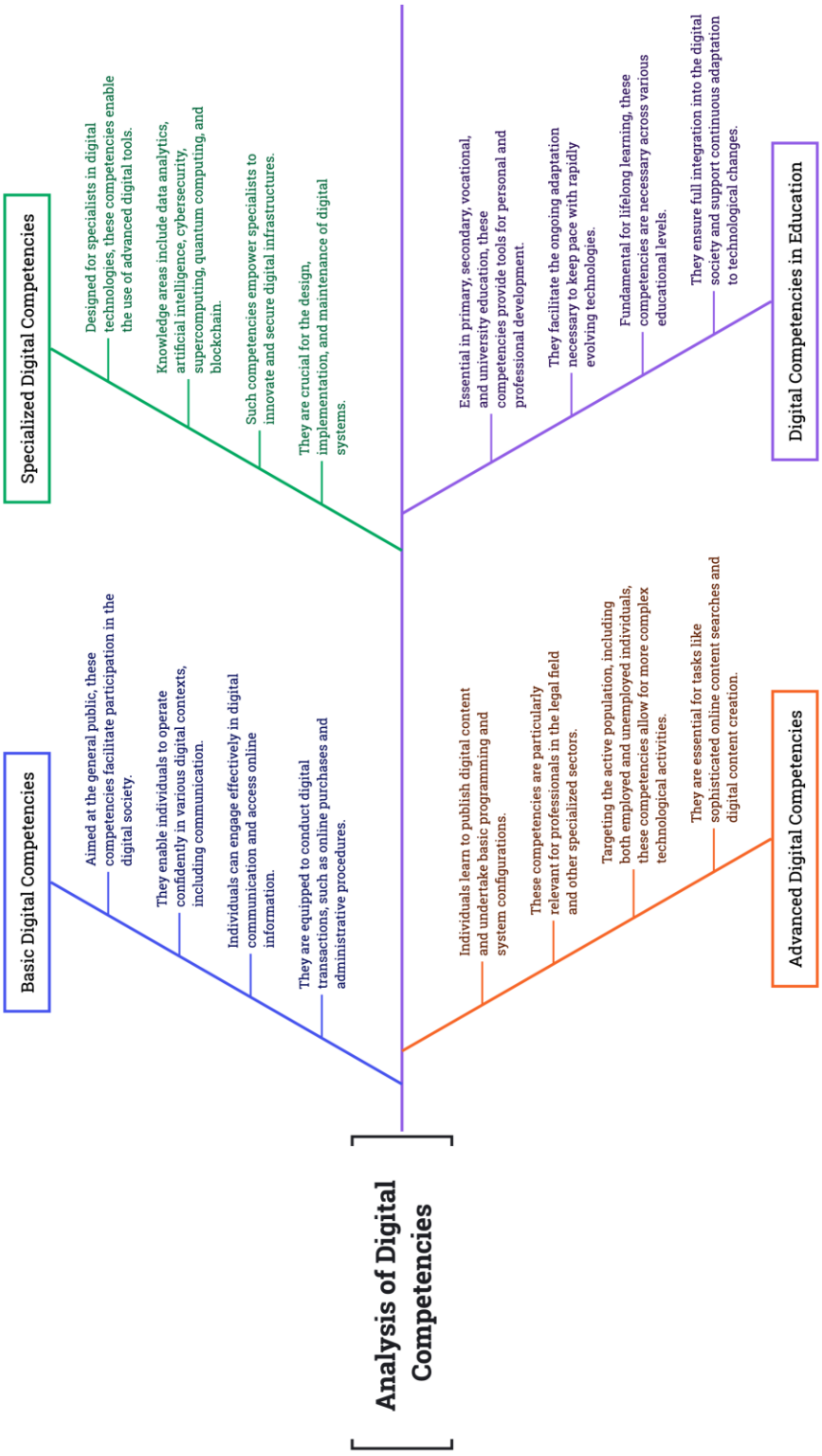
ANNEX I


Analysis of Digital Competencies
Basic Digital Competencies
Aimed at the general public, these competencies facilitate participation in the digital society.
They enable individuals to operate confidently in various digital contexts, including communication.
Individuals can engage effectively in digital communication and access online information.
They are equipped to conduct digital transactions, such as online purchases and administrative procedures.
Specialized Digital Competencies
Designed for specialists in digital technologies, these competencies enable the use of advanced digital tools.
Knowledge areas include data analytics, artificial intelligence, cybersecurity, supercomputing, quantum computing, and blockchain.
Such competencies empower specialists to innovate and secure digital infrastructures.
They are crucial for the design, implementation, and maintenance of digital systems.
Advanced Digital Competencies
Individuals learn to publish digital content and undertake basic programming and system configurations.
These competencies are particularly relevant for professionals in the legal field and other specialized sectors.
Targeting the active population, including both employed and unemployed individuals, these competencies allow for more complex technological activities.
They are essential for tasks like sophisticated online content searches and digital content creation.
Digital Competencies in Education
Essential in primary, secondary, vocational, and university education, these competencies provide tools for personal and professional development.
They facilitate the ongoing adaptation necessary to keep pace with rapidly evolving technologies.
Fundamental for lifelong learning, these competencies are necessary across various educational levels.
They ensure full integration into the digital society and support continuous adaptation to technological changes.

P8 ANNEX II

LinkedIn		**Nascor Formación**
Data Literacy		Artificial Intelligence (AI) and Machine Learning
Artificial Intelligence and Machine Learning		Digital Experience Design (UX/UI)
Human-Centered Design		Process Automation and RPA
Cybersecurity		Digital Marketing and Multichannel Strategies
Digital Communication Skills		Blockchain and Cryptotechnology Skills
		Application and Software Development
Infojobs		**Universiae**
Basic Digital Literacy		Basic Digital Literacy
Digital Communication Skills		Programming and Web Development
Competence in Tools and Software		Virtual Reality (VR) and Augmented Reality (AR)
Analytical Thinking and Decision-Making		Advanced Video Editing and Animation
Cybersecurity Literacy		Advanced Ethical Hacking
		Database Management
ISDI		Artificial Intelligence and Machine Learning
Multimedia Content Creation and Editing		Cybersecurity and Threat Management
E-commerce		Process Automation
Cybersecurity		SEO Optimization and Digital Marketing Analytics
Digital Marketing		UX/UI Design
Information Management		
Telefónica		**Scientific and Technological Park**
Data Analysis		Advanced Use of Office Tools and Management Software
Database Management		Programming and Web Development
Big Data		Digital Marketing and SEO
Brand Manager		Cybersecurity
Digital Marketing		Digital Project Management (Scrum and Agile)

Artificial Intelligence		Data Analysis and Big Data
Office Software		Cloud Computing
Cybersecurity		Artificial Intelligence (AI) and Machine Learning
Testing		Graphic Design and UX/UI
Programming		Knowledge in E-commerce
Association for Management Progress		**UNED**
Information Management		Information Processing
Knowledge of E-commerce		E-Communication
Knowledge of Digital Marketing		Digital Content Creation
Search Engine Optimization		Digital Security: Data Protection and Cybersecurity
Audiovisual Competencies		Problem Solving in Digital Environments
Social Media Management		
Knowledge of Online Advertising		**Iberdrola**
Big Data		Cybersecurity
Customer Service		Customer Service
Cybersecurity		Marketing
		Social Media
ESIC		Digital Image and Video Editing
Digital Management		Cloud Technology and E-commerce
Digital Marketing		Specialized Software
E-Commerce		Web Positioning
Digital Communication		
Web Marketing		**SAGE**
Digital Advertising		Data Analysis
Customer Experience		Programming
Big Data		Cybersecurity
Innovation		Digital Marketing
		Graphic Design and User Experience (UX)
		Project Management Skills
		Digital Communication
		Artificial Intelligence (AI) and Automation
		Knowledge of Process Automation

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Background

This report tries to foster CPD/CEE Continuing Professional Development/Continuing Engineering Education from the point of view of the Engineering Community. It includes, as stakeholders, academia, professional organizations, companies, official agencies and society in general. Trainers, educators and users of CPD/CEE have different attitudes towards Lifelong Learning (LLL) for engineers although these address similar problems and identical solutions. A clear example is the denomination CEE that is used commonly among trainers and higher education teachers while professionals call the same activity CPD. The root is of course based on the basis on the motivation of teachers, that underline education and training, and of engineers, that are concerned with the profession and its development (Smith, 2024).
Some professional engineering organizations have as one of their goals to develop and consolidate the professional capacity of its members. Some of these organizations even provide CPD opportunities for their members (Stanford Online, 2025).
Some key issues include whether annual CPD/CEE in each country is:

a) Voluntary (unregulated/unchecked, up to each individual) or Mandatory (regulated/specific number of hours recorded); and
b) Open-Choice (up to each individual to select what's relevant) or Guided (specific subjects to be addressed, possibly influenced by the employer or regulatory organisation).

Academia in certain cases try to respond to the needs of the Engineering Community by offering courses and training in different modes and topics according to the needs of upskilling and reskilling of engineers and companies. These responses from academia are, in many ways, very different. Some common issues have been identified in several research studies. There are a multitude of concepts covering a wide range of practices in terms of practices of CPD/CEE for engineers. The different forms of CPD/CEE include, for instance, distance education, part-time studies, full time university studies, tailor made courses, in company training and workshops/seminars (Väätäjä, 2024).
Regarding the legislative framework of CPD/CEE activities at higher education level, the involvement of governments and of official agencies varies widely. These interventions vary from setting up laws implementing CPD/CEE as mandatory to contexts where no CPD/CEE is required to maintain professional status. It should be noted that there are countries where engineering activities are not regulated and others where the profession is controlled by national bodies. However, in most European countries the topic CPD/CEE is on the political agenda and there is a general awareness of the need for CPD/CEE. Trade unions, companies, professional organizations and governmental bodies take CPD/CEE into account in their strategic plans. In general, a recurrent political argument is that investment in the engineering human capital is fundamental for the economic growth and development of society, and that increased access to training will help sustain economic competitiveness on a global scale (Endorsed, 2024).

Methods Used

This research was done using the Prisma methods and results of systematic reviews should be reported in sufficient detail to allow users to assess the trustworthiness and applicability of the review findings. The Preferred Reporting Items for Systematic reviews and Meta-Analyses (PRISMA) statement was developed to facilitate transparent and complete reporting of systematic reviews and has been updated to reflect recent advances in systematic review methodology and terminology ((Page, 2021).
The search words for using the PRISMA software and program were based on references, the analysis and the opinions made publicly known in the timeframe 2024-2025 were CPD, LLL, CEE, 2024, 2025, Engineers/Engineering. The results chosen addressed existing practices and guidelines by the stakeholders: academia, professional organizations, companies and governmental agencies, ongoing and finished projects, published journals, articles and conference proceedings. The criteria to choose findings was based on the usefulness for individual engineers and on the possible use by the

stakeholders like companies, professional organizations and academia. The findings of the research consisted in producing summaries and conclusions relevant to engineers, to academia, to companies, to professional organizations and to regulating agencies.

Findings

1. Teaching Engineering Lifelong Learners

Paper explores the pedagogical strategies used by seasoned educators in continuing higher education, particularly within Denmark's Diploma of Leadership Program. Unlike traditional university settings, this program caters to engineering professionals with significant work experience who seek practical, career-oriented knowledge. Using six semi-structured interviews analyzed through grounded theory, the study identifies key differences in teaching styles, revealing three distinct educator roles: **Facilitator**, **Coach**, and **Challenger**. All interviewed teachers incorporated elements of these roles but varied in emphasis and execution. Facilitators focused on delivering content to meet course objectives, often using deductive methods like lectures and structured discussions. Coaches tailored learning experiences to individual students, using case studies and reflective dialogue. Challengers promoted deeper transformation through experiential methods like case studies and storylines, pushing engineers to question assumptions and apply theory in practice. The teachers who most effectively integrated theory and practice often emphasized outcomes and impact in engineering, employing experiential learning to create reflective and collaborative environments. Such methods support transformative learning—where learners reassess beliefs and behaviors through critical reflection. Findings underscore the need for teacher training programs in lifelong learning for engineers to address not only teaching techniques but also the reflective mindset behind them. Recommendations include enhancing teachers' awareness of learning impacts, fostering experimentation, and encouraging professional communities for knowledge sharing. This research highlights the complexity and depth required to teach engineering professionals effectively, suggesting that transformative, practice-oriented education demands dynamic, reflective, and relational teaching strategies that recognize engineers' real-world experiences (Bold, 2024).

2. Use of E-portfolios in CPD for Engineers

The study explores the implementation of an e-portfolio, grounded in a five-step Personal Development Process (PDP), to foster lifelong learning (LLL) and CPS competencies among engineers. The e-portfolio enables engineers to personalize their learning paths, emphasizing reflection, goal-setting, and self-directed learning—skills essential for engineers navigating rapidly evolving professional landscapes. Findings, after a survey of involved stakeholders, indicate that while engineers value lifelong learning highly, they perceive it as less integrated and assessed within their knowledge, skills and competences. Post-test data show modest self-perceived competency levels, with variations across engineering life. Notably, less experienced engineers undervalue "creating a learning plan," suggesting a disconnection between theoretical and professional conceptions of LLL. A significant interaction effect was found for self-reflection: less experienced engineers rated it less important over time, while older engineers showed increased appreciation. The authors suggest this could reflect the Dunning-Kruger effect, where engineers reassess their skills after gaining experience. Although promising, the intervention's effectiveness remains inconclusive due to the absence of a larger control group. Future iterations will refine the e-portfolio design, include a control group, and incorporate qualitative data to better capture and validate LLL competency development for engineers (Dujardin, 2024).

3. CPD for Engineering Educators

The paper addresses the professional development of engineering educators, emphasizing the need for structured and continuous support across all career stages. Most engineering faculty enter academia based on research credentials, often lacking formal pedagogical training. The study advocates integrating teaching development into career progression using a four-level academic career framework. Conclusions are based on a workshop, with invited engineering educators and trainers, to reflect on career development practices at their institutions, share best practices, and identify challenges. Participants explored formal and informal professional development opportunities, including structured teaching programs, educational innovation involvement, and communities of practice. A key strategy discussed was co-creation using the Appreciative Inquiry

method to align development pathways with educators' goals. Positive outcomes highlighted existing support structures, mentoring systems, and the growing recognition of teaching excellence. Challenges included staff buy-in, sustaining engagement beyond foundational levels, tailoring development to individual needs, and aligning educational contributions with institutional promotion policies. It is recommended recognizing professional development beyond minimum tenure requirements. Suggestions include fellowships, learning labs, national mentorship programs, and cross-institutional collaborations in engineering. Linking teaching competencies to human resource policies and promoting recognition across institutions and countries (e.g., UK, Australia, Sweden) were emphasized. Ultimately, it is recommended to promote a shift in the engineering academic culture where educational roles are valued alongside research. It calls for universities to view engineering quality teaching as a core societal contribution and to embed professional development into the fabric of academic career pathways, enhancing both educator effectiveness and engineering student learning outcomes (Gomez Puente, 2024).

4. Micro-credentials for CPD in Construction

Environmental change has a strong impact on the construction industry, which creates a need for new skills, competences and knowledge in the workforce to achieve a green transition in construction. In this context, Green Circle project aims to identify, develop, test, and assess the use of micro-credentials in the construction sector to achieve a green transition, while demonstrating the potential for mainstreaming and transfer to other sectors. Green Circle project will not simply offer a collection of learning resources. The work carried out will show how a rigorous description of job profiles, learning needs, learning opportunities, and the relationships between them can, with appropriate technological support, facilitate the emergence of an ecosystem based on micro-credentials, and linking skills providers, employees, potential entrants to the workforce, and employers. This project outlines the establishment of a baseline for micro-credentials (MCs) in the construction sector for engineers, workers and technicians under the Green Circle project (Project number: 101132905), funded by ERASMUS-EDU-2023-PI-FORWARD. The project, running from December 2024 to November 2026, involves 11 partners across Portugal, Greece, Spain, and Germany. MCs are defined as short, flexible learning programs that certify specific skills and knowledge, complementing traditional engineering and technical education. They address labor market needs, particularly in green and digital transitions, and are designed to be portable, stackable, and learner-centered. The reference highlights the EU's framework for MCs, including mandatory and optional elements, and emphasizes quality assurance, transparency, and relevance. The construction sector's role in the European Green Deal is underscored, with a focus on upskilling workers to meet sustainability goals. The document reviews MCs in partner countries, noting varying levels of development and integration into national education systems. For instance, Spain is advancing MCs in vocational and higher education, while Portugal and Greece are in earlier stages. Germany's dual vocational system presents unique challenges and opportunities for MC adoption. Research into existing MCs reveals a focus on digital technologies, sustainability, and green building, with most courses offered online. However, gaps in information and standardization persist. The project is developing an unified MC framework to enhance skills recognition, workforce mobility, and alignment with industry needs, ultimately supporting the construction sector's transition to a sustainable future (Green Circle, 2025).

5. Engineering Human-Centred AI Upskilling and Reskilling

Text declares that AI (Artificial Intelligence) systems should augment human capabilities, not replace them, emphasizing ethical and inclusive development. Examples for engineers include voice assistants (e.g., Siri, Alexa), autonomous systems, and data-driven recommendation tools. The impact of AI in the engineering workforce in terms of CDP/CEE/LLL is expected to provoke an automation of processes and of tasks that will displace some jobs but will create new roles like AI specialists, engineers, data scientists, and AI ethicists. The probable leading sectors for AI adoption are construction, design, telecommunications, engineering consultancy, financial services, travel, and hospitality. The question of upskilling vs. reskilling in CPD/CEE/LLL involves, in upskilling, enhancing current roles with AI competencies and, in reskilling, training for entirely new job functions due to AI-driven shifts. It is expected that by 2025, 54% of workers may need significant reskilling/upskilling. Therefore it is recommended for CEE/CPD/LLL for engineers to align with the existing regional, company or national digital master plans to boost digital and ethical AI skills for economic competitiveness. It should be considered, for the existing scenarios, to balance technical

engineering capacities (e.g., AI programming, sustainability) and non-technical engineering competences (e.g., ethics, adaptability). A call to action for relevant engineering stakeholders (governments, educators, trainers, professional organizations and industries) must collaborate to implement frameworks ensuring workforce resilience and competencies in AI. It should be clear to all the urgency of proactive AI education to harness opportunities while mitigating disruptions in the evolving digital economy (MySet, 2024).

6. Engineering CPD/CEE/LLL for a Skills-First World

Engineering CPD/CEE/LLL is undergoing a transformative shift to align with dynamic workforce demands, emphasizing **flexibility, accessibility, and competency-based learning. Researcher highlights two key innovations: **stackable credentials** (modular courses, certificates, and microcredentials that build toward degrees) and **remote/hybrid learning**. These approaches enable rapid upskilling—such as AI-focused courses—while maintaining academic rigor and scalability. **Challenges** include trainers and faculty adaptation to modular curricula, infrastructure limitations for competency tracking, and ensuring hands-on experiential learning in remote settings. Solutions leverage **emerging technologies like AR, VR, and IoT (e.g., AR welding simulations, digital twin labs, safety and health) to replicate physical experiences virtually. **Remote learning** bridges geographic gaps, offering real-time engagement analytics and collaborative problem-solving tools. For workforce training, it allows on-site upskilling with actual equipment. However, **policy and accreditation frameworks** lag behind, hindering rapid curriculum updates. Research results advocate for agile systems to approve new credentials swiftly, mirroring industry evolution. **Future innovations** center on **AI-driven personalized learning pathways** and stronger **industry partnerships** to ensure curricula remain relevant. Microcredentials must gain broader recognition among employers to validate lifelong learning. **Key Takeaway**: The future of engineering education, CEE/CPD/LLL lies in **stackable, technology-enhanced models** that prioritize real-world competences, accessibility, and continuous adaptation. Success requires collaboration among institutions, policymakers, and industries to dismantle traditional barriers and embrace a skills-first paradigm (Palsole, 2025).

Possible directions

This CPD/CEE/LLL survey addressing engineers with EUR ING certificates and respective employers from across Europe was informative and presents a snapshot of needs and practices of the engineering community. It is relevant to note that CPD practices are, in a large part, independent of the CPD providers' organizations. It is clear that dialogue between CPD providers, engineering companies and engineering professional organizations could and should be developed and implemented. Another important conclusion is that engineers as well as their employers are putting their "technical knowledge" at the top of the list of CPD topics attended during training. Topics like Artificial Intelligence, Simulation and Virtual Reality appear as inevitable CPD for engineers.
Other frequent topics of CPD were existing regulations in areas of the European Union, safety, environment, sustainability, digital tools, etc.. Competences (knowledge, skills and attitudes) like leadership, coaching, mentoring related with the engineering community were also mentioned as possible interests for the engineers. The choice of the engineering community mode and process to develop these competences is to attend in-company or external courses and on-the-job training. Engineers also like to study on their own or through a formal postgraduate academic course. It appears that more can be done to design effective templates for evaluating the CPD needs of engineers. One of the suggestions was to deliver CPD through a personalized learning contract between company, engineer and provider to create work based learning and training. New micro-credentials (accredited 'badges'/mini-awards) required from universities, professional bodies/associations and technology providers with:

a) an increased focus on flexible participation (making it easier for engineers to complete the course and be assessed - fully online or hybrid); and
b) a series of follow-on options leading to 'full' postgraduate awards/qualifications (to gain deeper/expert knowledge, skills and wider competences).

From the study of the examples and of the recorded sources, it seems that the annual average of 40 hours as the total minimum of CPD for an active and updated engineer is commonly achieved. Those hours may consist of dedicated days of courses a year supplemented with CPD activities done by each engineer during private time. The collaboration of CPD providers with stakeholders to develop personal and company development plans may clearly benefit the organization and the

implementation of a robust and effective system of providing adequate CPD for the engineering community. It was observed that the practice of CDP is constant, the majority of engineers want to have CPD as a necessity to progress in the career, the majority of employers support CPD of engineers, time spent yearly in CPD is more than forty hours and payment of CPD is shared by engineers, employers and official agencies. Some of the engineers use a yearly personal development plan with details of the CPD learning objectives and intended competences.
It seems that building a structured and durable alliance between education and the engineering profession (professional bodies and industry) to foster innovation and resilience of European engineers through the acquisition of new skills and competences. The conclusions listed above indicate that some recommendations can be made to foster cooperation between the engineering professional sector and CPD providers. One possibility is the joint participation in projects and proposals funded by the European Commission related to innovation, technology development and qualification. Another possibility is the nomination of joint observatories and/or committees to define training programs and cooperating platforms. A third action might involve periodic surveys, like the one described in this paper, to define what is needed by engineers and what CPD providers can contribute. A better mutual understanding and knowledge among CPD providers and engineering professional associations could be promoted with benefits for all, but especially for the qualified engineering population.

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Secondary Research:
Digital Skills Requirements for Engineers

Developed by: European Council of Engineers Chambers

1. Background and conclusions:

New digital technologies, including AI and robotics are rapidly reshaping the (engineering) world and (engineering) skills need to be constantly adapted to new tasks and new ways of working.

Since the last decade, a rapidly growing number of publications deal with the topic of digital skills but increasingly also with the changing skill profiles and working tasks that come along with digital and AI developments.

The ***EU Digital Education Action Plan (2021-2027)*** was adopted in 2020 as a policy initiative that set out a common vision of high-quality, inclusive, and accessible digital education in Europe, with the aim to support the adaptation of the education and training systems of Member States to the digital age. The European Commission's ***2030 Digital Compass: the European way for the Digital Decade*** clearly set the aim to enhance a skilled population and highly skilled digital professionals and mentioned the construction sector as one of the five key ecosystems with the highest potential regarding the digital transformation. Also, the other four mentioned sectors (manufacturing, health, agriculture, mobility) are highly dependent on engineering services.

In 2023 the European Commission's ***Guidance to the Member States on the preparation of the national Digital Decade strategic roadmaps*** set a strong focus on different (funding) measures to enhance the digitalization of SMEs, to which the broad majority of Chartered Engineers in Europe belong. This also covered the enforcement of digital innovation in SMEs, which also shows that SME - and engineers especially - play many roles in the digitalization processes which has of course an important impact on the skills requirements:

- As for any other business, there is the factor of an increased use of digital (office) tools and processes in their business.
- Additionally, they increasingly work with specialised digital tools and KI applications in their engineering branch of expertise (e.g., Building Information Modeling in construction, use of digital twins in damage assessment, KI measurements in geodetic surveying etc) engineering professions increasingly.
- Finally, and especially important the engineering professions are also among the forefront players of the technical development of digital and AI applications.

In 2022 the OECD published ***Skills for the Digital Transition: Assessing Recent Trends Using Big Data.*** The focus is on digital occupations including IT engineers and the paper already gives unmistakable evidence that the digital and AI challenges require a heterogenous mix of technical but also in combination with other high-level cognitive skills and soft skills. Interestingly, the document also pointed out the increasing importance of social media skills for businesses in general.

While all these publications focus on digitalization in general, regarding engineering skills requirements it is also important to focus especially on the special challenges coming with the fast-developing AI.

The CEDEFOP document ***Skills empower workers in the AI revolution in 2023*** is based on the CEDEFOP AI skills survey and points out the fact that for the first time „many highly skilled individuals and jobs will not be shielded from the impacts of AI as was the case in previous waves of technological innovation ". This describes that now, even for complex high-level tasks AI can achieve better results than human intelligence, which is a particularly important development also for liberal professional services - ranging from medicine, legal and financial services to many fields of engineering - and thus for the related skills requirements for engineers that go far beyond technical aspects.

The document describes that basic AI literacy is referring to the knowledge and skills that people must have to critically understand, evaluate, and use AI tools and systems in such a way that they can safely and effectively communicate, collaborate, and use them. It points out that these competences encompass a wide range of different AI literacy aspects ranging from whether someone can accurately recognise an AI technology and its limits compared to human intelligence to an adequate understanding of the way with which AI systems and machines represent and learn from the world and also the awareness of the socioeconomic and ethical challenges implied by AI systems ('how should AI be used?')

Cedefop's AI skills survey therefore regards an AI competence framework in initial education and training as vital for adequately preparing new learners for the future AI-driven job market and clearly shows that it should also be a core priority in adult learning and continuing vocational training.

For the engineering profession the AI skills requirement go beyond that of basic users, which is very well shown in the ***ARISA AI Skills Strategy for Europe***.

ARISA, an Erasmus+ funded project to provide AI knowledge and skills helping people understand and use AI technology in business and policy contexts - considering privacy, bias, and trust - with a focus on current and emerging professional roles across four occupational domains — business leaders, technology leaders, technology practitioners, and policymakers in 2023 presented an ***AI Skills Strategy for Europa.*** This was based on an ***AI Skills Need Analyses*** *and* followed by concrete AI curricula for various kinds of professions. The needs analyses show the crucial element of individuals possessing the acumen to understand business opportunities and potential use-cases arising from AI implementation. This clearly goes beyond pure technical skills and has a focus on the ability to discern and leverage the potential benefits of AI technologies - which is considered paramount for driving strategic decision-making and for enhancing competitive advantage. Another important aspect is the capability of gathering, managing, and curating datasets that serve as the foundation for AI-driven applications and models and is essential for deriving accurate and actionable insights.

According to the World Economic Forum's ***Future of Jobs Report 2025*** the advancements in technologies, particularly AI and information processing (86%); robotics and automation (58%); and energy generation, storage, and distribution (41%), are expected to be

transformative and are expected to be fuelling demand for technology-related skills, including AI and big data, networks and cybersecurity and technological literacy, which are anticipated to be the top three fastest growing skills.

Apart from required technical, soft, and other related skills requirements there is the crucial ethical aspect that is especially important for publicly authorized Chartered Engineers, as a characteristic of their engineering services is the strong relation to (public) trust and responsibility. As also stressed in the ***EU AI Act*** *depending on the circumstances regarding its specific application, use, and level of technological development, AI may generate risks and cause harm to public interests and fundamental rights that are protected by Union law. Being able to oversee an* ethical and responsible use of AI is therefore also an essential topic of relevance for engineering skills requirements and is also based on the existing frameworks such as the ***EU AI Act*** and the ***OECD Recommendation of the Council on Artificial Intelligence.***

Beside ethical considerations and approaches, digitalization and AI applications also raise the need for a basic legal understanding especially in questions regarding liability and data sovereignty including copyright protection, protection of secrets under fair trading law and principles of data protection law (see for example ***Haftung und Datenhoheit beim Building Information Modeling*****,** 2025, Oliver Stefan Mandl, ISBN:978-3-214-26058-3).

With the growing importance of generative AI (GenAI) application also in engineering sectors the necessity arises to better understand the distinction between GenAI and foundation models and especially the impacts of that distinction. The EESC Study on ***Generative AI and foundation models in the EU: Uptake, opportunities, challenges, and a way forward*** that was presented in January 2025 tries to shed some more light on that aspect and the related skills requirements. Another interesting EESC study on ***Affordable sustainable housing in the EU*** was presented in 2024 and contains a Chapter on the “Digitalisation as a Pathway to Affordable Sustainable Housing” giving an overview of existing digitalization strategies in national housing policies. This can serve as a good example for the fact that new digital approaches gain relevance in all branches and even in very traditional parts of engineering and in manifold diverse ways.

While skills requirements in digital and AI basics range from understanding of various technologies and their possible applications & limitations to data analysis and prototyping, additional requirements relate for example to innovation and change management skills,

including creativity and problem-solving skills and knowledge how to implement digital projects and evaluate their costs and benefits. Other important basic skills relate to analytical thinking and the ability to define use-cases, penetrate business processes, and identify optimization potential.

All this shows that digital and AI skills requirements for engineers are extremely broad and go far beyond the classic technology approaches. Additionally, (up)skilling measures need to be very flexible and constantly adapt to ongoing changes. This also stresses the importance of continuous professional development as a crucial addition to the skills required in education and training.

Finally, it is important to stress that new European Commission, in its recently published communication on ***„The Union of Skills*** "expresses a strong commitment to build on a solid skills foundation in education and training and engage in lifelong upskilling and reskilling. An initiative on AI in education and training will lay down an AI literacy framework and support the integration of AI in education and training provision (in 2026). In the recently presented Competitiveness Compass for the EU it is stressed and acknowledged that the people with their skills are the foundation of Europe's competitiveness, and preparedness for the future. This especially related to engineers and their significant role for health, safety, and quality of life of the European citizens, for the overcoming of numerous societal challenges such as the climate change impacts and for a sustainable an economically advantageous development in Europe.

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ENGINEERS IRELAND | Empowering Innovation. Engineering The Future.

Introduction

Continuing Professional Development (CPD) is timely professional updating. It is the process of lifelong learning for professionals. A definition of CPD is: "The systematic maintenance, enhancement and development of knowledge and skill, and the development of personal qualities necessary for the execution of professional and technical duties throughout the practising engineering professional's career." (Engineers Ireland CPD Policy)
This report highlights Continuing Professional Development (CPD) as a transformative mechanism for building workforce adaptability and innovation, and draws on evidence and experience of engineering-led organisations in Ireland. By embedding continuous learning into their strategies, engineering-led organisations can position themselves as leaders in a fast-changing world. This report will provide examples in an Irish context, but these can be equally relevant to engineering organisations and engineers across Europe.

The engineering profession is at a crossroads, shaped by powerful global trends that are redefining industries and reshaping the way organisations and professionals operate. From the relentless pace of technological advancements to the urgent need for climate action, as well as demographic shifts and growing urbanisation, these forces are creating new challenges and opportunities that demand resilience, adaptability, and bold leadership.
Central to this resilience, adaptability and leadership is CPD, which provides professionals with the knowledge and tools to navigate evolving demands while reinforcing the foundational strengths of their organisations.

Forces such as climate change, demographic shifts, urbanisation, and geopolitical changes are converging to create a workplace landscape that is increasingly complex and interconnected. These trends are not just external pressures—they are catalysts for innovation, demanding forward-thinking strategies and agile responses.

Continuing Professional Development (CPD) is the linchpin in this evolution. It equips engineers with the tools to adapt to these changes, turning complexity into opportunity. By addressing the implications of these global forces, this report highlights the vital role CPD plays in enabling European engineering-led organisations to thrive, not only in navigating the challenges of today but also in shaping the possibilities of tomorrow.

Digital Technology

The rapid evolution of digital technology is transforming the engineering landscape, reshaping how professionals work, collaborate, and innovate. From artificial intelligence (AI) and robotics to the Internet of Things (IoT) and digital twins, these advancements are not just tools—they are the drivers of a new era in engineering.

CPD equips engineers to lead in this dynamic environment, offering targeted programmes to develop the skills needed to thrive. For example, courses on IoT systems, robotics, and AI integration ensure engineers remain at the forefront of technological innovation. Beyond technical expertise, CPD emphasises the importance of ethical and sustainable practices. The United Nations Sustainable Development Goals Report 2023 calls for urgent action to ensure technology advances inclusively and sustainably. With robotics and automation reshaping industries, CPD provides engineers with the frameworks to consider societal impacts, ensuring that innovation is balanced with responsibility.

The rapid pace of technological advancement presents both opportunities and challenges for engineers. The World Economic Forum's Future of Jobs Report 2023 projects that by 2027, analytical thinking, creative problem-solving, and expertise in AI and big data will be among the most sought-after skills (World Economic Forum, 2023).

In today's engineering landscape, data-driven decision-making is no longer optional—it is a fundamental driver of success. Organisations that leverage data effectively are better equipped to identify trends, optimise operations, and anticipate future challenges. According to the PwC Global Data and Analytics Report 2023 (PwC, 2023), data-driven organisations are three times more likely to achieve significant business improvements, underscoring the transformative potential of analytic

Continuous Professional Development (CPD) is essential in building the skills needed to harness the power of data. LinkedIn's 2023 Learning Trends Survey (LinkedIn, 2023) highlights data analysis and interpretation among the top five in-demand skills globally. CPD programmes focusing on data tools like Power BI and Tableau, along with advanced analytics techniques, equip professionals to turn data into actionable insights.

While the opportunities of data-driven decision-making are vast, challenges persist. The European Data Governance Report 2023 highlights that 42% of organisations have faced negative impacts due to biased data models or misinterpretation of analytics. These issues underscore the importance of ethical training as part of CPD. For instance, training on bias detection in algorithms, GDPR compliance, and responsible data use helps engineers design more equitable and accurate solutions. Moreover, as AI-driven analytics become more prevalent, CPD can prepare professionals to navigate complex ethical questions around data privacy and algorithmic transparency.

Continuing Professional Development (CPD) provides a solution to these challenges by equipping professionals with the technical expertise and adaptive skills required in the digital age. Targeted training initiatives, such as advanced technical training in AI, machine learning, and big data analytics, ensure that engineers can lead the integration of new technologies with confidence.

Climate Change

Climate change is not just an environmental issue—it's reshaping the engineering profession, presenting urgent challenges alongside opportunities to lead in designing a sustainable future. Meeting these ambitious goals requires cutting-edge skills and fresh thinking – exactly what CPD delivers through focused training programmes. Engineers engaged in CPD gain expertise in areas like lifecycle analysis, energy-efficient retrofitting, and the integration of renewable energy technologies such as solar panels and heat pumps. Such training ensures they can deliver sustainable solutions while adhering to evolving regulations and EU Green Deal commitments.

CPD equips professionals to adopt low-carbon materials, model energy performance, and design for long-term resilience. Training in mastering energy-efficient design and sustainable construction techniques, Building Information Modelling (BIM) and lifecycle assessment empowers engineers to balance performance, cost, and environmental impact in line with Ireland's sustainability targets.

CPD also addresses the human impact of sustainability. Training in leadership and communication enables engineers to collaborate effectively across multidisciplinary teams and advocate for innovative approaches. These skills are essential as engineers navigate the complex interplay of technical, regulatory, and societal pressures in delivering national and European climate commitments.

While 75% of organisations have committed to sustainability goals, only 43% have clear strategies for achieving them (European Climate Action Progress Report 2023). This gap highlights the critical role of Continuing Professional Development (CPD). Through tailored training programmes, CPD equips professionals with the skills needed to transition from commitment to actionable results.

Balancing immediate financial performance with long-term sustainability goals remains a significant challenge for 48% of executives (PwC Net Zero Future Report 2023). CPD addresses this by fostering leadership skills that prioritise sustainable decision-making, ensuring that profitability and environmental responsibility can coexist. Training on the circular economy, supply chain sustainability, and green certifications further equips professionals to integrate sustainability into every aspect of their work.

Through CPD, professionals are empowered to bridge the gap between policy ambitions and practical implementation, leading on retrofitting, renewable energy integration, and sustainable design. In doing so, CPD not only equips engineers with the skills to tackle today's challenges but also ensures they are ready to drive innovation in a rapidly changing world.

Demographic Shifts

Demographic shifts are redefining the engineering workforce, presenting challenges that demand fresh thinking—and opportunities that call for visionary leadership. Continuing Professional Development (CPD) is at the heart of this transformation, equipping engineers with the tools to bridge generational gaps and foster collaboration. Through mentoring programmes, senior professionals pass on invaluable institution knowledge while learning from younger colleagues who bring fresh perspectives and expertise in emerging technologies. It's a two-way street: reverse mentoring allows junior engineers to share insights on digital tools, while seasoned professionals offer strategic guidance honed through years of experience.

CPD also empowers engineers to address critical skills shortages by offering training in high-demand areas like renewable energy and digitalisation. By fostering intergenerational learning and creating pathways for upskilling, CPD ensures engineering teams are not only resilient but ready to thrive in a changing world. It's not just about managing demographic shifts—it's about turning them into a powerful force for innovation and growth.

Continuing Professional Development (CPD) plays an essential role in embedding Diversity, Equity and Inclusion into workplace culture. Targeted initiatives such as unconscious bias training, inclusive leadership programmes, and mentorship schemes equip organisations with the tools to support underrepresented groups and ensure all voices are valued. CPD also supports inclusive design practices, ensuring that engineering solutions address the needs of diverse end-users—from accessible infrastructure to community-led urban planning. Ultimately, fostering a sense of belonging goes beyond compliance. It involves cultivating an environment where everyone feels valued, respected, and empowered to contribute fully. For engineering-led organisations in Ireland, embracing DE&I is not only about addressing representation gaps but also about driving innovation, collaboration, and long-term success.

Urbanisation

Engineering solutions are essential to addressing the challenges associated with growing urbanisation. Smart city innovations, like IoT-powered traffic systems, are slashing congestion by up to 30% in global pilot programmes. In Ireland, the MetroLink project aims to increase Dublin's public transport capacity by 50%, reducing road congestion and emissions while enhancing urban mobility. Similarly, modular construction techniques, which are being adopted in urban housing projects, have decreased construction times by 20%.

To leverage these solutions effectively, engineers require advanced technical skills and strategic leadership capabilities. CPD initiatives play a crucial role in bridging these gaps. For example, training in lifecycle assessment methods has enabled Irish engineers to design urban systems with 25% less resource waste, while CPD courses on IoT integration are preparing professionals to implement real-time management systems for urban infrastructure (Engineers Ireland Annual Report 2023).

Career Path Diversification

As the engineering profession evolves, so too do the career paths within it. Traditional linear trajectories are giving way to more diverse, dynamic models that prioritise flexibility, cross-functionality, and opportunities for continuous growth. This shift, driven by changing workforce expectations and rapid technological advancements, challenges organisations to rethink how they structure career progression and development strategies. Continuing Professional Development (CPD) emerges as a vital enabler in navigating these changes, equipping engineers and organisations alike to adapt and thrive.

Continuing Professional Development (CPD) serves as a cornerstone for enabling career diversification. By equipping engineers with the skills to adapt to emerging roles, CPD ensures that professionals remain agile and organisations competitive. Structured CPD programmes address critical areas such as: Cross-Functional Training: providing exposure to multiple disciplines to prepare engineers for hybrid roles that combine technical and managerial expertise, Leadership Development: developing managerial capabilities to meet the growing demand for leadership within technical industries, Emerging Technologies Training: offering specialised programmes in artificial intelligence, sustainability, and smart infrastructure to enable transitions into high-demand areas.

Recruitment Challenges and Skills Shortages

Recruitment challenges are reshaping the engineering profession, with demand for specialised talent far outpacing supply across multiple disciplines. Global competition, demographic shifts, and rapid technological change have amplified these issues, forcing organisations to rethink how they attract, develop, and retain their workforce. For engineering-led organisations, addressing these shortages is not just about filling roles—it's about safeguarding resilience and competitiveness in an increasingly dynamic market.

To address these challenges, engineering-led organisations must adopt multi-pronged strategies. Continuing Professional Development (CPD) plays a central role, focusing on: Upskilling Existing Talent: developing in-house training programmes to close skills gaps in high-demand areas such as renewable energy and digitalisation, Early Career Development: establishing graduate schemes and apprenticeships to attract and nurture young professionals, Diversity and Inclusion: expanding recruitment pipelines to include underrepresented groups, leveraging CPD to support their integration and growth within the sector.

By embedding CPD into their recruitment and retention strategies, engineering organisations can create sustainable solutions to skills shortages. Equipping professionals with the competencies needed to navigate complex projects ensures not only organisational success but also the long-term resilience of the industry.

Continuing Professional Development (CPD) offers a proactive solution to mitigate the skills shortage by upskilling the existing workforce and preparing them for future demands. CPD programmes focusing on emerging technologies, project management, and sustainability practices can significantly enhance workforce agility and resilience.

Flexibility and agility have become essential attributes for organisations seeking to thrive in an increasingly complex and unpredictable world. These values are reflected in practices like hybrid work arrangements, decentralised decision-making, and iterative processes that enable rapid adaptation to change. According to LinkedIn's 2023 Workplace Learning Report (LinkedIn, 2023), organisations that prioritised agility in their workforce reported increased employee satisfaction and better retention rates. Similarly, McKinsey's Workforce Insights 2023 highlights (McKinsey & Company, 2023) that agile organisations are 1.5 times more likely to meet their performance targets compared to their peers.

For Irish engineering-led organisations, flexibility and agility are crucial in addressing shifting project demands, evolving client expectations, and dynamic regulatory environments. The adoption of hybrid work models, Agile project management practices, and cross-functional collaboration fosters a culture of responsiveness and innovation. However, these approaches require ongoing training and upskilling, making Continuing Professional Development (CPD) a critical enabler of success. Structured CPD initiatives bridge the gap between traditional workflows and agile mindsets. For example, microlearning modules focused on Agile principles or Lean methodologies can help engineering teams reduce inefficiencies and improve productivity. Research from Ibec's 2022 Innovation Survey shows (Ibec, 2022) that organisations implementing Agile and Lean frameworks achieved significant improvements in project delivery timelines and overall efficiency. CPD programmes tailored to the engineering sector—including areas like Building Information Modelling (BIM) and digital twin technology—equip professionals to excel in collaborative, data-driven environments.

Continuous learning and professional growth are now cornerstones of organisational resilience and success. As industries evolve and new technologies emerge, the ability to build skills proactively has become a defining factor for thriving organisations. According to LinkedIn's 2023 Workplace Learning Report (LinkedIn, 2023), 94% of employees indicated they would stay longer at a company that invests in their career development. For Irish engineering-led organisations, embedding a culture of lifelong learning is both a strategic imperative and a key competitive advantage.

Engineers Ireland's Engineering 2023 report highlights that 72% of employers identify the lack of appropriately skilled engineers as a significant growth barrier. By fostering innovation and delivering sector-specific training, CPD is a key driver in bridging critical skill gaps and enhancing workforce resilience.

Leadership Development

Leadership development is another vital aspect of CPD. A 2023 PwC Ireland Future of Work Survey found that organisations prioritising leadership-focused CPD reported improved employee engagement and stronger organisational performance. For engineering teams, leadership skills are indispensable for managing complex, multidisciplinary projects effectively and fostering collaboration across teams.

At the intersection of innovation, sustainability, and digitalisation lies a wealth of opportunity for Ireland's and Europe's engineering sector. By addressing current skills gaps through targeted CPD initiatives, the sector can sustain its trajectory of growth and excellence. Engineers who embrace continuous learning are well-positioned to lead transformative projects, strengthen global competitiveness, and contribute meaningfully to a sustainable future.

Conclusion: Navigating the Future with Vision and Resilience

Ireland's and Europe's engineering sectors are at a pivotal moment in its history, navigating the interplay of rapid global trends and local opportunities. From addressing the challenges of urbanisation and sustainability to embracing technological innovation and the dynamics of mergers and acquisitions, the sector continues to evolve, adapt, and lead. Each of these forces brings complexity, but they also present unparalleled opportunities for growth, collaboration, and Innovation. At the heart of this transformation lies Continuing Professional Development (CPD). More than a tool for upskilling, CPD is a strategic enabler—empowering engineers to bridge gaps in expertise, foster innovation, and tackle emerging challenges with confidence. As Ireland's engineering firms integrate new technologies, expand into global markets, and adapt to shifting economic landscapes, CPD serves as a cornerstone of resilience, equipping the workforce to adapt dynamically and lead with confidence in a rapidly evolving sector.

However, despite its importance, continuous learning is not yet a reality for every workplace. The 2023 CIPD Learning and Development Survey reveals that only 48% of organisations have effective lifelong learning strategies in place, often due to resource constraints or a lack of structured frameworks. Additionally, organisational inertia and competing short-term priorities can hinder the implementation of comprehensive CPD initiatives. Addressing these barriers requires leadership commitment and the integration of CPD into long- term business strategies, ensuring learning aligns with measurable outcomes.

Looking ahead, the engineering sector's success will depend on its ability to embed a culture of continuous learning while staying aligned with broader economic and environmental goals. By doing so, Ireland's and Europe's engineers can not only rise to the challenges of today but also shape a future defined by sustainable growth, technological excellence, and global leadership. This report underscores the crucial role of CPD in making that vision a reality.

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E4E

Engineers for Europe

September 1, 2022 - August 31, 2025

Project Ref. Nr.: 101054872 — E4E — ERASMUS-EDU-2021-PI-ALL-INNO

Secondary Research Report

Developed by: UPORTO

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1. Introduction

The Engineers for Europe (E4E) project is not an academic endeavour but an operational answer to the many challenges of the engineering profession in Europe. An integral part of the project is the design of a mechanism to gauge the dynamics of the profession: such “monitoring tool” should be able to capture the dynamics and trends of the profession as a whole. By being a European project concerning the engineering profession “at large”, the methodology should not be too granular and specific, precisely to identify trends that affect the profession across industries, functions and countries.

Unlike thorough literature reviews required for academic papers or publications, the goal is to investigate the evolution of the engineering profession from an operational perspective. The E4E project includes a variety of partners, each representing a different facet of the engineering profession. Thus, the methodology used for the secondary research provides a common ground for E4E partners to gauge the dynamics, challenges and opportunities of the engineering profession, culminating in the yearly Engineering Skills Strategy.

1.1 The E4E project

The role of engineering in shaping our social and economic interactions has become increasingly important. Nowadays, engineering is crucial in designing and delivering products and services related to health, education, transportation, mobility, infrastructure, water, sanitation and telecommunication. The profession's importance has been further amplified by the digital and green transformations, which have created new opportunities and challenges in Artificial Intelligence, the Internet of Things, and the process of green growth, circular economy and decarbonization.

Despite the growing importance of engineering, significant asymmetries, mismatches, and polarization have undermined the profession's potential impact. Official statistics, data, and empirical evidence illustrate how there is a shortage of engineers in Europe, which is chronically needed to meet the 2030 and 2050 targets. Additionally, there is a lack of reliable data and information about the profession's dynamics and trends.

The focus on technical skills for engineers has led to skill polarization dynamics, creating a considerable gap in transversal skills. Employers are increasingly seeking multidisciplinary and soft skills in engineers. There is also a growing distance between the world of education and the world of work in engineering. Lack of integration among HE, VET, and Industry to upskill and reskill engineers has further exacerbated these issues.

The skills mismatch in the domain of soft skills and transversal competences is widening and Europe is facing an "engineering innovation and competitiveness challenge" with competitive pressures from the USA and Asia. These factors make it even more urgent to reinforce the profession and take steps to address these challenges.

E4E aims to establish a well-organized and long-lasting partnership between the education sector, including higher education + vocational training and the engineering profession, represented by professional organizations and industry players. The primary objective is to enhance the innovation

and resilience of European engineers by enabling them to acquire new competencies and skills such as digital, green, resilient and entrepreneurial ones.

There are three primary objectives of E4E:

1. Contribute to strengthening the capacity of the engineering profession to address EU's societal challenges and priorities, such as digital and green transformations and decarbonization.
2. Bridge the gap between education, training and industry in the engineering field.
3. Implement EU competence frameworks, including DigComp, LifeComp and EntreComp, in the context of the engineering profession.

1.2 Aim of this document

This document reports UPORTO's third round of secondary research as described in "The E4E Common Methodology to Assess, Anticipate and Monitor the Evolution of the Engineering Profession with a Focus on Competences", which will be incorporated in deliverable 2.4 "E4E Skills Strategy: Anticipating Skill Requirements for the Engineering Profession". This third round included the period of January 2024 to April 2025, focusing on a literature review related to Entrepreneurial skills for Engineers. Figure 1 shows the number of publications per year on this subject. It is clear that apart from a couple of years after the COVID-19 pandemic, this theme has continuously increased in publications since the beginning of the XXI century, highlighting the relevance of entrepreneurship skills for engineers.

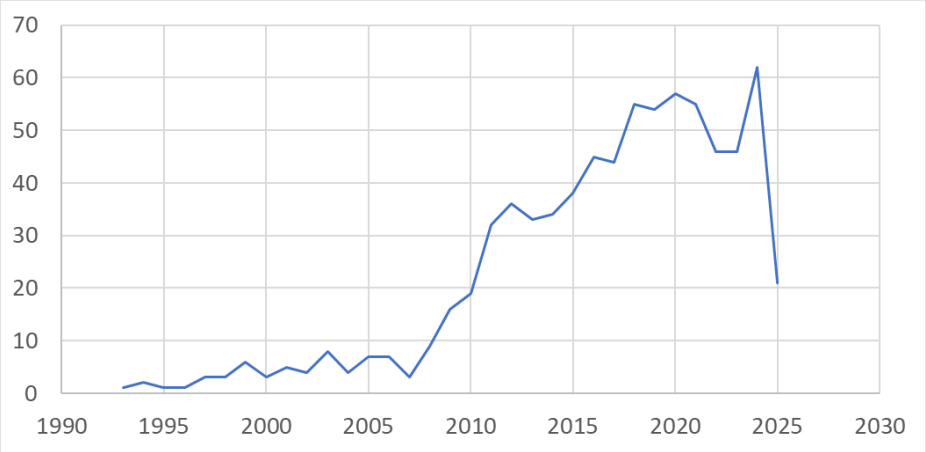

Figure 1 - Publications on entrepreneurship skills for engineers (source: SCOPUS)

3. Methods

The methodology used for the secondary research was based on the search of relevant keywords in document databases (SCOPUS, Web of Science) and the search for the most recent policy documents in reference institutions. The search was limited to the most recent period, that is, covering the years of 2024 and 2025. Due to its broader scope of documents catalogued, the SCOPUS database (https://www.scopus.com) was used as the source of references. The query used was "((TS=(entrepreneur*)) AND TS=(engineer*)) AND TS=(skill*)" for the period 2024-01-01 to 2025-04-

15[1]. This means that terms related to engineering (engineer, engineering, etc), entrepreneurship (entrepreneur, entrepreneurship, etc) and skills were searched for within the topic (title, abstract, keyword plus, and author keywords) of the articles that were published within the search period. The query resulted in 78 articles, which are presented in Table 1. The results were sorted by order of relevance and analysed in two steps. Firstly, the title and abstract were read to determine the relevance of the content. Only documents focusing on engineering curricula and the professional skills related to entrepreneurship were analysed in the second step. The most relevant articles, highlighted in bold in Table 1, were then analysed in detail by the authors.

Table 1 - SCOPUS query results

Authors	Title	Publication
Mareque, M et al.	The effects of personal and educational variables on the entrepreneurial culture of university students	JUL 2025
Lucena, L et al.	Innovating forest science education through problem-based learning: Insights from a public university in Brazil	MAY 2025
Branca, E et al.	The impact of entrepreneurial education on key entrepreneurial competencies: A systematic review of learning strategies and tools	JUL 2025
Ganefri et al.	**Cultivating digital entrepreneurs: Unravelling factors shaping digital entrepreneurship intention among engineering students in higher education**	JUL 2025
Alonso-Galicia, PE et al.	**Complex thinking as a component in entrepreneurship education and engineering classes: an empirical study**	MAR 2025
Letting, C et al.	Unveiling founder archetypes: the effect of distinct entrepreneurial traits on resource accuracy	MAR 2025
Krishna, VV et al.	The Rise of Chinese Universities: Research, Innovation and Building World-class Universities	MAR 2025
Shekhar, P et al.	(Dis)Engaging with entrepreneurial training: perspectives and experiences of women STEM faculty	FEB 2025
Cola, PA & Mangosh, TL	Empowering biomedical learners to navigate FDA regulatory processes and entrepreneurship with a novel interdisciplinary training approach	FEB 2025
Cocu, A et al.	**Technology-Enabled Learning for Green and Sustainable Entrepreneurship Education**	FEB 2025
Jones, PM	In search of the 'invisible' artisan during Europe's Industrial Enlightenment: James White, 1762-1825	JAN 2025
Chans, GM et al.	Exploring transversal competencies in engineering students through international experiences	JAN 2025
Arias, M & Flad, M	**Exploring the Factors Influencing Entrepreneurial Intentions of Engineering Students: A Comparative Study**	2025
Gallegos, A et al.	Factors that determine female entrepreneurial intention: A systematic review of the literature	2025
Korsah, GA & Amanquah, N	Developing Interest, Skills and Professional Dispositions in Computing and Engineering through a Multidisciplinary Enrichment Program for High School Students	2025
Zoelner, M	A discursive approach to the identity work of highly skilled transnational professionals in ambivalent contexts	2025
Chadha, D & Heng, JYY	**A scoping review of professional skills development in engineering education from 1980-2020**	DEC 2024
Sandhu, K et al.	Understanding entrepreneurial thinking for designers: Perspectives from entrepreneurs, academicians, product designers, and students	JUN 2025
Suto, Y et al.	**Developing future engineering leaders: Evaluating a novel entrepreneurship education course**	JUL 2025
Alnaser, AA et al.	Transforming Architectural Programs to Meet Industry 4.0 Demands: SWOT Analysis and Insights for Achieving Saudi Arabia's Strategic Vision	DEC 2024
Baltador, LA et al.	Design Thinking in Education: Evaluating the Impact on Student Entrepreneurship Competencies	DEC 2024
Friebe, M et al.	Sparking Technological Innovation Through CASS Educational Entrepreneurship Initiative	DEC 2024

[1] https://www.webofscience.com/wos/woscc/summary/4aea76fe-d2f2-41e5-9405-465c486661cc-015ae988a9/relevance/1

Jokic, SV et al.	Alignment of Learning Outcomes in the Technique and Technology Curriculum in Serbia with Key Competencies for Lifelong Learning: A Mixed-Method Convergent Design Approach	NOV 2024
Jung, SG et al.	Anthropometric Analysis of the Faces of Chinese Women in Leadership Roles	OCT 2024
Martínez, CGH	Investigative Competencies in High School Students: Contributions from the STEM (Science, Technology, Engineering and Mathematics) approach	MAR 2024
Ardeshir, A et al.	The strategic role of entrepreneurial computer engineers in shaping innovation ecosystems: innovation engineering	NOV 2024
Barcellos, DS et al.	Sectoral priorities in the modernisation of engineering education in Brazil	NOV 2024
Feola, R et al.	Developing cross-cultural competence in entrepreneurship education: What is the role of the university	NOV 2024
Shah, N et al.	Boosting entrepreneurial intentions among potential TVET entrepreneurs of higher education institutes	OCT 2024
Konak, A et al.	Enhancing student learning in innovation competitions and programs	MAR 2025
Hammoda, B & Winkler, C	Active methods in Entrepreneurship Education: a case study with engineering students	NOV 2024
Ilyas, IM et al.	Rethinking entrepreneurship and management education for engineering students: The appropriateness of design thinking	NOV 2024
Dávila-Morán, RC	Entrepreneurship perceived by students of private and public universities in Peru	JUL 2024
Rosienkiewicz, M et al.	Enhancing Technology-Focused Entrepreneurship in Higher Education Institutions Ecosystem: Implementing Innovation Models in International Projects	JUL 2024
Azeez, F & Aboobaker, N	Exploring new frontiers of experiential learning landscape: a hybrid review	NOV2024
Suárez-Brito, P et al.	Complex thinking and robotics: a proposal for sexual and gender diversity and inclusion training	JUL 2024
Marques, CP et al.	Attraction, passion and confidence: the paths to undergraduates' entrepreneurial intentions	OCT 2024
Barth, K et al.	Designing and Delivering a Cross-Campus Entrepreneurship Education Program	JUN 2024
Guo, X et al.	CREATION OR DESTRUCTION? RESEARCH NOVE STEM OPT EXTENSION AND EMPLOYMENT OF INFORMATION TECHNOLOGY PROFESSIONALS1	JUN 2024
Malhotra, S & Kiran, R	Integrating Cognitive Competency, Social Competency and Risk Propensity with the Theory of Planned Behaviour to Attain Sustainable-Development-Goal-8-Driven Sustainable Entrepreneurial Intentions	MAY 2024
Brakaj, EP & Safránková, JM	Navigating Entrepreneurial Horizons: Students Perspectives Analysis of the Entrepreneurial Competences in Teaching Context	MAY 2024
Brophy, M et al.	Competency-based training within the prison system: enhancing the likelihood of entrepreneurial activity upon release	MAY 2024
Tobar, LT et al.	Innovation with purpose: creation of an App for people with visual disabilities through the development of business and entrepreneurial skills in engineering students	MAR 2024
Qin, WW	How to unleash frugal innovation through internet of things and artificial intelligence: Moderating role of entrepreneurial knowledge and future challenges	MAY 2024
Alkhawaldeh, KA & Dabaghie, YM	Developing an entrepreneurial engineer mindset to expand future career opportunities for engineering graduates in Jordanian universities	OCT 2024
Rivas, DF et al.	Ultrasound and sonochemistry enhance education outcomes: From fundamentals and applied research to entrepreneurial potential	FEB 2024
Berbegal-Mirabent, J et al.	Boosting entrepreneurial competences beyond business and management-related disciplines. The case of engineering programs	FEB 2024
Kizilay, E et al.	A rollercoaster STEM activity involving virtual reality	APR 2024
Janowski, A & Szczepanska-Przekota, A	Entrepreneurship education in Poland: Contemporary problems and future opportunities	MAR 2024
Robles, S & Rampersad-Ammons, J	High impact sustainable transdisciplinary collaboration model for food justice	JAN 2024
Abu Bakar, K et al.	Entrepreneurial Intention Challenge in TVET Education	2024
Al-Juboori, H & Noonan, G	Concepts of Engineering Education Innovation and Design Thinking: Implementing the CDIO-approach Themes	2024
Al-Zoubi, A et al.	The Middle East Higher Education Experience: Implementing Remote Labs to Improve the Acquisition of Skills in Industry 4.0	2024
Baggetta, M et al.	Introducing CAD/CAE tools in Robotics Education: a Case Study from the Deetechtive Project	2024
Baima, RL et al.	Hybrid Active Teaching Methodology for Learning Development A Self-assessment Case Study Report in Computer Engineering	2024

Browning, JW & Bustard, J	A Systematic Literature Review of Entrepreneurial Education in Electrical, Electronic, and Computer Engineering Curricula	2024
Crudele, J et al.	Integrating Entrepreneurial Learning in Engineering Design Courses: Assessment of Entrepreneurial Self-Efficacy	2024
Escudeiro, P et al.	Revolutionizing Education: The European STEAME Teacher Facilitators Academy Project	2024
Fedorova, Y et al.	Emotional Intelligence Training Tools in Entrepreneurship Education	2024
Fontanella, S et al.	Technology in Engineering Education: The Sustainable Enterprise Business Game	2024
Garnapuspita, G et al.	Mapping Of Non-Formal Education In Pastry And Bakery Skills In West Java	2024
Kaminsky, O et al.	ASSESSING THE RESULTS OF TRAINING IN DIGITAL ENTREPRENEURSHIP IN THE AGE OF HIGH AND DEEP TECH	2024
Margherita, A et al.	Digital Transformation and Green Operations: A Successful Entrepreneurial Journey at Portobello Shop	2024
Martell, F et al.	Work in Progress: Innovation and Technology Management Key Topics for Engineering Graduate Education	2024
Mukhanova, MN	INNOVATIVE SOCIAL GROUPS IN THE INSTITUTIONAL CHANGES OF THE RUSSIAN COUNTRYSIDE	2024
Musa, T et al.	Catalyzing Sustainable Futures: Innovative Approaches in Capacity Building for the Community Engineering Response Team	2024
Ng, PHF et al.	Reimagining STEM Learning: A Comparative Analysis of Traditional and Service Learning Approaches for Social Entrepreneurship	2024
Pacher, C & Glinik, M	Fostering Entrepreneurial Mindsets in Deep Tech Disciplines: Exemplary Development of a Toolkit	2024
Probst, A et al.	Students' Views on the Internet of Things in Engineering Education	2024
Rico-Cortez, M et al.	Exploring the Industrial Engineering Competences in the Changing Landscape of the New Industrial Revolution	2024
See, CL et al.	Entrepreneurship in Engineering Curriculum	2024
Shekhar, P et al.	Investigating mechanical engineering students' approaches to opportunity recognition process	JAN 2024
Sitaridis, I & Kitsios, F	Digital Entrepreneurial Intentions: The Role of IT Knowledge and Entrepreneurial Program Learning	2024
Sitjongsataporn, S & Pantuprecharat, P	Development of Innovation-based Learning on Basic Electronic Components	2024
Susnea, I et al.	Digital Environments for Open-Access Entrepreneurship Education	2024
Vitliemov, P	HOW TO EDUCATE STUDENTS IN TECHNOLOGY ENTREPRENEUSHIP	2024
Lehoux, P et al.	What entrepreneurial skillsets support responsible value creation in health and social care? A mixed methods study	OCT 2024
Sahin, E et al.	STEM professional development program for gifted education teachers: STEM lesson plan design competence, self-efficacy, computational thinking and entrepreneurial skills	MAR 2024

4. Secondary research Discussion

Chadha & Heng (2024) conducted a scoping review of six professional skills development in engineering education from 1980 to 2020. Initially, entrepreneurship appeared less central in engineering education than other skills. However, the review's key findings indicate that all six skills, including entrepreneurship, became more prominent as a development focus over the 40 years. Notably, entrepreneurship experienced one of the most significant incremental changes in the frequency with which it was mentioned in the literature. This suggests a growing recognition of its importance for engineers.

Several factors contributed to this increased emphasis on entrepreneurship skills. The review notes that engineers increasingly turn their research outputs into business ventures, highlighting a practical

need for these skills. Furthermore, the review's literature analysis shows a trend of engineering students increasingly nurturing their entrepreneurial intent, especially in later decades (2010-2020).

The methods for developing entrepreneurship skills also evolved, including:

- Using e-teams to set up entrepreneurship projects and learning opportunities (1990-1999).
- Introducing an introductory course to develop entrepreneurship through product design (2000-2009).
- Supporting entrepreneurship through technology via bespoke programmes (2000-2009).
- Introducing project-based learning approaches to support students' entrepreneurship skills (2010-2020).
- Integrating entrepreneurship programmes into the curriculum (2010-2020).
- Using ICT tools to monitor student online activity in virtual companies set up to develop entrepreneurship (2010-2020).
- Utilising maker spaces to support entrepreneurship (2010-2020).
- Employing online business simulation platforms for teaching entrepreneurship (implied in the 2010-2020 discussion).

By the 2010-2020 decade, ABET (Accreditation Board for Engineering and Technology) was considered a significant driver of skills development, with entrepreneurship bridging creative problem-solving, business acumen, and technology. This indicates a formal recognition of entrepreneurship as a crucial skill for engineering graduates.

Finally, the review suggests a shift in the perception of entrepreneurship, moving from a purely "soft" skill to a more integrated and accepted competency, often linked with business acumen. This evolution reflects a greater understanding of the value of entrepreneurial thinking and skills for engineers in a changing world.

Ganefri et al. (2025) explored the impact of digital literacy, entrepreneurial mindset, digital entrepreneur attitudes, and locus of control on engineering students' intentions to pursue digital entrepreneurship. It also examined the moderating effect of perceived behavioural control on these relationships. The research focused on students at the Faculty of Engineering, Universitas Negeri Padang in Indonesia. Data was collected from 410 students who had taken digital entrepreneurship courses and analysed using partial least squares structural equation modelling (PLS-SEM).

The study concluded that digital literacy and digital entrepreneur attitudes significantly predict engineering students' digital entrepreneurship intention. Enhancing digital literacy and fostering positive attitudes towards digital entrepreneurship is crucial for cultivating future digital entrepreneurs.

The study acknowledges limitations, including the sample being restricted to one university and the cross-sectional design, which prevents the determination of how intentions evolve. Nevertheless, some of its key findings present valuable insights:

- Entrepreneurial mindset positively influences digital entrepreneurial attitudes and locus of control. This suggests that students with a proactive and opportunity-oriented mindset are

more likely to have positive views towards digital business and believe in their ability to control outcomes.

- Digital literacy positively influences digital entrepreneurial attitudes, entrepreneurial mindset, and digital entrepreneurial intention. This indicates that students proficient in using technology are more likely to have positive attitudes towards digital entrepreneurship, possess an entrepreneurial mindset, and intend to start digital businesses.
- Digital entrepreneurial attitudes positively influence locus of control and digital entrepreneurial intention. This implies that students with positive perspectives on innovation, technology, and digital commerce are likelier to believe they can control their outcomes and are more inclined to pursue digital ventures.
- Locus of control was found to have an insignificant influence on digital entrepreneurial intention. This suggests that whether students believe they control their lives did not significantly affect their intention to become digital entrepreneurs in this study.
- Perceived behavioural control did not significantly moderate the relationship between digital literacy and digital entrepreneurial intention, digital entrepreneurial attitudes and digital entrepreneurial intention, or locus of control and digital entrepreneurial intention. This was unexpected, suggesting that students' existing levels of self-regulation might not significantly alter how digital literacy, attitudes, or locus of control affect their digital entrepreneurial intentions.

The Alonso-Galicia et al. (2025) study aimed to analyze and compare engineering and entrepreneurship students' perceived mastery of reasoning-for-complexity competency and its sub-competencies (systemic thinking, critical thinking, and scientific thinking) at a private university in Mexico. The objective was to demonstrate that entrepreneurship is a valid discipline for developing scientific thinking, comparable to STEM fields like engineering. The findings indicated that reasoning for complexity is a relevant component in both entrepreneurship and engineering education, with no statistically significant difference in the overall perceived mastery between the two groups. Overall, the article advances the concept that scientific thinking can be a strength in entrepreneurship education, challenging the notion that it is solely the domain of STEM fields like engineering. The study supports the idea that entrepreneurship is a valid discipline for cultivating scientific thinking in its students.

Cocu et al. (2025) discuss developing and implementing technology-enabled learning tools and pedagogical strategies for green and sustainable entrepreneurship education (EE). The study highlights the urgency of addressing global crises through bottom-up initiatives driven by entrepreneurs and local communities. It argues that widespread education in green and sustainable entrepreneurship is a key strategy for tackling these challenges.

The main objective of the research was to develop a methodological framework for creating educational content for green and sustainable entrepreneurship and a scalable digital platform to deliver this content. The study addressed four research questions concerning the role of digital systems in supporting EE, the contribution of digital tools to green and sustainable EE, the fostering of creativity and innovation skills through these tools, and the potential of generative AI in creating effective digital content.

The researchers conducted literature reviews, stakeholder surveys, interviews with green entrepreneurs, and iterative platform design to achieve these objectives. They developed a cloud-based entrepreneurship educational system featuring three e-learning platforms: the business modeling (BM) platform, the business innovation and networking (BIN) platform, and the green and sustainable business (GSB) platform. The GSB platform was specifically designed for green and sustainable EE.

Key outcomes of the research include:

- A methodology for designing pedagogical strategies and learning content for green and sustainable EE.
- The creation of digital tools such as the green business innovation canvas (GBIC), TRIZ-inspired matrices, and AI-driven recommendation systems. The GBIC is a digital framework integrated into the GSB platform to help users design eco-friendly business projects.
- The development of a cloud-based educational system (CSEE) integrating the three e-learning platforms.
- The creation of a data repository of real-world case studies on green business practices gathered through interviews with entrepreneurs.
- A methodology for converting raw data on green businesses into structured digital content using generative AI and retrieval-augmented generation (RAG) technology.
- The development of ontologies (GBTrig-O and GBTeach-O) and corresponding knowledge graphs (GBTrig-KG) to support conceptual learning in green entrepreneurship.
- A Green Business Recommendation system, an AI chatbot enhanced with a GraphRAG pipeline, to provide answers on implementing sustainability in business projects.

The study's originality lies in integrating advanced digital tools with original pedagogical strategies to provide a scalable framework for incorporating sustainability into entrepreneurship education. The findings have practical implications for educators and policymakers promoting eco-friendly business practices.

The authors also discussed the importance of the digital economy and the challenges posed by the digital divide in the context of technology-enabled learning. They compared their research with related studies, highlighting the novelty of their approach in detailing the development of a cloud-based system and specific e-learning platforms using knowledge graphs and generative AI.

Based on the study by Arias & Flad (2025), several factors affect entrepreneurship in engineering students. The research explores explicitly entrepreneurial intention and its underlying factors, namely entrepreneurial mindset and attitudes, in engineering students compared to non-engineering students. Engineering students exhibit lower levels of entrepreneurial intention compared to non-engineering students. Entrepreneurial intention is an individual's drive to undertake entrepreneurial actions and is a reliable indicator of future entrepreneurial behaviour. The study found that the engineering group showed lower entrepreneurial mindset levels than the non-engineering group. An entrepreneurial mindset involves adaptive thinking and decision-making in complex, uncertain, and dynamic environments. The development of an entrepreneurial mindset in students is influenced by

providing regular opportunities to engage in entrepreneurial thinking and action through curricular and extracurricular activities.

While engineering students show lower entrepreneurial intention and mindset, the study found no significant difference in entrepreneurial attitudes between the engineering and non-engineering groups. Entrepreneurial attitude refers to the degree to which an individual holds a favourable or unfavourable evaluation of starting a business.

The study reveals that an entrepreneurial mindset significantly impacts entrepreneurial intention among engineering students. This suggests that developing an entrepreneurial mindset is vital for promoting their entrepreneurial intentions. While attitudes are generally linked to intention, this study found that mindset plays a more significant role in driving the entrepreneurial intentions of engineering students than non-engineering students, where mindset did not significantly influence intention.

Participating in entrepreneurship courses positively increases entrepreneurial intention, mindset, and attitudes for both engineering and non-engineering students. However, the study did not find a significant difference in the increase level between the two groups. Interestingly, the lower baseline values in mindset and intention among engineering students suggest they might have a higher potential for increase through targeted entrepreneurship education. Entrepreneurship education, particularly using hands-on learning projects, could increase engineering students' mindsets and, thus, their intentions. Integrating real-world assignments like internships at startups or established firms can also help cultivate a robust entrepreneurial mindset. Incorporating engineering projects that stimulate innovation and problem-solving abilities into the curriculum, like capstone projects, can also enhance students' entrepreneurial intentions.

Suto, Y et al. (2025) discuss a novel extracurricular entrepreneurship education course designed to develop future engineering leaders at a research-intensive university in Japan. The study aims to theoretically position this course, develop an evaluation method for entrepreneurship education, and structurally evaluate the course using this method. The authors highlight the increasing global demand for engineers with entrepreneurial skills due to factors like globalisation, uncertain environments, and social challenges like the Sustainable Development Goals (SDGs). They argue that engineers are now expected to go beyond technical skills and engage in marketing, management, and financing, requiring them to be more entrepreneurial and understand market and business contexts.

The course, named the Global Strategy Course, targets primarily first- and second-year undergraduate engineering students and aims to equip them with essential skills to establish new businesses, even within large organisations. The key objective is to cultivate the ability to adopt a bird's eye view of the world, analyse changes based on numerical data, identify the essence of these changes, and formulate global strategies. This key ability is broken down into five essential abilities: Global View, Corporate Analysis, Future Strategy, Future Needs, and Beyond Present. The course uses annual reports of real companies as learning materials, challenging students to develop business proposals for the next 10–20 years for a smaller company to overtake a larger one. The course involves desk research, lectures, exercises, and discussions with business leaders. Developing a new business proposal involves four phases: Observations by desk research, Finding deep insights, Business ideation and formulation, and Business proposal with desk simulation. The teaching model is categorised as a demand-competence

model. Evaluating the course's impact involves analysing students' new business proposals based on the five essential abilities and their self-reflective reports.

The study concludes that the course develops several entrepreneurial/entrepreneurship competencies in engineering students, including marketing skills, learning skills and attitudes (to accept uncertainty), opportunity skills, strategic skills, financial and economic literacy, and interpersonal skills. The authors propose a method for evaluating entrepreneurship education programmes by linking practical conditions with the assessment of student work and offer a practical framework for entrepreneurship education.

5. Conclusions

This document reports the third round of secondary research done by UPorto and which will be incorporated in deliverable 2.4 “E4E Skills Strategy: Anticipating Skill Requirements for the Engineering Profession”.

The latest literature on the entrepreneurship skills for engineers was analysed. The main source of information resulted from the SCOPUS database. The literature review revealed an increased relevance of the entrepreneur mindset for future engineers. Several articles published in the last months present studies on incorporating this skill set in engineering curricula. Some of the analysed articles analyse the curriculum design incorporating courses on entrepreneurship for engineers.

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ENGINEERS 4 EUROPE

E4E

Engineers for Europe

September 1, 2022 - August 31, 2025

Project Ref. Nr.: 101054872 — E4E — ERASMUS-EDU-2021-PI-ALL-INNO

Contribution to Secondary Research:
The Role of VET Systems in the Future Skills of European Engineers

SEV IVEPE
Leading knowledge & skills

Partner: IVEPE-SEV

31st March 2024

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ENGINEERS 4 EUROPE

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I. The Role of VET Systems in the Future Skills of European Engineers

Vocational Education and Training (VET) systems play a vital role in shaping the future workforce, particularly in technically demanding professions such as engineering. Across the European Union (EU), these systems function both as initial entry points into the engineering profession and as mechanisms for reskilling and upskilling engineers in response to technological advancements, industrial transformation, and sustainability transitions.

II. The Diversity of VET Systems Across Europe

VET systems vary considerably between EU countries in structure, governance, and effectiveness. Germany's dual system is frequently cited as a model of excellence due to its close integration of on-the-job training and classroom instruction (Euler, 2013). By contrast, countries like Spain, Italy, and Greece have historically relied more heavily on school-based vocational education with limited industry collaboration, resulting in weaker employment outcomes for VET graduates (Cedefop, 2020a).

Such differences highlight the need for systemic reforms and greater coherence in European VET systems, especially when considering their potential to serve as a credible pathway into engineering. The European Commission has responded with initiatives like the European Alliance for Apprenticeships and the promotion of mutual recognition of qualifications (European Commission, 2020).

III. Best Practices and Innovative Approaches

Industry Collaboration

Effective VET systems in engineering rely on robust collaboration with industry partners. Austria, Denmark, and the Netherlands are notable for involving industry in curriculum development, quality assurance, and certification processes (Cedefop, 2020b). This ensures VET remains aligned with the dynamic needs of the engineering labor market, especially in digitalization and green technologies.

Centres of Vocational Excellence (CoVEs)

CoVEs are emerging as key actors in innovation, lifelong learning, and regional economic development. These centres combine vocational training with applied research and partnerships with SMEs, enabling them to serve as regional hubs for workforce transformation (European Training Foundation, 2023). Their relevance to engineering is especially notable in areas such as green energy, robotics, and sustainable construction.

Flexibility and Pathways to Higher Education

A major strength of VET systems in countries like Finland and Sweden is their permeability—students can transition from vocational qualifications into higher education pathways, including engineering degrees (OECD, 2019). This flexibility enables upward mobility while supporting lifelong learning principles, which are essential for engineers to remain relevant in a fast-changing technological environment.

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IV. VET and Reskilling the Engineering Workforce

As industrial sectors transition toward green and digital paradigms, engineers need to continuously adapt. VET systems are uniquely positioned to offer flexible, targeted reskilling programs. For example, the automotive industry's shift to electric mobility has led to new VET-based curricula focusing on battery systems and e-mobility engineering (Reuters, 2024). These rapid-response programs are often faster and more adaptable than traditional university programs.

Additionally, initiatives such as "Pact for Skills" under the EU Skills Agenda promote public-private partnerships to drive large-scale upskilling for engineers in sectors like construction, electronics, and sustainable manufacturing (European Commission, 2020).

V. Key Challenges Facing VET Systems

Despite their potential, VET systems face a series of persistent challenges:

Quality and Standardization: Disparities in training quality and recognition hinder mobility and equivalency of qualifications (Cedefop, 2020a).

Technology Integration: Rapid developments in AI, robotics, and sustainability call for constant updates in engineering training content—something many systems struggle to achieve (European Commission, 2023).

Inclusivity: Social barriers still limit access to engineering-related VET programs, particularly for women, migrants, and people with disabilities (European Agency for Special Needs and Inclusive Education, 2021).

VI. Proposals to Enhance the Attractiveness and Effectiveness of VET for Engineering

Despite its strategic importance, VET often suffers from a perception problem in many EU countries, where it is viewed as a "second-class" option compared to academic pathways (Cedefop, 2017). If the EU wants to meet future skills needs—particularly in technical professions such as engineering—VET must become a more visible, flexible, and aspirational part of the lifelong learning ecosystem.

a. Raising the Status of VET Through Branding and Awareness

VET suffers from a persistent image problem in many European societies. Campaigns like the European Commission's *European Vocational Skills Week* and national initiatives such as Austria's *Lehre mit Matura* (apprenticeship with higher education access) show that branding matters. More coordinated communication strategies—promoting success stories of VET-to-engineering career pathways—could shift public perceptions (Cedefop, 2020a; European Commission, 2020).

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Policy Proposal: A Europe-wide campaign highlighting VET engineers as "next-generation problem-solvers" in green energy, infrastructure, and digital technology fields

b. Strengthening Cross-Border Recognition and Mobility

To enhance labor mobility and student exchange, qualifications gained through VET should be more transparently recognized across borders. Instruments like the European Qualifications Framework (EQF), the European Credit System for VET (ECVET), and Europass are steps in the right direction—but adoption is uneven.

Policy Proposal: Enforce consistent implementation of EQF-aligned qualifications and modular learning units that allow engineers-in-training to move freely across EU member states while accumulating credits (Cedefop, 2020b).

c. Embedding Green and Digital Skills in VET Curricula

Engineering professions are at the heart of the twin transitions—digital and green. However, Cedefop's (2023) research indicates that many VET programs lag behind in embedding sustainability principles, circular economy practices, and digital competencies.

Policy Proposal: Make green and digital skills *core* elements of all VET curricula by 2030. Include hands-on projects in areas like renewable energy design, smart manufacturing, and low-carbon construction technologies.

d. Integrating Entrepreneurial and Soft Skills

The future engineer needs more than just technical knowledge. Skills in communication, teamwork, adaptability, and entrepreneurship are increasingly important (OECD, 2020). Yet, these are often undervalued in VET programs.

Policy Proposal: Introduce mandatory "21st-century skills" modules in VET engineering pathways, co- designed with professional chambers and industry experts

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e. Lifelong Learning Incentives and Microcredentials

Given the pace of technological change, mid-career engineers require rapid, accessible ways to upskill. Microcredentialing—a system of short, verified learning units—can complement full qualifications and enable continuous learning.

Policy Proposal: Create a European platform for engineering-specific microcredentials that are stackable, industry-recognized, and linked to the EQF. VET providers should be funded to co-develop these in partnership with chambers of engineers and trade unions (European Training Foundation, 2023).

f. Funding and Infrastructure for VET Innovation

Many VET institutions lack modern labs, digital infrastructure, or faculty development budgets. To remain relevant, they need funding akin to that of universities.

Policy Proposal: Expand the EU's *Digital Europe* and *European Social Fund Plus (ESF+)* allocations to support equipment, AI integration, and digital twin technologies in VET centers specializing in engineering education (European Commission, 2023).

VII. Conclusion

To address Europe's engineering skills gap, VET systems must not only serve as effective training platforms but also as aspirational, future-facing engines of professional development. By improving their image, ensuring cross-border recognition, integrating green and digital competencies, and supporting lifelong learning, the VET ecosystem can become a powerful tool for attracting talent into engineering. Forward-thinking policy interventions, sustained funding, and deep industry collaboration are essential to unlocking this potential.

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ENGINEERS 4 EUROPE

E4E
Engineers for Europe
September 1, 2022 – August 31, 2025
Project 101054872 - ERASMUS-EDU-2021-PI-ALL-INNO

KU LEUVEN

Title of the report: Partner Snapshot KU Leuven – the evolving nature of the engineering profession

Work Package: WP2

Date: 21.02.2025

Developed by: research associate Polina Jansen

Project Partner Manager: Prof. Greet Langie

Contents

1. Background section

A special place in the list of the competencies necessary for a modern engineer is taken by professional competencies, which are also called transversal or transferable competencies.

Unfortunately, as we mentioned in the previous study, there is currently no single universal definition of professional competencies. UNESCO resources mainly use the term "transversal skills", which is defined as "skills that are typically considered as not specifically related to a particular job, task, academic discipline or area of knowledge and that can be used in a wide variety of situations and work settings (for example, organisational skills)." (UNESCO-UNEVOC, TVETipedia Glossary, 2025). However, many academic researchers prefer the term 'professional competencies'. The Faculty of Engineering Technology of KU Leuven also belongs to this category.

To grasp the latest trends in modern engineering education, it is essential to examine the overall state of the global labour market. According to the Future of Jobs (2025) report, the following trends exists today:

- Rising cost of living and a general slwdown in economic growth are two facts affecting job creation, which is expected **to increase demand for creative thinking and skills of resilience, flexibility and agility.**
- Geo-economic fragmentation is also driving the need for people-centred skills such as **resilience, flexibility, agility, leadership** and **social influence,** as well as **global citizenship**. In a world where crises are becoming more frequent, employers need leaders and teams that can adapt to uncertainty and manage complex social dynamics.
- **Analytical thinking** remains the most sought-after core skill among employers, with seven out of ten companies considering it essential in 2025. It is followed by resilience, flexibility and agility, as well as leadership and social influence (see Fig.1).
- **Resilience, flexibility and agility** are growing in demand more quickly in **Information** and **Technology Services sectors**.
- By 2030, skills such as analytical and creative thinking, resilience, adaptability, agility, and technological literacy are expected to become even more essential than they are today. Equally important will **be leadership, social influence, curiosity, lifelong learning, systems thinking, talent management,** and **self-awareness**, emphasizing the enduring value of human-centric capabilities in an era of rapid technological advancement.

The Royal Academy of Engineering and the National Engineering Policy Centre (2024) also highlight the importance of qualities such as **resilience, future orientation, social responsibility and inclusiveness for modern engineers** (see Fig.2).

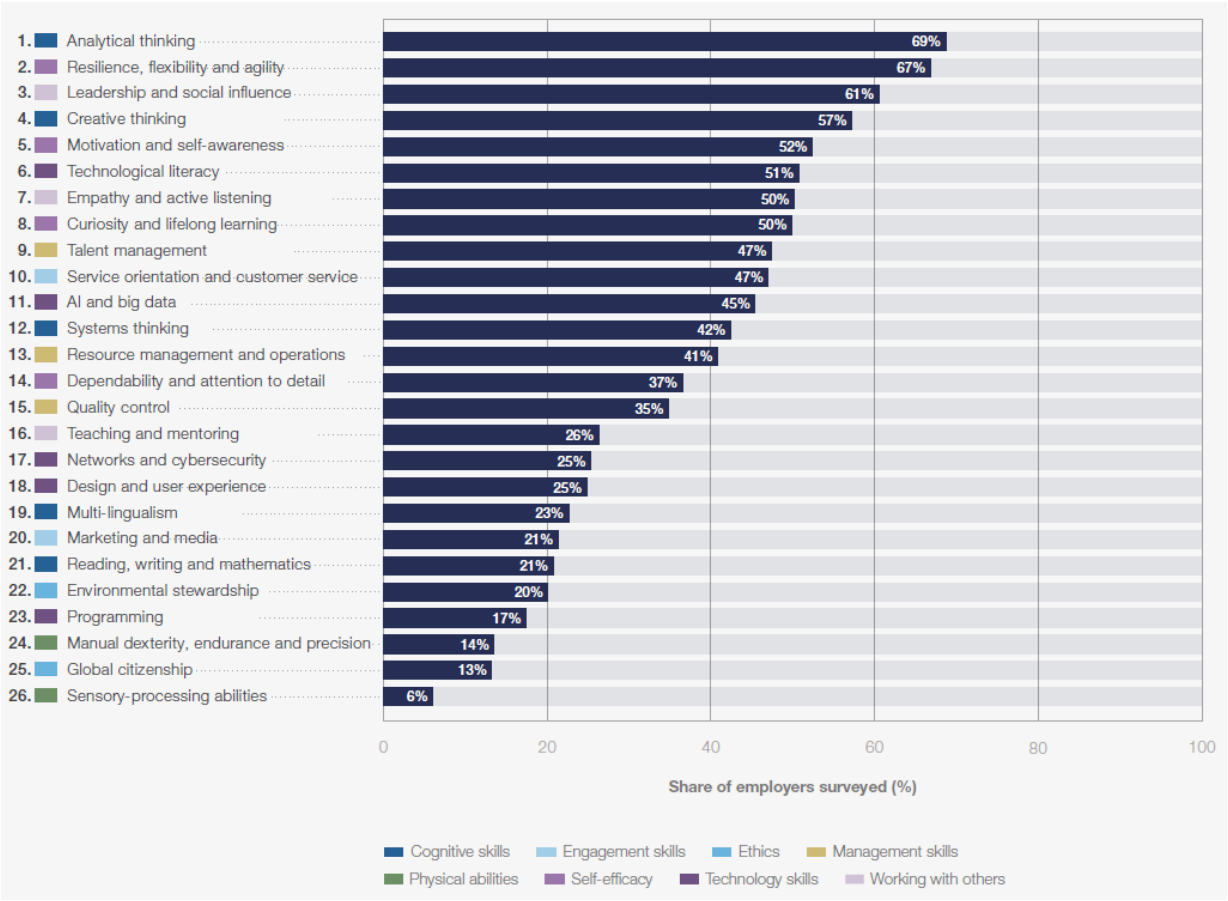

Figure 1. Share of employers who consider the stated skills to be core skills for their workforce (Future of Jobs report 2025).

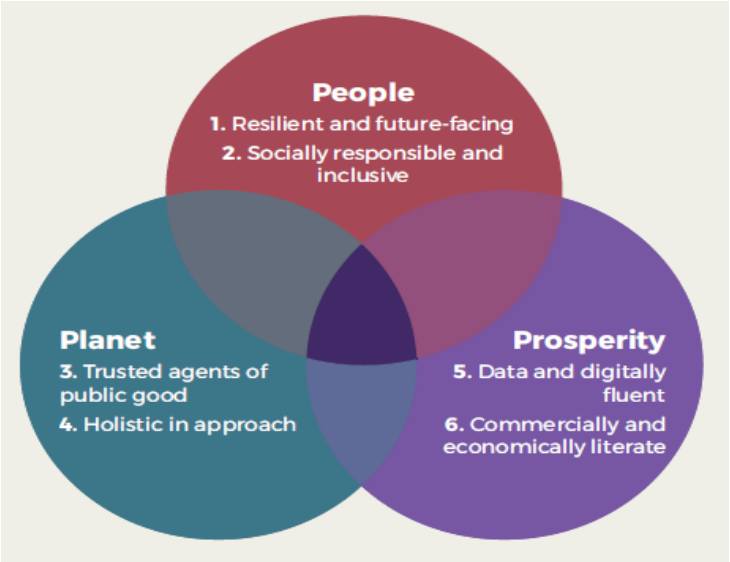

Figure 2. The six principles of the Engineers 2030 report (The Royal Academy of Engineering and the National Engineering Policy Centre (2024).

2. Methods

The search was made through the databases:

- Limo Libis KU Leuven;
- ResearchGate;
- Scopus;
- Web of Science.

The following keywords were used for the search in the title and the abstract as recommended by the E4E-management:

1. “engineering profession” AND “evolution” AND “5 years” OR “10 years”
2. “engineering” AND “professional competencies” OR “professional skills” OR “transversal skills” OR “non-technical skills”
3. “engineering” AND “teaching” AND “professional competencies” OR “professional skills” OR “transversal skills” OR “non-technical skills”
4. “engineering profession” AND “skills and competencies” AND “changing nature” AND “challenges” OR “opportunities”

Inclusion/exclusion criteria:
Only scientific resources from mid-2024 onwards were included in the search.

Number of resources included in the review:

18 resources were found. However, after checking the content, only 7 of them were found to be relevant to the current topic:

- 4 academic articles,
- “Future of Jobs Report 2025”
- “Rethinking engineering and technology skills for a world in which both people and planet can thrive. Vision and principles. A consultation. National Engineering Policy Centre, UK & Royal Academy of Engineering”
- UNESCO-UNEVOC. (n.d.). TVETipedia Glossary.

3. Findings

In this chapter, it is outlined which professional competencies are considered to be the most in-demand for the modern engineers from the perspectives of students (Barr et al. 2024), early-career engineers (Akinci-Ceylan & Ahn, 2024) and industry representatives (Salaj et al. 2024). In addition, gender differences in engineering students' professional competencies were analysed to address potential barriers to gender inclusiveness in this field (Craps et al. 2024).

In their multiple-case study, Akinci-Ceylan & Ahn (2024) interviewed **26 early-career engineers** from seven organisations in the Aerospace and Defence industry across the U.S. The findings highlighted the need for teaching professional competencies, fostering collaboration between different engineering departments, promoting lifelong learning, and enhancing collaboration between academia and industry. Interviewed participants emphasized that professional competencies were lacking in their engineering study programs. Thus, they recommended that engineering programs place greater emphasis on professional competencies. Participants also emphasized the importance of learning about workplace structure before entering the job market. They noted the differences between university and professional environments and recommended incorporating content on business practices and professional conduct into the engineering curriculum. Alongside understanding workplace dynamics, they highlighted the significance of social and networking skills, particularly effective communication with colleagues. They stressed that interacting with others in professional settings is just as crucial as technical expertise. Additionally, they underscored the value of relationship-building, teamwork on group projects, and offering support to others. Success in these areas, they suggested, enhances technical skills and helps alleviate challenges by fostering a supportive network of colleagues. Thus, they recommended offering courses on *communication skills* and *navigating professional environments*, as one participant recounted: "If you're not taught good communication skills, when you come out of college, you can really hurt your career by how you interact with others. I think it's probably one of the most important skills we could ever know, because even if somebody graduated engineering and then went a completely different route with their life, they still need to know how to talk to people. I don't think it's really taught in school".

The importance of communication skills for young engineers was also emphasized in a study by Barr et al. (2024), which they based on the analysis of **38 student assignments**, wherein apprentices were asked to identify the competencies they have demonstrated, with reference to a portfolio of work. The necessary framework for this study was provided by the UK Standard for Professional Engineering Competence and Commitment (UK-Spec), which outlines the competencies required for certification as an Incorporated Engineer. Of the five areas (A-E) into which the UK-Spec is organised, those competencies related to D. *Communication and inter-personal skills*, A. *Knowledge and understanding*, and B. *Design and development of processes, systems, services and products* proved to be the most widely claimed. Meanwhile, those competencies that fall under C. Responsibility, management or

leadership were less prevalent, and those related to E. Professional commitment were much less so.

The results of a study conducted by Salaj et al. (2024) among industry representatives in Norway also highlighted the need for the development of *communicational skills* among employees (see Table 1). This study was based on the questionnaire that was delivered to **63 major construction companies, SME and association centres in Norway**. **24%** of the respondents replied. The focus of this research was to investigate the expectations of companies on developing 21st-century competencies in the labour market. The research questions aimed to uncover the diverse perspectives of companies about the lack of competencies and skills that need to be developed in the higher educational workforce. Table 1 summarises the competencies that companies believe are the most lacking for their employees and have a strong impact on their performance. These competences are considered very important requirements in the labour market.

Corporate Social Responsibility and Inclusion	20%
Environmental justice	20%
Written and oral communication skills in a native language	20%
Self-initiative and self-control	13.33%
Innovation	13.33%
Creative solving of complex problems	13.33%
Learning to learn (ability to learn and persist in learning, organize own learning)	13.33%
Versatility (ability to fill in for absent employees)	13.33%
Ensure security (data privacy, human health, environmental protection, safe work with equipment)	13.33%
Collaboration and networking (with colleagues, clients)	13.33%
Ability to handle uncertainty	13.33%
Management and planning of processes, technologies, and people's work	13.33%
Advanced data/IT skills (e.g. artificial intelligence)	13.33%
Business and entrepreneurial skills	13.33%
Customization for change	13.33%
Proper and safe use of devices and materials	7.14%
Multicultural communication	6.67%
Experimentation and testing	6.67%
Written and oral communication skills in a foreign language	6.67%
Media literacy	6.67%
Reliability and accuracy	6.67%
Creativity	6.67%

Table 1. The lack of competencies among higher education employees, rated by company representatives (Salaj et al. 2024).

The last, but not least, important topic which we would like to highlight in this chapter relates to the gender differences in professional competencies. Craps et al. (2024) investigated gender differences in professional competencies among engineering students using the PREFER model. The aim of the study was to address potential barriers to gender inclusivity in the field.

The results indicated that female engineering students performed better in competencies related to customer-oriented roles, such as empathy and client focus, while male students excelled in areas like innovation and process optimization, including creativity and vision. However, most competencies showed no significant gender differences, suggesting that gender disparities in engineering competencies may be less pronounced than traditionally assumed. These findings highlight the need for engineering education programmes to integrate professional competency development, ensuring a comprehensive skill set for all students and preparation for diverse career paths.

Addressing these differences through educational curricula could promote gender equality and enhance the attractiveness of engineering for a broader audience.

4. Discussion

This secondary research confirms the results of two previous secondary research studies conducted within the E4E project regarding the importance of developing professional competences in engineering.

A new and interesting finding of this study was that all three groups of respondents (engineering students, early-career engineers and industry) unanimously identified communication skills as one of the most in-demand skills. This differs from our previous studies, in which the importance of professional competences was assessed differently by different groups of respondents. It is also crucial that all three studies that analysed respondents' views on the importance of competencies were conducted in different countries (USA, UK and Norway) and in different engineering industries (aerospace, defence and construction), but showed similar results.

Early-career engineers noted a lack of professional competencies in their engineering curricula and recommended offering several courses on communication skills and navigating the professional environment. Engineering students who had an internship in the industry also noted the importance of communication and interpersonal skills for the work process. Industry representatives also highlighted the need for the development of communicational skills among employees.

In this light, the research of Craps et al. (2024) on gender differences in professional competencies is of particular relevance. This study showed that competencies related to customer-oriented roles, which include communication competencies, are better performed by female engineering students, while male students excelled in areas like innovation and process optimization. In this context, promoting engineering among female youth and raising their awareness of various engineering roles is of particular importance.

In addition, we would recommend organising group assignments for students in such a way that there are representatives of both genders in each group. In this way, students will be able to help each other in developing missing professional competences.

5. Conclusions

Based on the conclusions of previous research reviews in the context of the E4E project and professional competences, the importance of professional competences is again confirmed. The type of knowledge and skills that are in most demand seem to evolve. When finalizing this review, the communication skills seem to be the most valued by engineering students, early-career engineers and industry.

This result is unique for two reasons:

Firstly, in previous studies, different groups of respondents prioritised professional competences in different ways. Engineering students payed more attention to project planning, business planning and competitor analysis (Mavriodou & Nanos 2023, Rico-Cortez et al. 2024). Industry professionals have other priorities: ethics (Aranda-Jimenez et al. 2024, van Heerden et al. 2023, Mavriodou & Nanos 2023, Rico-Cortez et al. 2024), problem-solving (Aranda-Jimenez et al. 2024, Fleming et al. (2023) and management (Abina et al 2024, Aranda-Jimenez et al. 2024) . Whereas in this study, they all agreed on the need to develop communication skills. As explored by Craps et al. (2024) female engineering students tend to value customer-oriented roles which require these communication skills.

Secondly, although communication skills were mentioned earlier as necessary, they were not identified as the top priority this time.

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World Economic Forum. (2025). Future of jobs report. Insight report.

Appendix – Evidence table

No	Author, year, study title,	Problem statement	Methodology	Key Findings	Limitations
1	Akinci-Ceylan, S., & Ahn, B. (2024, July 23). 'I think it's probably one of the most important skills we could ever know': insights from early-career engineers on the preparedness of undergraduate degrees for the aerospace industry. *European Journal of Engineering Education*. doi:10.1080/03043797.2024.2380888	This study examined how early-career engineers perceive their undergraduate engineering programs in preparing them for the workplace. Additionally, it investigated what domains the engineers identify for improvement in engineering programs.	In this multiple-case study, reseachers interviewed 26 early-career engineers from seven organisations in the Aerospace and Defense industry across the U.S. They employed open coding to examine their responses and derive common themes.	The findings showed that early-career engineers view technical knowledge and skills, persistence, and personal development instilled through their programs as valuable takeaways. However, they also highlighted the need for teaching professional skills, fostering collaboration between different engineering departments, promoting lifelong learning, and enhancing collaboration between academia and industry. The findings highlight areas in which engineering education and organisations can collaborate to better prepare students for the workplace.	This study offers insights from 15 male and 11 female newly hired engineers across seven A&D companies. Given the sample size, future studies could involve a larger and more diverse group of early career engineers, including those from other engineering disciplines, to capture a broader range of perspectives. Considering that the study mostly consisted of White participants and the lack of diversity in the A&D industry, examining the experiences and suggestions of underrepresented new engineers would be beneficial for identifying additional areas of engineering education that need improvement.
2	Barr, M., Morrison, A., Andrei, O., & Nabi, S. W. (2024). The Development of Students' Professional Competencies on a Work-Based Software Engineering Program. *SIGCSE 2024: The 55th ACM Technical Symposium on Computer Science Education*, (pp. 81-87). doi:10.1145/3626252.3630944	Researchers have used the five dimensions of the UK-Spec to design a framework for assessing professional computing competencies in a workplace-based module in a degree-level apprenticeship in software engineering program. Using such framework in assessing professional competency is essential since the faculty members are not (expected to be) expert practitioners in the tasks students have completed in their respective workplace.	The paper is based on an analysis of 38 student assignments, wherein apprentices were asked to identify the competencies they have demonstrated, with reference to a portfolio of work. The UK Standard for Professional Engineering Competence and Commitment, which outlines the competencies required for certification as an Incorporated Engineer, provided the necessary framework.	Competencies relating to communication and interpersonal skills were among those most often cited by apprentices, with competencies relating to knowledge and understanding and design and development systems also featuring prominently. Competencies relating to responsibility, management, or leadership were less prevalent, with professional commitment proving to be the least commonly cited category of competencies.	The most obvious threat to validity in this research is the self-report nature of the data: these are the competencies that apprentices report they have developed in the workplace.

No	Author, year, study title,	Problem statement	Methodology	Key Findings	Limitations
3	Craps, S., Matthijs, M., & Cannaerts, M. (2024). Exploring Gender Differences In Professional Competencies In Engineering Students. Insights From The Prefer Match Test. *52nd Annual Conference of SEFI.* Lausanne, Switzerland. doi:10.5281/zenodo.14254904	This study investigates gender differences in professional competencies among engineering students, aiming to address potential barriers to gender inclusivity in the field.	Utilizing the PREFER model, three distinct engineering roles were examined: Product Leadership, Operational Excellence, and Customer Intimacy. Through a situational judgment test, participants rated the appropriateness of responses to practical scenarios, allowing for an evaluation of competency levels.	Results reveal that female students scored higher in competencies associated with customeroriented roles, such as empathy or client focus, while male students excelled in innovation and process optimization competencies, such as creativity and vision. However, most competencies showed no significant gender differences, suggesting that gender disparities in engineering competencies may be less pronounced than traditionally assumed.	Cultural nuances and potential biases in assessment methodologies
4	Salaj, A. T., Torp, O., & Andalib, E. (2024). Competencies for smart city challenges. *IFAC-PapersOnLine. 58 (3)*, pp. 298-303. Elsevier Ltd. doi:10.1016/j.ifacol.2024.07.167	In accordance with European Skills Agenda, the study focuses on identifying skills needed for the future labor market and society. By analyzing the missing competencies identified by construction companies, it is possible to better renew the study programs for new students.	In the Competence Center of RESPO project, the KOC-TOP competence model has been prepared, in which the findings from EU recommendations (European Skills Agenda, Action plan for digital education 2021-2027, European green plan, New European Research Area, Eurostudent) was also considered. On the top, the competencies for the future were added, noted in different tender programs, such as creativity, innovation, empathy, critical thinking, solving problems, self-management and information technology. The questionnaire was delivered to 63 major construction companies, SME and association centres in Norway. 24% of the respondents replied.	The focus of the result part is on the competencies companies mostly miss from their employees from digital perspectives, e.g. reason to hire highly educated people, training possibilities for digitally upskilling employees, lacking appropriate competencies (critical thinking, systems etc.)	The study focused on Norway's labour market but did not include other countries.
5	The Royal Academy of Engineering & the National Engineering Policy Centre. (2024). *Rethinking engineering and technology skills for a world in which both people and*	The purpose of this study is to determine how industry employer-sought professional and technical competencies vary among engineering	Using a large sample (n=26,103) of mined job advertisements, we use the O*NET competencies database to determine the frequencies of	The most frequently sought professional competency is problem-solving; the	This study analyzes job advertisements scraped from one point in time (April 2021), therefore reflecting the job market

No	Author, year, study title,	Problem statement	Methodology	Key Findings	Limitations
	planet can thrive. Vision and principles. A consultation.	disciplines and levels of education.	different professional and technical competencies for biomedical, civil, chemical, electrical, environmental, and mechanical engineers with bachelor's, master's, and PhD degrees.	most frequently sought technical competencies across disciplines are Microsoft Office software and computer-aided design software. Although not the most frequently requested competencies, job advertisements including the Python and MATLAB programming languages paid significantly higher salaries than those without.	at that point in time. As the job market is rapidly changing and inflation is rapidly increasing in the United States, the available types of jobs and their associated salaries can change. Additionally, reseachers were limited to only being able to use one job advertisements website because of the terms of service for other (and possibly more popular) job advertisements websites, such as indeed.com or LinkedIn.
6	World Economic Forum. (2025). *Future of jobs report.* Insight report.	the World Economic Forum's bi-annual Future of Jobs Report has tracked the labour-market impact of the Fourth Industrial Revolution, identifying the potential scale of occupational disruption and growth alongside strategies for empowering job transitions from declining to emerging roles.	The core of the 2025 Future of Jobs Report is based on a unique survey-based data set covering the expectations of a wide cross-section of the world's largest employers related to job trends and directions for the 2025—2030 period.	**Analytical thinking** remains the most sought-after core skill among employers, with seven out of ten companies considering it essential in 2025. It is followed by resilience, flexibility and agility, as well as leadership and social influence **Resilience, flexibility and agility** are growing in demand more quickly in **Information** and **Technology Services sectors**. By 2030, skills such as analytical and creative thinking, resilience, adaptability, agility, and technological literacy are expected to become even more essential than they are today. Equally important will **be leadership, social influence, curiosity, lifelong**	**Survey Scope and Representation**: The report's conclusions are based on responses from over 1,000 employers, collectively representing more than 14 million workers across 55 economies. While extensive, this sample may not fully capture the diversity of global labor markets, potentially overlooking regional nuances and the perspectives of smaller enterprises.

No	Author, year, study title,	Problem statement	Methodology	Key Findings	Limitations
				learning, systems thinking, talent management, and **self-awareness**, emphasizing the enduring value of human-centric capabilities in an era of rapid technological advancement.	

E4E

Engineers for Europe

September 1, 2022 - August 31, 2025

Project Ref. Nr.: 101054872 — E4E — ERASMUS-EDU-2021-PI-ALL-INNO

Partner Snapshot [Newport Group]

LABOUR MARKET TRENDS IN THE ENGINEERING PROFESSION

Developed by: Newport Group, a. s.,
Dáša Sedláčeková, Daryna Mulchenko

Table of Contents

Executive summary

The nature of job postings in the EU is evolving, mainly occurring online. Consistent with this evolution, statistics will include online advertising, offering limited data. Demand for engineers is expected to grow both in the EU and Slovakia, driven by innovation, digitalisation, and the green transition. The clear need for a shift towards skills-based hiring has not yet translated into the recruitment models, which focus on degrees and traditional roles. Zooming for skills, strong hard skills (math, physics, software tools) are required for the engineering profession, with soft skills including adaptability, teamwork, computer literacy and stress and pressure resistance. Emotional intelligence strongly correlates with the employability of engineers.

Despite the drop in the job vacancy rate in Slovakia, engineering roles remain in high demand. As a strongly industry-oriented economy with a focus on automotive, where automation has cut jobs, still more roles are created than disappearing. Employers cannot count on the strong hard skills of graduates as research has shown a declining level of math literacy over the past decade. More than half of Slovak enterprises struggle to find adequately skilled staff. A mismatch between skills taught and labour market needs persists. Dialogue between VET and businesses remains limited with few initiatives to bridge the gap.

To address the demands and developments more flexibly, all stakeholders in the engineering labour market – educational institutions, businesses, and talents will need to refocus and reinvent their approaches. Also, hybrid employment models will continue to be in demand and the VET sector will need to implement changes more expediently to keep up with the fast pace of global developments.

Introduction

This research, as the activity of the Engineers for Europe project, aims to provide an in-depth analysis of labour market trends in the engineering profession, the digital transformation of industries and skills required, and the implications of the green transition.

To ensure the comprehensiveness and relevance of the study, 43 sources have been reviewed, including national reports, policy briefs, analyses, academic studies, and private-sector and consulting research. The selection of sources is guided by criteria such as relevance to the research topic, publication date (with a focus on data no older than 2020), peer-reviewed status, and geographic scope (Europe and the Slovak Republic).

The findings of this research are intended to inform stakeholders about emerging trends in the engineering profession.

Factors affecting the engineering labour market

In the past decade, green transition jobs and skills implications for the labour market have not been analysed, so CEDEFOP has prepared a forecast. Employment growth in architecture and engineering is forecast to be 2.7% higher, which is almost double compared to legal, accounting and consulting services in 2020–30. This reflects increased demand for engineers designing circular economy processes. In sectors such as energy, they will drive green-tech breakthroughs and shape newly-emerging high-skilled occupations. **Investing in engineering and scientific skills to ensure their availability should be a top policy priority[1].**

Skills shortages in construction also hinder achieving the ambitious EU green goals set for the sector. Between 2019 and 2022 companies in the construction sector that looked for green profiles were mainly recruiting construction supervisors, engineering professionals, civil engineers and research and development managers. Lean manufacturing – a production principle targeting the elimination of waste and improvements in efficiency – was the most sought-after green skill for all advertised green occupations. Environmental engineering – a field of knowledge centred around ensuring that societal development and the use of water, land and air resources are sustainable – was the second most in-demand skill across online ads for green jobs targeting civil engineers[2].

Interestingly, the introduction of new digital technologies in enterprises was associated more with the creation of new jobs than with their elimination. The highest demand was for workers with technical and IT education. Half of the enterprises participating in the survey into impacts of robotisation and automation experienced labour force shortages. Finding adequately

[1] https://www.cedefop.europa.eu/files/4206_en.pdf

[2] https://www.cedefop.europa.eu/files/9197_en.pdf

skilled employees emerged in the survey as the most significant obstacle to the introduction of new technologies. Almost 54% of enterprises considered it to be a major problem. [3]

The increasing adoption of automation and AI is reshaping the nature of work, with demand for technological skills expected to grow by 25% by 2030[4]. Roles requiring advanced IT capabilities, data analysis, and social-emotional skills will be prioritised as businesses adapt to digital transformations. Simultaneously, traditional roles reliant on basic cognitive tasks are likely to diminish, intensifying the need for large-scale reskilling and upskilling efforts.

Europe's emphasis on sustainability and digitalisation continues to create employment opportunities. Investments in renewable energy and low-emission infrastructure projects are driving demand for physical and manual labour in construction and related fields.

Hybrid working models and flexible employment arrangements are becoming standard practices to attract and retain talent. Additionally, immigration policies designed to address skill shortages and promote diversity in the workforce are being considered by many European nations.

The European engineering shows promising signs of growth. According to the latest Industry Barometer from the European Federation of Engineering Consultancy Associations (EFCA), 95% of countries report stable or increasing markets. The positive outlook is backed up by stronger order books, growing revenue, and growing profitability. Investments in transport infrastructure, climate adaptation, energy infrastructure, and building up resilient manufacturing industries are **key drivers**[5].

The dynamic expansion of the engineering sector is creating substantial demand for real estate and infrastructure development. The engineering sector is on a robust growth path, driven by investments in infrastructure, energy, and climate adaptation projects.

Despite the positive growth trends, the engineering job market faces several challenges. Staff shortages and increasing labour costs are the biggest hurdles facing the consultancy and engineering industry in Europe [6]. Engineering companies are focusing on strategic resourcing and workforce stability to deal with these challenges. Maintaining a flexible workforce, developing talent, and investing in current employees are key. In order to mitigate the impact of external hiring difficulties and talent shortages, employers should prioritize strategic hiring, development, and retention. As a job seeker, it shows the value of adaptability and continuous professional development.

[3]https://ivpr.gov.sk/vplyv-robotizacie-automatizacie-a-digitalizacie-na-trh-prace-v-sr-vysledky-empirickehoprieskumu-daniela-keselova-rastislav-bednarik-daniel-gerbery-darina-ondrusova-2022/

[4] https://www.euroengineerjobs.com/article/919/what-will-the-job-market-in-europe-look-like-in-2025

[5] https://www.darwinrecruitment.com/engineering-sector-growth-shaping-hiring-and-job-opportunities-in-2024-and-beyond/

[6] Jones, C. (2024). EFCA: 'Engineering consultancies of Europe remain strong and optimistic'. Construction Europe.

VET and labour market interactions

The responsibility for VET lies primarily with Member States, with the EU playing a supporting role. Since 2002, EU national authorities and social partners have taken part in initiatives to improve the performance, quality and attractiveness of VET in Europe. Known as the **Copenhagen Process**[7], this cooperation has been developed through a series of declarations; the current **Osnabrück Declaration**[8] expires in 2025.

The **European Education Area**[9] initiative also seeks to increase the exposure of VET graduates to work-based learning. The EU supports VET with funding under Erasmus+ and the European Social Fund Plus (ESF+). The EEA Strategic Framework impacts VET by promoting adaptability, quality, and inclusiveness in line with labour market needs. It encourages the integration of skills for the green and digital transitions. It also fosters closer collaboration between VET providers, employers, and social partners for the curricula matching real-world requirements.

Council Resolution on a strategic framework for European cooperation in education and training towards the European Education Area and beyond (2021-2030) 2021/C 66/01 can be found by the link.

In March 2024 **Labour and skills shortages in the EU: an action plan**[10] addressing labour and skills shortages in the EU, the European Commission committed to working with Member States and social partners to adopt a new declaration on VET in 2025. This declaration aims to continue the Copenhagen Process by aligning VET policies and reforms with the evolving labour market, *particularly in response to technological developments such as artificial intelligence*.

Highlighting the importance of VET, Commission President Ursula von der Leyen, in her **political guidelines**[11], emphasised enhancing the status of VET and increasing the number of individuals obtaining a secondary VET degree.

Additionally, Roxana Mînzatu, the Commission's Executive Vice-President for Social Rights and Skills, Quality Jobs, and Preparedness, has been tasked with developing a comprehensive EU strategy for VET, which is part of the broader initiative known as the Union of Skills.

In **Dradhi's report on the future of EU competitiveness**[12] (Mario Draghi – former European Central Bank President and one of Europe's great economic minds – was tasked by the European Commission to prepare a report of his personal vision on the future of European competitiveness). Mario Draghi acknowledged that the quality and effectiveness of VET systems across the EU are highly inconsistent and emphasised the need for wide-ranging

[7] https://ec.europa.eu/commission/presscorner/detail/en/memo_04_293

[8] Guido, N. (2021). Agenda europea per le competenze, Raccomandazione VET, Dichiarazione di Osnabrück.

[9] https://education.ec.europa.eu/about-eea/strategic-framework

[10] https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A52024DC0131&qid=1738059623002

[11] https://commission.europa.eu/document/e6cd4328-673c-4e7a-8683-f63ffb2cf648_en

[12] https://commission.europa.eu/topics/eu-competitiveness/draghi-report_en

reforms to prepare the workforce for technological advancements. This perspective was echoed during the **December 2024 Council meeting (EPSCO),** where EU ministers adopted conclusions stressing the importance of enhancing upskilling, reskilling, and lifelong learning opportunities to ensure that workers are equipped to adapt to the constantly evolving labour market.

Key Draghi report findings concerning the skills and labour market depending (M. Draghi, 2024, pp. 257 -280[13]):

- Future labour markets will be more automated and dynamic, which will put premia on skills that allow workers to complement machines, equip them to master new (digital) technologies and adapt to new developments.
- The shift towards highly skilled occupations will require significant upskilling and reskilling of the workforce. CEDEFOP predicts that highly skilled occupations will expand by some 12 million jobs, whereas skilled (non-manual and manual) occupations will shrink by around 3.5 million positions.
- **The influence of the green and digital transition will certainly be a source of change in the labour market during the next decade.**
- **An example of a severe shortage of occupation which can impact the EU's competitiveness is science and engineering professionals and associate professionals, which are essential to implement the twin transitions. There are currently 15 million workers in these jobs in the EU's workforce. According to CEDEFOP projections, there will be around 8 million job openings (new and replacement needs) between now and 2035. The majority of these jobs will be due to the replacement of current employees (six million job openings), but also around two million new jobs will be created due to the needs of the economy.**
- A contributing factor to skills gaps is the insufficient pace of STEM graduate production, which is failing to keep up with the growing demand in STEM-related jobs. Although the number of STEM graduates has increased from 18.5 per 1,000 individuals aged 20-29 in 2014 to 22 per 1,000 in recent years, this growth remains inadequate.

Job posting research: EU level

Globally, but also at the EU level, job posting has widely moved to and occurred at job portals or employers' websites, allowing for higher visibility, better targeting and spread across various countries and industries.

Indicative of the trend is that Eurostat has recently introduced the online job advertisement rate as novel indicator for measuring labour demand. As conducting surveys to offer detailed breakdown by profession would come at large cost and burden, the office's existing job vacancy statistics lack detailed breakdown by profession, which are essential for comprehensive assessment of recruitment bottlenecks. To address this issue, Eurostat has

[13] Draghi, Mario. The future of European Competitiveness: In-depth analysis and recommendations. European Commission, 2024.

amended the published job vacancy rate by occupation-specific breakdown obtained from the online job advertisement[14].

Engineering professionals (excluding electrotechnology) were among the top 10 occupations with the highest online job advertisement rate (2023)[15].

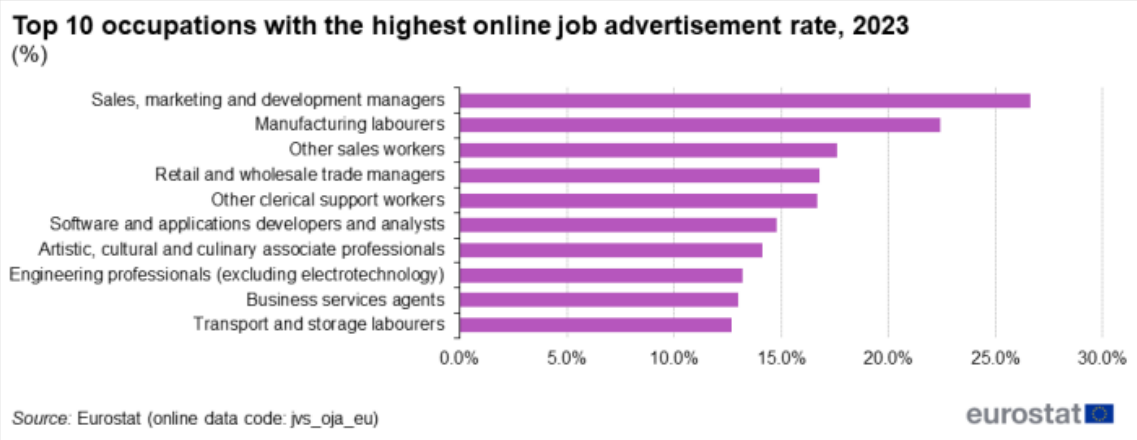

Figure 6: Top 10 occupations with the highest online job advertisement rate, 2023
Source: Eurostat (jvs_oja_eu)

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There is an array of engineering fields and majors as the global community needs to address diverse and changing problems. Triggered by the unprecedented challenge of the pandemic and the need to overcome never-before-faced challenges, the demand for researchers and engineers increased dramatically (from 4 percent of total EU employment, or 7 million in 2022). Most researchers and engineers are employed in the professional, scientific, and technical activities sector and in the manufacturing sector[17].

The employment of researchers and engineers is projected to increase by 23 per cent between 2022 and 2035. The diffusion of technological developments across economic sectors – such as Internet of Things in automotive and BIM in construction – will require researchers and engineers to develop new skills. [18]

By fields, engineering professions in most demand are Electronic Engineers (120), Industrial Engineers (103), and Mechanical Engineers (102)[19].

[14] https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Job_vacancy_statistics
[15] https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Job_vacancy_statistics
[16] https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Job_vacancy_statistics#Explore_further
[17]https://www.cedefop.europa.eu/en/data-insights/researchers-and-engineers-skills-opportunities-and-challenges-2023-update
[18]https://www.cedefop.europa.eu/en/data-insights/researchers-and-engineers-skills-opportunities-and-challenges-2023-update

[19] https://www.euroengineerjobs.com/

As trends suggest, analyses of skills required for a job role would call for skills-based hiring as a basis for evaluation, as opposed to credential-based hiring[20].

"Skills-based organisations," where skills – rather than jobs– are used as the basis for decision making about work and the workforce,[21] will be the organisations to outperform their peers. As LinkedIn's Workplace Learning Report suggests, skill-sets for jobs have changed by around 25% in the last 8 years[22]. By 2027, this number is expected to double. Accordingly, The Future of Jobs Report 2025[23] by the World Economic Forum reports that on average, workers can expect that two-fifths (39%) of their existing skillsets will be transformed or become outdated over the 2025-2030 period.

Skills-based organisations rethink traditional workforce practices to move the emphasis from jobs and roles to current and future workforce skills[24]. Applying skills-based hiring could help organizations access new talent pools, thus closing the workforce shortage gap. Still, only few job postings advocate for this approach.

Empirical research has revealed that majority of engineering job openings posted at job boards with a more representative sample still contain outdated descriptions of job roles, such as industry, education level, experience, and location. For a mechanical engineer, as an example, the prerequisite to be considered for the role is to hold a university degree in mechanical engineering[25].

A skills revolution is necessary to respond to the impact of the green transition in the short- and medium-term. All workers, across qualification and seniority levels, sectors and occupations need to be trained in an array of skills. Particular focus is necessary for occupations that drive "greenovation", which lies at the core of the green transition[26].

Skill requirements are subject to change as we see rapid technological changes, digital transformation of businesses and other external factors.

Eurostat found, that the most frequently sought skills in online advertisements (for all professions) in 2023 were adapt to change, work in teams, computer literacy, and English[27].

By category, online advertisements for engineering jobs normally include traditional hard skills, encompassing math and physics skills as these are necessary in nearly every engineering field.[28] In addition to mastering core concepts and methods of the discipline, proficiency in using tools and software for modelling, testing, calculations, and simulations will be needed. Depending on the specialisation, standards, codes and regulations knowledge is required by employers.

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[20] https://www.mckinsey.com/capabilities/people-and-organizational-performance/our-insights/right-skills-right-person-right-role

[21] Building tomorrow's skills-based organization: Jobs aren't working anymore
Sue Cantrell, Michael Griffiths, Robin Jones, and Julie Hiipakka, Deloitte,

[22] https://learning.linkedin.com/resources/workplace-learning-report-2023

[23] https://reports.weforum.org/docs/WEF_Future_of_Jobs_Report_2025.pdf

[24] https://www.deloitte.com/uk/en/services/consulting/blogs/2025/learning-for-a-skills-based-future.html

[25] https://www.euroengineerjobs.com/job_display/272376/Plant_Electrical_Control_Systems_Senior_Engineer_Westinghouse_Electric_Company_Madrid_Spain

[26] https://www.cedefop.europa.eu/en/data-insights/thyroid-occupations-biogas-technicians

[27] https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Job_vacancy_statistics

[28] Sadraey, M. H. (2022). Engineering fundamentals: An introduction to engineering. Springer.

These are complemented by soft skills, such as problem-solving, communication skills, creativity, and lifelong learning[29]. Stress and pressure resistance – emotional intelligence lies at the forefront of other skills[30].

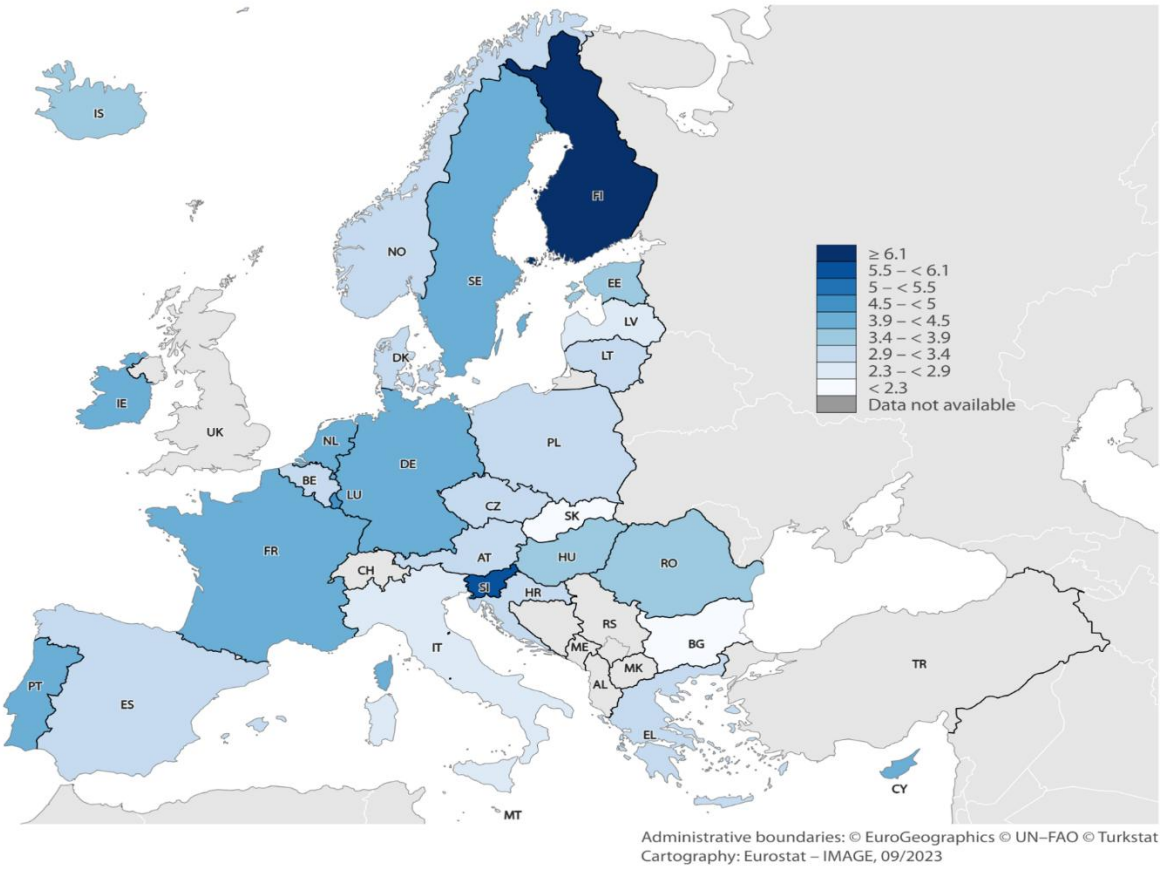

Figure 1: Researchers and engineers as a share of country employment (2021, in %)[31]

As a study devoted to socio-emotional competencies of engineers found, Emotional intelligence was proven to be a predictor of engineers' employability, which, in turn, depends on three factors: personal strengths that increase employment potential, self-perceived employment opportunities, and career development as a realization of employment potential[32].

29 https://www.linkedin.com/advice/1/youre-starting-mechanical-engineering-career-tdabc

30 **https://www.trend.sk/spravy/zabudnite-technicke-zrucnosti-buducnostou-pracovneho-trhu-je-nieco-uplne-ine?itm_brand=zivot**

31 https://www.cedefop.europa.eu/en/data-insights/researchers-and-engineers-skills-opportunities-and-challenges-2023-update#_employment_and_job_demand

32 Yepes Zuluaga, S.M. (2024), "Socio-emotional competencies as predictors of employability in engineering", *Higher Education, Skills and Work-Based Learning*, Vol. 14 No. 1, pp. 146-161. https://doi.org/10.1108/HESWBL-02-2023-0025

In 2021, the vast majority of researchers and engineers (89 per cent) have attained a qualification level of ISCED 5 or above, equivalent to the education level achieved after completing upper secondary education/ post-secondary non-tertiary education. The qualification level of the occupation is not expected to change over the period to 2035.[33]

Sadly, despite efforts to strengthen education and adult training over the last decade in the EU, adult literacy and numeracy skills in EU Member States mostly declined or stagnated, according to the second international Survey of Adult Skills (PIAAC).[34]

According to 2024 State of the Digital Decade package, the EU has not yet fully achieved convergence on most targets and objectives, and the pace of progress on some targets is slower than anticipated. This is particularly true in the fields of skills, high-quality connectivity, the adoption of Artificial Intelligence (AI) and data analytics by businesses, semiconductors, and start-up ecosystems[35].

Job posting research: Slovak level

In the Slovak Republic, the YOY domestic production growth in January 2025 slowed, reflecting softer increases in new construction (1.6% vs 12.2%) and buildings (3% vs 7.7%), along with a decline in engineering construction (-7.4% vs -2.4%). However, repairs and maintenance work went up (1.6% vs -14.9%)[36].

The Job Vacancy Rate in Slovakia decreased to 1.10 percent in the fourth quarter of 2024 from 1.20 percent in the third quarter of 2024. Job Vacancy Rate in Slovakia averaged 0.96 percent from 2004 until 2024[37].

The number of job vacancies in the Slovak Republic was consistent with the economic indicators of growth, mainly in the construction industry, where the construction engineers are most demanded profession (– profesia job portal (158 vacations as at 21 March 2025[38]).

Slovakia has a strong industrial and production tradition. Demand for high-qualified professionals in engineering roles grows every year. This is due to the pace of technological growth and the need for digitalisation and product innovation. Most demanded (highly-qualified) engineers are electrical planners/architects and HW and SW developers. Businesses

[33]https://www.cedefop.europa.eu/en/data-insights/researchers-and-engineers-skills-opportunities-and-challenges-2023-update
[34]https://employment-social-affairs.ec.europa.eu/news/survey-finds-adult-skills-have-declined-or-stagnated-last-decade-2024-12-10_en
[35] https://digital-strategy.ec.europa.eu/en/policies/2024-state-digital-decade-package
[36]https://slovak.statistics.sk/wps/portal/ext/home/!ut/p/z1/04_Sj9CPykssy0xPLMnMz0vMAfIjo8ziA809LZycDB0NLPyCXA08QxwD3IO8TAwNTEz1wwkpiAJKG-AAjgZA_VFgJc7ujh4m5j4GBhY-7qYGno4eoUGWgcbGBo7GUAV4zCjIjTDIdFRUBADse0bP/dz/d5/L2dBISEvZ0FBIS9nQSEh/
[37] https://ec.europa.eu/eurostat/
[38]https://www.profesia.sk/praca/stavebny-inzinier/?search_anywhere=udr%C5%BEate%C4%BEnos%C5%A5&sort_by=relevance&page_num=4#popover-box-out

look for various types of employment or forms of hiring other than employment, becoming more flexible in these terms[39].

While Slovakia has the National Digital Decade Strategic Roadmap of the Slovak Republic in place with a view of achieving more than 90% SMEs reaching at least a basic level of digital intensity, it is faced by a persistent lower rate of business productivity and insufficient up-take of digital technologies, especially in small and medium-sized enterprises[40].

Consistent with the EU development, universities and employers in Slovakia have registered declining levels of mathematical literacy among high school graduates in recent years. The situation is particularly critical in STEM fields of study at universities, for which the quality of mathematical knowledge, skills and capabilities of students affected by the post-2008 curriculum reform is insufficient to be properly trained for the current and future labour market needs. Astonishingly, the number of maths graduates has almost halved over the last 10 years[41].

Automation in the Slovak economy has caused a decline in technical professions with medium-level qualifications. This has not translated yet in the growing or falling tendency in employment rates. Slovakia also faces regional differences, where plans to level up the lower-performing regions are underway.

Slovak VET and labour market interactions

The hard and soft skills mismatch for the engineering profession in Slovakia calls for a dialogue between educators and employers. Empirical research has shown the lack of such dialogue, with some attempts to support the interaction between VET and businesses in Slovakia, e.g. the Catching-up regions initiative. The relevant means of dialogue identified by working groups in the domain are excursions and visits. Businesses can elicit needs by engaging in discussions in their role as practitioners with students within the framework of the educational process, as the Report on Cooperation between vocational schools and the employers in context of the job market suggests. [42] Low attractivity of study fields often stems from unreasonable expectations or the title not being attractive enough for applicants to consider application. It is recommended to align the study field titles with the job positions. A proper form of communication towards applicants can raise interest in VET in engineering fields.

[39] https://www.trend.sk/trendy-v-biznise/kvalitnych-ludi-je-trhu-nedostatok-klucom-uspechu-mozu-byt-inzinieri-kluc?itm_brand=trend&itm_template=article&itm_modul=neprehliadnite&itm_position=1

[40] https://mirri.gov.sk/wp-content/uploads/2024/03/National-Digital-Decade-Strategic-Roadmap-of-the-Slovak-Republic.pdf#page=2.33

[41] https://mirri.gov.sk/wp-content/uploads/2024/03/National-Digital-Decade-Strategic-Roadmap-of-the-Slovak-Republic.pdf#page=2.33

[42] https://web.vucke.sk/files/sk/kompetencie/skolstvo/dokumenty/report.pdf

In the area of skills, The Slovak Institute of VET (ŠIOV) has joined the EU Pact for Skills at national level with a view of promoting upskilling and reskilling for workforce in productive age.

When it comes to job placement, 58% of employed graduates stated in a survey conducted by ŠIOV that they work in the study field they studied or in a related field. Most frequent reasons for working outside the studied field were lack of interest in that field or problems with finding a job. The graduates found the skills acquired during the studies useful, occasionally inadequate for the current job market requirements. This primarily applies to technical skills where lack of practical training has been identified. 31% of graduates in dual VET were able to find employment in the business where they did the practical part of the studies. This is indicative of the lack of interaction between the businesses and the VET sector in accommodating the newly required skills into their agendas.[43]

[43] https://siov.sk/wp-content/uploads/2025/01/Narodna-sprava-k-pilotnemu-trasovaniu-absolventov-2024-final.pdf

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Partner Snapshot [Ordem dos Engenheiros]

ORDEM
DOS
ENGENHEIROS

Developed by: [Ordem dos Engenheiros]
2025

Contents

1. LIFELONG LEARNING AND CONTINUOUS FORMATION - BACKGROUND

Faced with an increasingly competitive market, investing in lifelong learning can be a determining factor in a successful professional career. In addition, companies also have a lot to gain from employees who are trained and up-to-date, contributing greatly to the evolution of countries.

Nowadays, the knowledge acquired in a bachelor's or master's degree is not enough. It's very important to have professional training, but it makes less and less sense to end the studies at the end of a three-year degree. In a world that is constantly evolving, lifelong learning allows everyone to keep up with the demands of their area of work and the world in general.

The culture of continuing education makes sense both personally and professionally, and is not just limited to conventional teaching methods. With so many resources at our disposal, such as the internet, videos, micro-accreditations, postgraduate courses, online courses and podcasts, for example, it is possible to dedicate time to continuing the studies at any time and from anywhere. (Fundação José Neves, 2020) (Empower up, 2024) (ABNT, 2024)

The concept of continuous training is related to the concepts of upskilling (improving and optimizing skills that have already been acquired) and reskilling (learning new skills that allow you to change careers or professional areas, for example). (Fevereiro, 2023)

Any engineer who invests in lifelong learning gains a number of advantages:

- Development and improvement of skills: engineers are allowed to acquire new skills or develop skills they already have;
- Keeping up with developments in the job market: the premise that a diploma is a certificate of knowledge for life no longer exists. Technical training has great value, but recurrent updating and training are just as important;
- Increased creativity: stimulating the mind to discover new paths and solutions allows creativity to develop; when we fall into a routine, the brain always works with the same references and does not evolve;
- Access to new job opportunities: companies value professionals who invest in updating their training, as it shows a willingness to evolve, a capacity for growth and proactivity; by learning more technical skills, it is possible to build the knowledge bases needed to be suitable for certain positions, opening doors to new job opportunities. (Fundação José Neves, 2020) (Nova School Business of Economics, 2024) (Empower up, 2024) (ABNT, 2024)

However, it's not just engineers who benefit from continuous training; institutions/companies also have a lot to gain from investing in training their employees, which can create added value for companies and the country.

Continuous training also creates a more dynamic working environment in a company,mora integration into the business project, as everyone shares knowledge with each other and grows together. Engineers stay motivated, looking for new solutions and encouraging continuous improvement.

Another benefit of lifelong learning is that it increases productivity, which means the company becomes more competitive, as it has better trained employees, better placement on the national or international market and higher profits. A country that has technically up-to-date engineers can have political influence and put the country on the front line. (Fundação José Neves, 2020) (Empower up, 2024) (Marra, 2025)

Examples of lifelong learning initiatives:

- Courses: programs focused on developing knowledge, available at higher education schools, continuing education companies, businesses, etc;
- Workshops and webinars: short training courses, with specific themes and objectives, in dynamic and interactive sessions aimed at improving skills;
- Mentoring/Coaching: personalized guidance for professional development;
- Online courses: educational programs accessible via the Internet;
- Debate Groups: participating in debates facilitates the exchange of information and knowledge;

In Portugal, it is currently compulsory for each company to provide 40 hours/year of training to each employee. (Marra, 2025)

2. METHODS

To prepare this document, secondary research was carried out using key words such as continuing education, lifelong learning, importance of lifelong learning for engineers; continuing education in engineering.

Research was also carried out in the INE (National Statistics Institute) database, the José Neves Foundation, newspapers, among others.

As exclusion criteria, we tried not to repeat sources used in previous Partner Snapshots, and that the bibliography should be no more than 5 years old.

3. FINDINGS AND DISCUSSION

In terms of **quantitative indicators**, it was possible to discover that:

- In Portugal, more than 50% of the young population over the age of 18 is in higher education. It should be remembered that the country has committed itself to reaching the European target of 60% by 2030;
- In 2022, the proportion of the resident population in Portugal aged 18 to 69 who participated in at least one formal education, non-formal education or informal learning activity in the last 12 months was 77,1 % (this rate decreased by 12,9 percentage points (p.p.) compared to 2016);

- Lifelong Learning, which encompasses participation in formal or non-formal education activities in the last 12 months, covered 45,6% of the population aged 18 to 69 living in Portugal in 2022, with the youngest and most educated populations having the highest participation rates in education and training (compared to 2016, this rate fell by 1,4%);
- The participation rate in formal education was 12,6%, well above the figure for the inactive student population (92,3%) (compared to 2016, the rate increased by 2,3%);
- The participation rate in non-formal education activities was 39,4%, with higher participation among the employed working population (49,5%);
- For 88,1% of people who took part in non-formal education activities, there was at least one activity that was work-related;
- Participation in informal learning activities was 70,4% in 2022, with 49,3% of the population aged 18 to 69 identifying at least one informal learning activity as work-related.

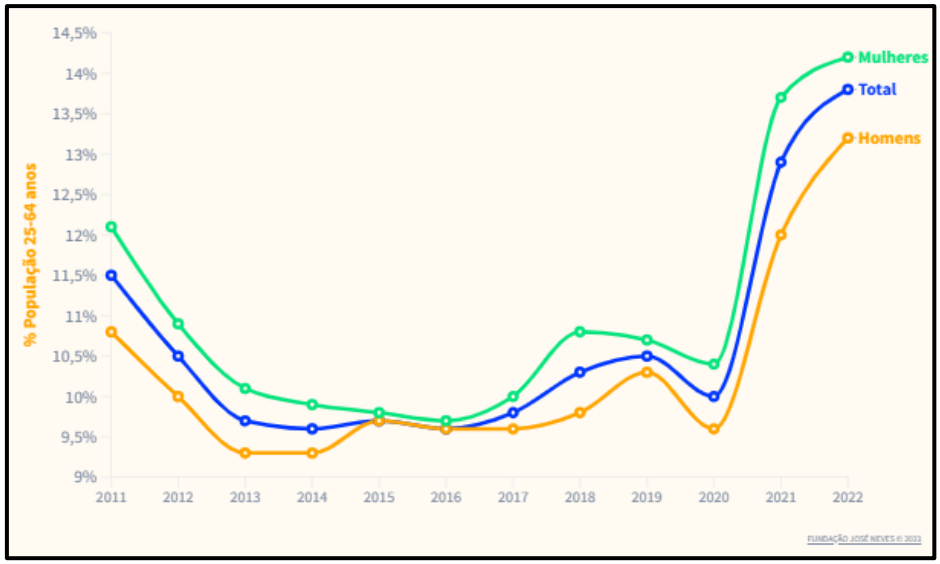

Figure 1: Percentage of adults participating in some kind of education or training program, by gender, throughout the years (in orange, man; in green, woman; in blue, the total). (Fundação José Neves, 2023)

The graphic in figure 1 shows that women are more likely than men to take part in continuing training activities. You can also see that more and more adults aged 25 to 64 are taking part in continuous education/training programs. (Fundação José Neves, 2023) (Pessoas 2030, 2024) (Instituto Nacional de Estatísticas, 2023)

In terms of **qualitative indicators**, the secondary research reveals:

- Lifelong learning is one of the most topical issues of the moment in Portugal;
- At least since 2016, the topic has been gaining prominence alongside the term “reskiling” and “upskilling”, and has been highlighted by the World Economic Forum as a necessity to guarantee employability and the supply of professionals in the midst of the digitalization of economies;

- “Reskiling” is the retraining of people, which is part of a broader approach to continuing education and lifelong learning;
- “Upskilling” aims to teach a worker new skills to optimize their performance;
- The Fourth Industrial Revolution has prompted major internal changes in companies in recent years. They have focused on renewing their corporate culture, digitizing their processes and promoting creativity and innovation among their employees. The latter, for their part, have been forced to embrace lifelong learning in order not to be left behind in the job market;
- In an increasingly competitive and uncertain world, it is crucial to invest in the continuing education of the adult population, so that everyone's knowledge is constantly updated;
- For universities, it is crucial to bring this public into the institutions through specific programs, such as professional master's degrees;
- Lifelong learning is needed in all areas;
- In Portugal, there is a skills shortage among the adult population;
- Society must promote inclusion. As such, everyone should have access to education, regardless of their background (no one should stop studying because of economic difficulties);
- Engineers must be prepared for the unpredictable. In this sense, resilience must also be promoted so that they can face the world's emergencies;
- New courses have emerged in force following the pandemic, as it has further highlighted the need for continuous training;
- The practice of always seeking new learning also leads to benefits in personal life, ensuring that engineers are always up to date with new technologies;
- Multigenerational education is already a reality in institutions. In Portugal there are already programs that train engineers - of all ages - with a specific skill, in order to respond to a specific need of a particular company;
- After training, engineering students do a six-month internship in companies, where they are then hired;
- In Brazil, there are Career Centers, which help students chart their path through education, and which apply the concept of multiversity (an aggregation of informally gathered institutions that provide a set of educational, research and consultation services, among others, to society);
- Educational institutions must be open and collaborative platforms, especially with society;
- Increasingly, we need to bring the job market into education. We must realize that today's engineering students are different and have different needs;
- Only education transforms, and you can't train without being aligned with society's needs;
- Despite the fact that the country has faced record unemployment due to the pandemic, the area of Information Technology has grown in 2020, which in turn has caused the number of applications for training courses in this area to rise;

- Even if the choice is personal, the desire to learn should be encouraged so that engineers feel more fulfilled and so that the job market has more and more specialized and competent professionals, thus positively impacting the country's economy;
- To ensure that learning is absorbed, teaching must be geared towards applying theory to practice. In William Glasser's famous pyramid, which shows how we learn, the act of doing and the act of teaching a subject to others are the main ways of absorbing new knowledge. That's why it's important to bring theoretical learning into the practical context of personal and professional life;
- Some measures implemented in Portugal at the moment:
    - Continuous training, by creating mechanisms to facilitate access to lifelong learning for workers through modular training included in the National Qualifications Catalog (Catálogo Nacional de Qualificações - CNQ);
    - Strengthening vocational education and the link between schools and companies, in order to raise qualification levels and significantly improve the quality of the offer in vocational education and training courses.;
    - Improving the professional certification system, with the enhancement and initial qualification of young people and the professional certification of young people and adults, both those who continue their training in long-term courses and those who opt for modular training, or even through the validation and recognition of skills obtained throughout life;
    - The Order of Engineers sponsors Futurália, which is the largest education and training event in Portugal, bringing together thousands of young people and professionals, eager for new opportunities and innovation. In 2024 it had 64,000 visitors, 15 countries represented, 336 entities and companies. More than an event, it is an opportunity for direct contact with educational institutions, training programs and professionals from different sectors. (https://futuralia.fil.pt)
    - The Order of Engineers is implementing a system of professional development for engineers, VALOR e, with a score being given to all basic and ongoing training, as well as years of proven professional experience. (Fevereiro, 2023) (Silva, 2023) (Instituto Nacional de Estatísticas, 2023) (Sena, 2021) (Do it Better, 2024)

4. CONCLUSIONS AND RECOMMENDATIONS

Despite the importance of continuing education and lifelong learning, there is still a long way to go to make it the rule rather than the exception in Portugal. Enrollment in continuing education and lifelong learning courses has increased since the pandemic, possibly due to the fact that more distance learning methods have also been developed.

There is a growing range of ways to promote continuing training, from workshops to face-to-face and online courses, etc., which makes it increasingly accessible.

Although there are already some measures in place to facilitate continuing training for professionals, more need to be developed, as there is an increasing need to complement the knowledge obtained in higher education with new knowledge.

There is also an increasing need to upskill and reskill more professionals, because the world of work is changing at a dizzying pace, and only in this way can professionals keep up to date.

It is very important that training courses combine theoretical knowledge with practical application, in order to maximize the knowledge retention rate of those enrolled.

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Annex 3: Template of the Partner Snapshot

E4E
Engineers for Europe
September 1, 2022 - August 31, 2025
Project Ref. Nr.: 101054872 — E4E — ERASMUS-EDU-2021-PI-ALL-INNO

Partner Snapshot REHVA

Developed by: Sofia Bazzano, REHVA

REHVA
Federation of European Heating, Ventilation and Air Conditioning Associations

TABLE OF CONTENTS

1. Introduction

REHVA, The Federation of European Heating, Ventilation, and Air Conditioning Associations, represents over 120,000 professionals in the HVAC sector across 26 European countries. This report presents insights from a recent survey on Green Skills within the HVAC industry, highlighting the evolving nature of the profession, key challenges, and recommendations for the future.

In this report, we provide the perspective on Green Skills in the HVAC sector in the countries that REHVA represents:

1. BULGARIA
2. ROMANIA
3. LATVIA
4. ITALY
5. FRANCE
6. MOLDOVA
7. SPAIN
8. BELGIUM
9. UNITED KINGDOM
10. DENMARK
11. ESTONIA
12. HUNGARY
13. FINLAND
14. SERBIA
15. LITHUANIA
16. NORWAY
17. PORTUGAL
18. POLAND
19. SLOVENIA
20. SLOVAKIA
21. CZECH REPUBLIC
22. SWEDEN
23. SWITZERLAND
24. TÜRKIYE
25. GERMANY
26. NETHERLANDS

2. Methodology

To assess the state of Green Skills in the HVAC sector, REHVA designed and conducted a structured questionnaire targeting professionals across various European countries. The methodology included the following steps:

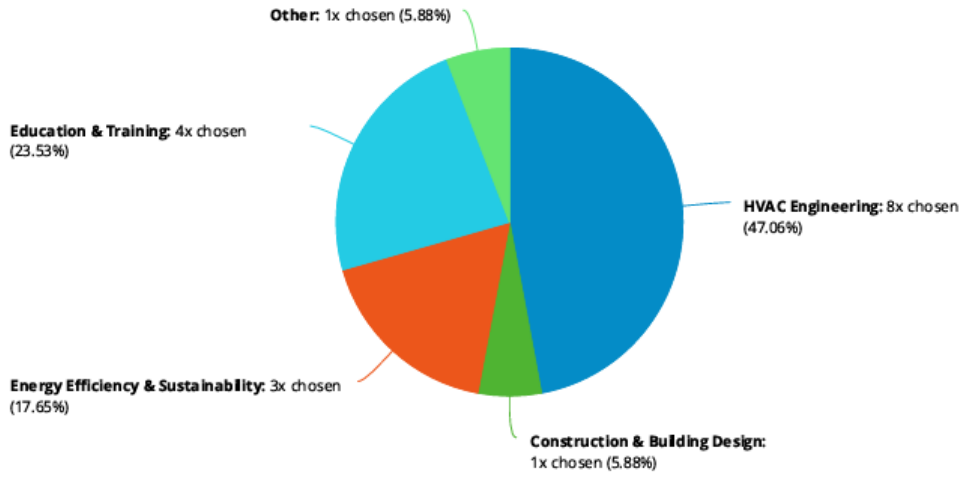
1. **Survey Design:** The questionnaire was developed with input from industry experts to ensure relevance to current HVAC trends. It included both qualitative and quantitative questions to capture a broad spectrum of insights.
2. **Target Audience:** The survey was distributed among HVAC engineers, educators, policymakers, and sustainability professionals across different sectors within the industry.
3. **Data Collection:** Responses were collected through online platforms, ensuring wide participation across multiple countries. A total of 17 responses were analyzed.
4. **Analysis Approach:** Quantitative data were assessed using statistical tools to identify key trends, while qualitative responses were reviewed for common themes and expert insights.
5. **Expectations:** The study aimed to provide a comprehensive understanding of industry needs, barriers, and opportunities for Green Skills adoption. The results serve as a foundation for future initiatives in training and policy development.

3. Quantitative indicators

Survey responses from 17 participants indicate a strong representation of HVAC Engineering (47.06%) and Education & Training (23.53%), with additional expertise in Construction & Building Design (5.88%) and Energy Efficiency & Sustainability (17.65%).

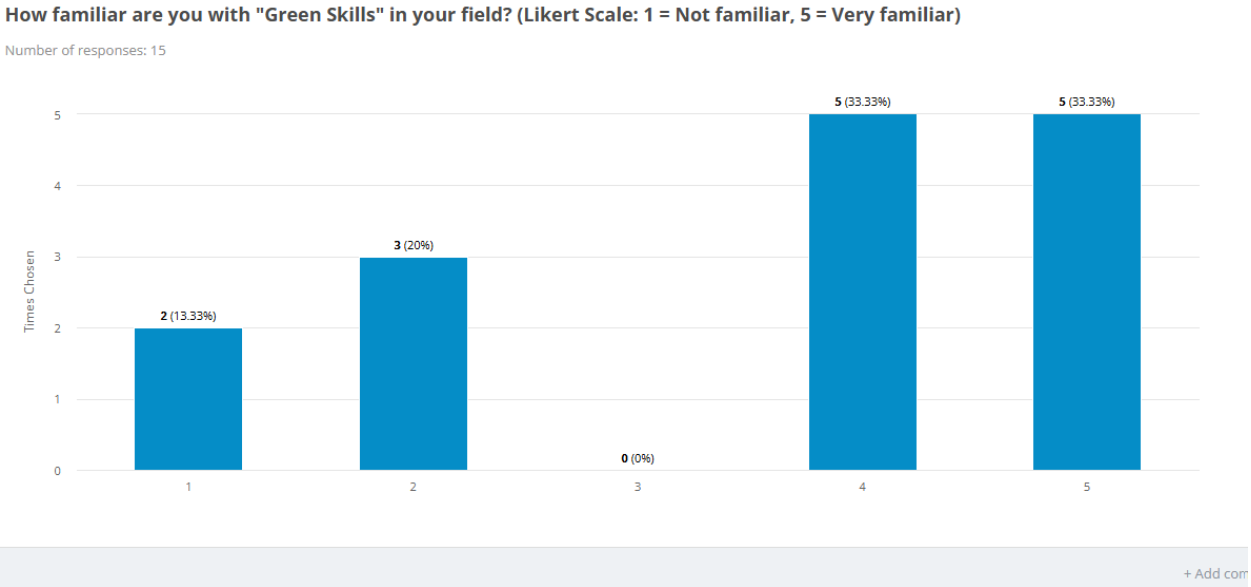
What is your primary area of expertise?

Number of responses: 17



Respondents work across various European countries, including the UK, Spain, Poland, Switzerland, and Romania.

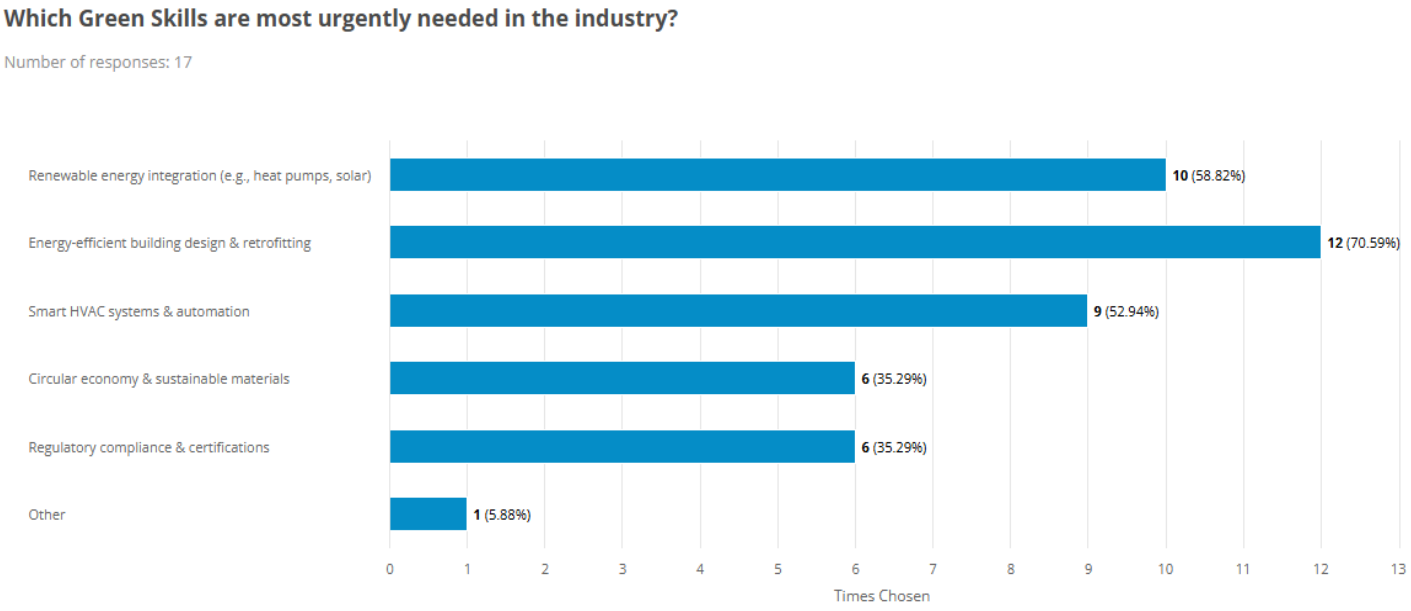
Familiarity with Green Skills is moderate to high, with 66.66% of respondents rating their knowledge at level 4 or 5 on a Likert scale. However, 13.33% reported minimal familiarity, suggesting gaps in awareness and training.



4. Qualitative descriptions

Key Green Skills identified as crucial for the industry include:

- Energy-efficient building design & retrofitting (70.59%)
- Renewable energy integration (58.82%)
- Smart HVAC systems & automation (52.94%)
- Circular economy & sustainable materials (35.29%)
- Regulatory compliance & certifications (35.29%)

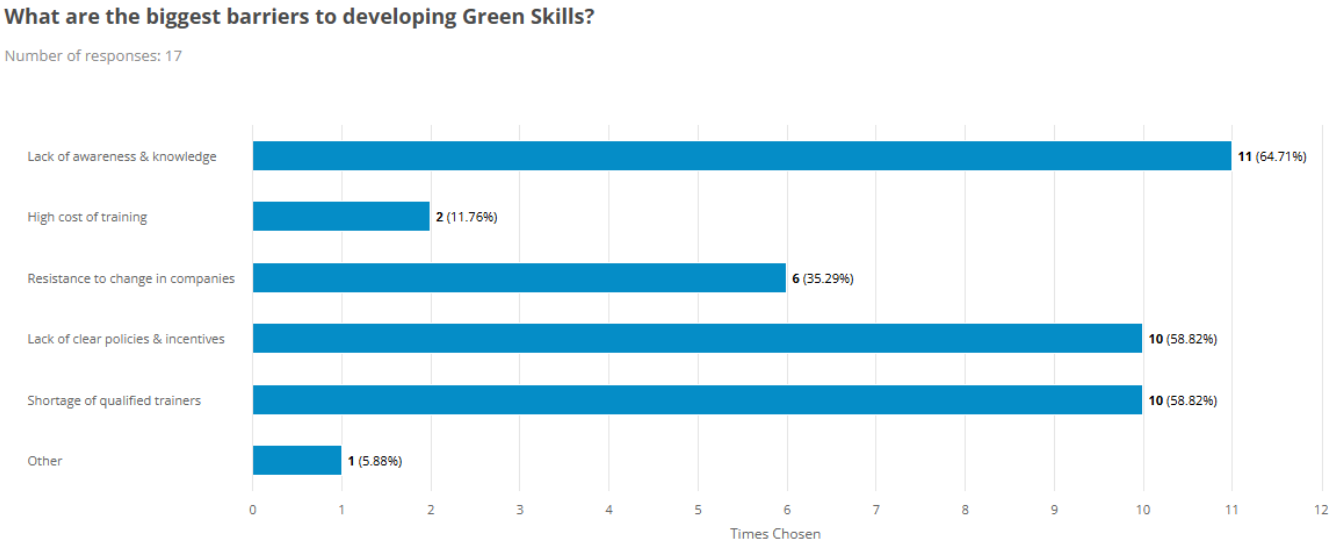


These findings emphasize a shift towards sustainability-driven competencies, with increased emphasis on digitalization, AI-driven energy optimization, and the expansion of sustainability regulations.

5. Conclusions and recommendations

Challenges:

- Lack of awareness & knowledge (64.71%)
- Resistance to change in companies (58.82%)
- Lack of clear policies & incentives (58.82%)
- High cost of training (35.29%)
- Shortage of qualified trainers (5.88%)

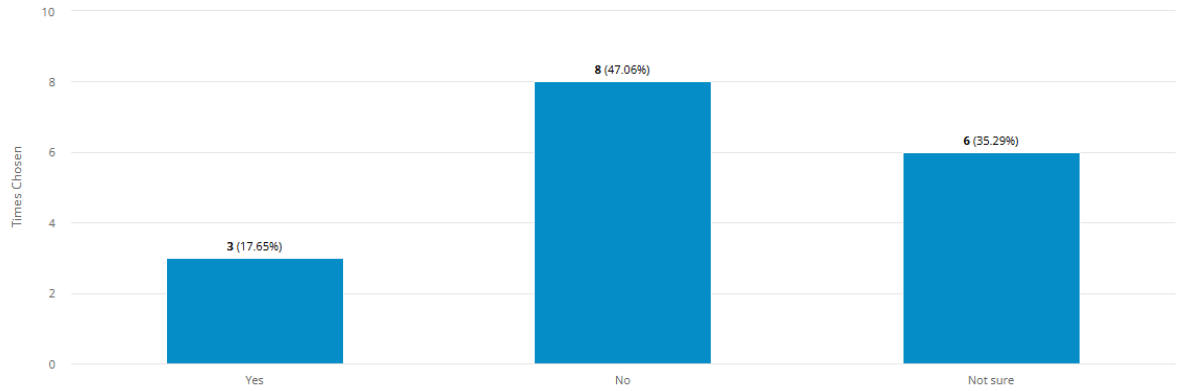


Opportunities & Training Needs:

- Effective training formats include in-person workshops (64.71%), vocational training (64.71%), and online courses/webinars (52.94%).
- University degrees/certifications are also seen as valuable (47.06%).

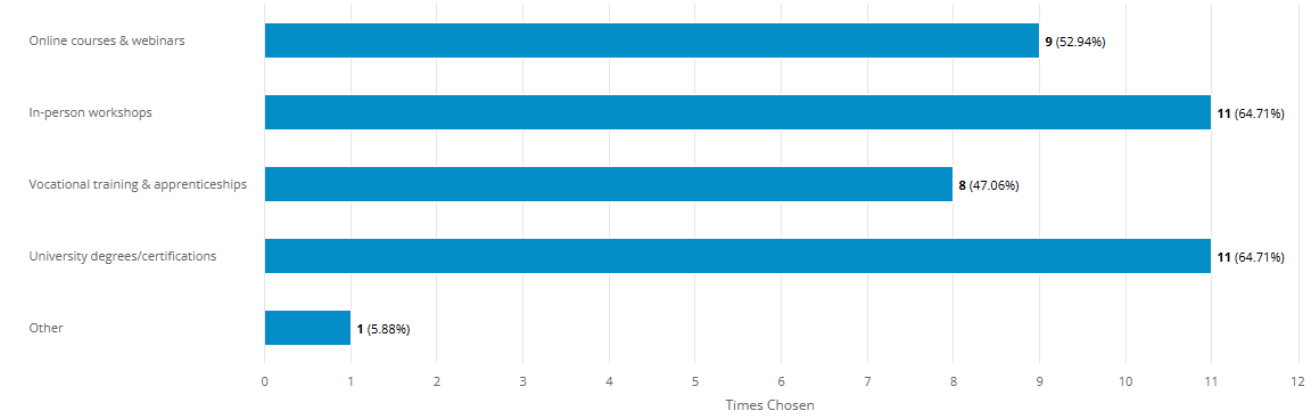
Do current training programs cover Green Skills sufficiently?

Number of responses: 17



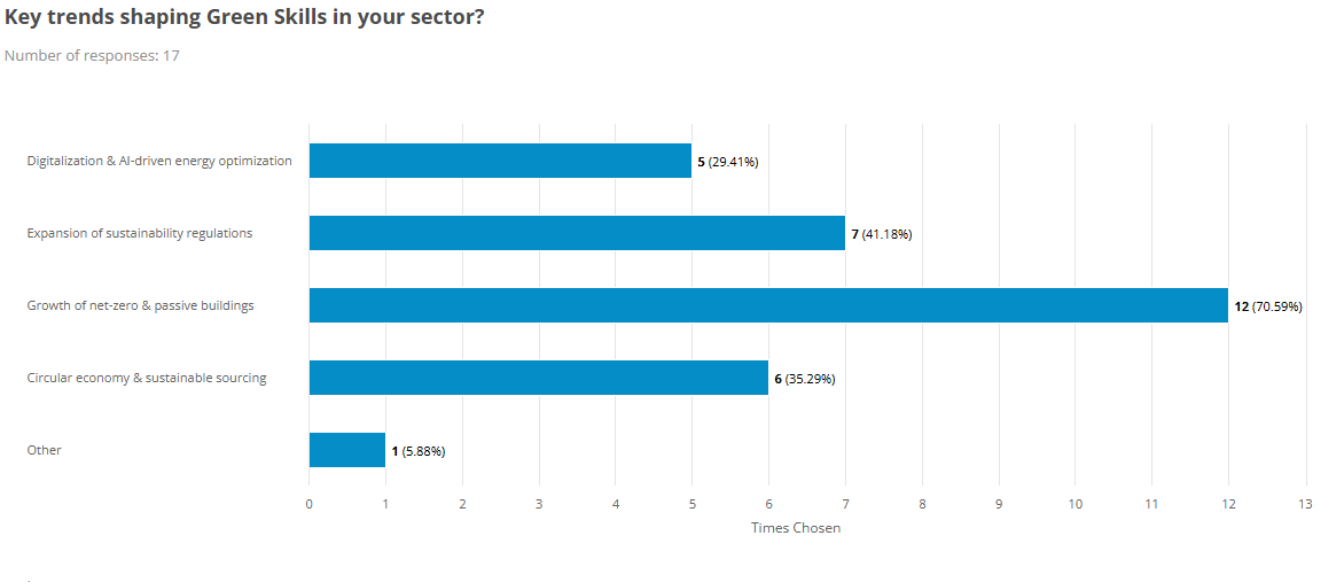
What training formats would be most effective?

Number of responses: 17



Recommendations:

- Greater investment in employer-led training initiatives.
- Development of standardized Green Skills certifications.
- Expansion of EU cooperation for training tools and knowledge sharing.
- Integration of hands-on, real-world training experiences in educational programs.



The transition to Green Skills in the HVAC sector requires a multifaceted approach to overcome existing challenges and capitalize on emerging opportunities.

Firstly, raising awareness and improving knowledge about Green Skills must be a priority. This can be achieved through targeted educational campaigns, industry-led seminars, and government-supported initiatives. Companies should actively promote internal upskilling programs and encourage participation in professional development courses.

Secondly, financial and policy-based incentives should be introduced to support companies and individuals investing in Green Skills. Governments and industry bodies need to collaborate to create funding schemes, tax breaks, or subsidies for Green Skills training programs. Additionally, clearer regulations and standards will help drive adoption and implementation across the sector.

Training programs should also be diversified to meet various professional needs. While university degrees provide in-depth theoretical knowledge, practical vocational training and apprenticeships ensure hands-on experience, which is crucial for successful implementation. Employers must be encouraged to invest in employee training and recognize Green Skills as a key competence for career advancement.

Furthermore, digital transformation and technological advancements should be leveraged to enhance training efficiency. Online platforms, AI-driven simulation tools, and remote learning opportunities should be integrated into Green Skills development programs to increase accessibility and scalability.

Lastly, fostering international cooperation and knowledge-sharing networks will accelerate progress in Green Skills adoption. Establishing partnerships between European universities, industry leaders, and regulatory bodies will facilitate best practice exchange and innovation in sustainable HVAC solutions.

In conclusion, the HVAC industry must embrace the Green Transition by overcoming barriers, enhancing training opportunities, and fostering collaboration. With the right policies, investments, and commitment from stakeholders, the sector can successfully integrate Green Skills and contribute to a more sustainable future.

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- REHVA internal research on HVAC engineering trends

Integration of Green Skills into Higher Education Programmes – A review of best practice

Introduction

Over the past thirty years, climate change has become increasingly urgent, sparking a global movement for climate action. A pivotal moment came in 2015, marking two significant developments in response to the changing climate: the establishment of the 17 UN Sustainable Development Goals and the Paris Agreement. These historic milestones have since shaped national strategies aiming to create societies and economies that are less polluting, less dependent on carbon, and ultimately, greener.

The rise of international agreements has spurred regional and national governments to pursue ambitious environmental policies focused on reducing emissions and restoring ecosystems. A prime example is the 2019 European Green Deal, which aims to make Europe climate-neutral by 2050. Ireland has also taken significant steps through its Climate Action Plans, supported by the Climate Action and Low Carbon Development Act of 2015. Alongside initiatives such as the EU Green Industrial Plan 2023, the revised Energy Performance of Buildings Directive 2024, and the EU Bioeconomy Strategy 2018, these policies emphasize the urgent need for economies and societies to transition towards sustainable, resource-efficient, and environmentally friendly practices.

Transitioning to greener initiatives to tackle climate change will yield immediate effects. Under the European Industrial Strategy, the green transition is expected to generate one million new jobs, necessitating the upskilling and reskilling of 120 million individuals. While existing jobs will evolve to become less polluting, new positions will arise in response to this shift, creating an economy that supports environmental health. Additionally, fostering a greener society will require individuals to cultivate a strong environmental awareness and a commitment to sustainability.

The necessity of equipping the workforce with green skills is acknowledged across a variety of policies and reports in Ireland. Skills reports like Green Skills 2030-The 1st National Further Education & Training (FET) Strategy for the Green Transition, National Skills Strategy 2025, Skills for Zero Carbon, Building Future Skills 2020, and Future Jobs Ireland 2019 highlight this critical need. National policies and strategies, including the Climate Action Plan 2024, the Action Plan for Apprenticeship 2021-2025, and the National Further Education and Training Strategy 2020 – 2024, demonstrate the government's commitment to addressing the demand for green skills. Additionally, sector-specific documents such as Housing for All 2021, Powering Prosperity: Ireland’s Offshore Wind Industrial Strategy 2024, the National Retrofit Plan 2021, and the Report on the

Analysis of Skills for Residential Construction and Retrofitting 2023-2030 point to the recognition of this need.

As the shift toward a greener economy continues to present new challenges, the demand for these skills will inevitably rise across all sectors. Cultivating a more sustainable economy is key, further emphasizing the importance of enhancing our workforce's green skill set.

Ireland's high level strategies on sustainability in education

The 2nd National Strategy on Education for Sustainable Development (ESD) in Ireland for the year 2030 outlines five key priority action areas: advancing policy, transforming learning environments, enhancing educators' skills, empowering young people, and accelerating local actions. These areas are interconnected and should be considered as part of a comprehensive approach to ESD within the educational framework in Ireland.

This strategy serves as a vital reference for creating an ambitious, inclusive, and collaborative roadmap for ESD across the education sector. It aligns with complementary efforts such as the Council Recommendation (2022) on Learning for the Green Transition and Sustainable Development, the European Sustainability Competence Framework (Bianchi et al., 2022), UNESCO's Education for Sustainable Development: A Roadmap (2020), and the UN's Education for SDGs: Learning Objectives (2017).

In recent years, there has been a noticeable increase in the commitment of higher education institutions (HEIs) to sustainability, climate action, and the Sustainable Development Goals (SDGs). This is demonstrated through the establishment of various Vice-President and Associate Vice-President roles, as well as dedicated offices or centers focused on sustainability. Furthermore, some HEIs have appointed specific ESD lecturers, officers, or fellows who are leading efforts to integrate sustainability more thoroughly throughout the curriculum.

The national strategy for the FET sector, Future FET: Transforming Learning, emphasizes that "climate change and sustainable development must also be a critical focus for FET." It highlights the necessity of updating curricula across all apprenticeships and relevant FET programs to incorporate sustainable development principles. Importantly, it calls for a strong focus on developing crucial climate change and environmental knowledge, ensuring that FET campuses embody a robust sustainability ethos (SOLAS, 2020, p.43).

Additionally, the FET sector plays a critical role in fostering a greener society by equipping learners with the environmental awareness necessary to drive meaningful change (SOLAS, 2020).

Given the cross-sectoral nature of this challenge, evidence suggest that the higher education sector is prepared to lead in providing further education and support for learners, while also engaging with areas outside its direct focus. For instance, further and higher education can significantly contribute to migration policy, addressing the green skills gap by offering broader education and language training to non-nationals. Moreover, the FET sector can engage with industry partners to stay attuned to emerging skills requirements in the green economy, focusing on specific sectors and job roles.

Paper Objectives

From the evidence above it is clear that high level policy is strongly leaning towards the integration of sustainability into higher level programmes but the challenge remains as to what is the best approach to achieving this goal at the coal face. The focus of this paper is to review published literature on how educators have integrated sustainability into HE programmes.

Methodology

Academic papers were screened using AI technology that met the following criteria.

- Educational Level: Was the study conducted in a higher education setting with undergraduate students?
- Pedagogical Approach: Does the study describe specific teaching methods or pedagogical approaches used for developing green skills?
- Outcomes Assessment: Does the study include measurement or evaluation of learning outcomes?
- Study Design: Is the study empirical (quantitative, qualitative, mixed methods) OR a systematic review/meta-analysis?
- Skills Development: Does the study focus on developing specific green skills (not just environmental awareness)?
- Teaching Method Clarity: Are the pedagogical approaches clearly specified and described in the study?
- Academic Scope: Is the study's context clearly situated within an identifiable academic discipline?

The search was conducted across over 126 million academic papers from the Semantic

Scholar corpus. Fifty of the most relevant papers were retrieved and the ten most suitable papers are reported on.

Results

The most successful integration of green skills in undergraduate education occurs through active learning, interdisciplinary collaboration, and project-based methods across multiple academic disciplines.

Ten studies from diverse undergraduate disciplines show that green skills flourish when learning is active, con- textual (i.e. or relating to the circumstances that form the setting for an idea), and integrative. Educators who use hands-on approaches report that:

1 Interdisciplinary and transdisciplinary learning builds systems thinking, environmental awareness, and collaborative skills. For example, interdisciplinary collaborations increase student confidence in tackling complex sustainability challenges.
2. Project-based and problem-based methods promote critical thinking and practical problem-solving. In several cases, students in modules employing these techniques gain transferable skills and directly apply sustainable practices.
3. Experiential and transformative pedagogies shift the focus from passive content delivery to active, real- world learning. Multiple studies cite enhanced sustainability competencies, such as reduced ecological footprints and improved low-carbon skills.

Assessment techniques ranging from pre-post surveys to qualitative case analyses consistently indicate improved green skills. No study reported adverse or null impacts, suggesting that active, integrative pedagogical strategies are most effective for embedding green skills into the undergraduate curriculum.

Characteristics of Included Studies

Study	Study Design	Discipline Area	Integration Approach	Key Outcomes
Affolderbach, 2020	Case study	Geography	Problem and project-based learning in a third-year module	Enhanced critical thinking, context-dependent assessments and transferable skills
Albareda-Tiana et al., 2019	Case study	Primary Education	Problem-based learning, project orientated learning, and cross-disciplinary workshops	Acquisition of sustainability competencies and reduction on ecological footprint
Boarin and Martinez-Molina, 2022	Theoretical / conceptual paper	Architecture	Review of various approaches in architectural education	Shift from context-focus to pedagogical approaches and implementation processes
Bray et al., 20222	Quantitative systematic review	Healthcare	Workshops and clinical skills sessions	Positive impacts on knowledge, attitudes, and skills related to sustainable healthcare
Chen et al., 2020	Qualitative study	Green chemistry	Collaborative interdisciplinary, and problem-based learning	Enhanced environmental awareness, systems thinking. and problem-solving skills
Lozano et al., 2019	Survey	Multiple disciplines	Various pedagogical approaches	Correlation between pedagogical approaches and sustainability competences
Noy et al., 2017	Mixed methods case study	Interdisciplinary (Science, Arts, Business, Health)	Interdisciplinary collaboration and awareness	Increased skills and confidence in interdisciplinary sustainability collaboration
Sibilla and Kurul, 2020	Qualitative case study	Built environment (Architecture, Engineering, Urban Design)	Transformative pedagogy, inquiry-based learning	Development of low-carbon transition skills and systems thinking
Tayloy et al., 2021	Theoretical conceptual paper and case study	Sustainable Urban Development	Interdisciplinary, transdisciplinary, and experiential learning	Holistic understanding of sustainable development and practical problem-solving skills
Taşdemir and Gazo, 2020	Quantitative study	Wood products Industry	Transdisciplinary and project-based learning	Increased sustainability awareness and application of modern management techniques

Analysis of the included studies:

- Study designs: It was found that a variety of study designs existed across the 10 studies, with case studies being the most common (5 studies). Other designs included theoretical/conceptual papers (2), qualitative studies (2), and one each of systematic review, mixed methods, survey, and quantitative study.
- Disciplines: The studies covered a diverse range of disciplines, with no single discipline dominating. One study covered multiple disciplines, and another was explicitly inter-disciplinary.
- Integration approaches: Integration approaches were varied, with problem-based learning (3 studies), project-based learning (3 studies), and interdisciplinary approaches (3 studies) being the most common. Other approaches included:
  - Transdisciplinary learning (2 studies)
  - Workshops
  - Clinical skills sessions
  - Collaborative learning
  - Transformative pedagogy
  - Inquiry-based learning
  - Experiential learning
- Key outcomes : Reported outcomes across the studies included:
  - Sustainability-related outcomes:
    - Sustainability competencies (2 studies)
    - Environmental awareness (1 study)
    - Sustainability awareness (1 study)
    - Ecological footprint reduction (1 study)
  - Cognitive skills:
    - Critical thinking (1 study)
    - Systems thinking (2 studies)
    - Problem-solving (2 studies)
    - Holistic understanding (1 study)
  - Practical skills:
    - Transferable skills (1 study)
    - Low-carbon skills (1 study)
    - Management techniques (1 study)
  - Other outcomes:
    - Pedagogical shift (1 study)
    - Knowledge improvement (1 study)
    - Attitude change (1 study)
    - Interdisciplinary skills (1 study)
    - Increased confidence (1 study)

Among the studies reviewed, there was no reports of negative or null outcomes from integrating

sustain- ability into higher education curricula.

Thematic Analysis

Interdisciplinary Learning Approaches

Interdisciplinary learning emerged as a key theme across multiple studies, reflecting the complex nature of sustainability challenges. Key findings include:

- Noy et al. (2017) found that interdisciplinary collaboration and awareness were valuable for sustainability learning, with students reporting increased skills and confidence in interdisciplinary sustainability collaboration.
- Sibilla and Kurul (2020) emphasized the importance of interdisciplinary discussions in developing systems thinking and low-carbon transition skills.
- Chen et al. (2020) highlighted the effectiveness of interdisciplinary learning in green chemistry education, noting that it promotes systems thinking and the ability to tackle complex sustainability issues.
- Taylor et al. (2021) advocated for interdisciplinary and transdisciplinary learning approaches in sustainable urban development education, emphasizing their role in fostering a holistic understanding of sustainability challenges.

Project-Based and Experiential Learning

Project-based and experiential learning approaches featured prominently across the studies as effective methods for integrating green skills into the curriculum:

- Affolderbach (2020) reported positive outcomes from a problem- and project-based learning approach in a geography module, noting enhanced critical thinking and transferable skills.
- Albareda-Tiana et al. (2019) found that project-oriented learning contributed to the acquisition of sustainability competencies.
- Taşdemir and Gazo (2020) implemented a project-based learning approach in the context of the wood products industry, resulting in increased sustainability awareness and the ability to apply modern management techniques to sustainability challenges.
- Chen et al. (2020) highlighted the effectiveness of problem-based learning in green chemistry education.

These findings suggest that hands-on, practical approaches to learning are particularly effective in developing green skills. Such approaches appear to bridge the gap between theoretical knowledge and practical application, allowing students to engage with real-world sustainability challenges and develop problem-solving skills in context.

Cross-Disciplinary Integration Methods

Several studies highlighted the importance of integrating sustainability concepts across disciplines:

- Boarin and Martinez-Molina (2022) noted a shift in architectural education from a focus on content to an emphasis on pedagogical approaches and implementation processes for integrating sustainability.
- Lozano et al. (2019) found a correlation between pedagogical approaches and sustainability competences across various disciplines, indicating that the method of integration is crucial to developing green skills.
- Sibilla and Kurul (2020) emphasized the importance of transformative pedagogy in developing low- carbon transition skills, suggesting that cross-disciplinary integration requires not just content changes but also shifts in teaching approaches.

These findings highlight the need for holistic approaches to integrating green skills across the curriculum, rather than confining sustainability education to specific courses or modules.

Assessment Strategies and Effectiveness

The studies revealed diverse approaches to assessing the effectiveness of green skills integration:

- Albareda-Tiana et al. (2019) used ecological footprint measurements as a concrete indicator of the impact of sustainability education.
- Noy et al. (2017) employed a mixed-methods approach, combining quantitative surveys with qualitative student journal data to assess the development of interdisciplinary skills and confidence.
- Taşdemir and Gazo (2020) used pre- and post-education surveys to measure changes in sustainability awareness and familiarity with sustainability concepts.

The variety of assessment methods used across the studies reflects the multidimensional nature of green skills and the challenges in measuring their development. While some studies focus on knowledge acquisition, others emphasize behavioral changes or the development of specific competencies.

Implementation Frameworks

Integration level	Pedagogical Strategy	Success Factors	Challenges
Course level	Problem-based learning	Hands-on experience, real-world applications	Time constraints, resource limitations
Programme-wide	Interdisciplinary collaboration	Cross-faculty engagement, diverse perspectives	Coordination challenges, disciplinary silos
Institution-wide	Transformative pedagogy	Institutional support, curriculum redesign	Resistance to change, lack of expertise
Industry integration	Project-based learning	Industry partnerships, real-world projects	Aligning academic and industry goals
Curriculum-embedded	Cross-disciplinary workshops	Integration with existing courses	Balancing discipline-specific and sustainability content
Clinical/Professional	Workshops and skills sessions	Relevance to professional practice	Limited time in professional curricula
Theoretical/Conceptual	Literature review and framework development	Comprehensive analysis, theoretical grounding	Gap between theory and practice
Mixed methods	Combination between theoretical and practical approaches	Holistic skill development	Complexity in implementation and assessment
Transdisciplinary	Integration of multiple disciplines and stakeholders	Comprehensive approach to complex problems	Coordination and communication challenges
Competency-based	Focus on developing specific sustainability competences	Clear learning outcomes, targeted skill development	Defining and measuring competencies

Analysis of implementation frameworks:

- Ten distinct pedagogical strategies across the integration levels, with each strategy mentioned once. These ranged from problem-based learning and project-based learning to more theoretical approaches like literature review and framework development.
- Success factors were diverse, with 15 unique factors identified:
  - Real-world applications, as a success factor, was the most frequently mentioned (2 times)
  - All other success factors were mentioned once each, including hands-on experience, cross-faculty engagement, institutional support, and targeted skill development
- Fourteen unique challenges were identified across the integration levels:
  - Time constraints and coordination challenges were the most frequently mentioned (2 times each)
  - Other challenges, each mentioned once, included resource limitations, resistance to change, theory- practice gap, and difficulties in defining and measuring competencies.
  - The integration levels varied widely, from course level and program-wide to institution-wide and industry-integrated approaches. We also found theoretical/conceptual, mixed

methods, transdisciplinary, and competency-based approaches.
- There were no clear patterns of specific challenges or success factors being consistently associated with particular integration levels or pedagogical strategies.

Conclusion

The integration of green skills within undergraduate education is most successful when it involves active learning, interdisciplinary teamwork, and project-based approaches across various fields of study. Research from ten different undergraduate programs reveals that green skills thrive in environments that are engaging, contextual, and holistic. Educators who adopt hands-on strategies observe several benefits:

1. Learning that spans multiple disciplines fosters systems thinking, environmental awareness, and collaborative abilities. For instance, students involved in interdisciplinary projects often feel more confident in addressing intricate sustainability issues.
2. Utilizing project-based and problem-based learning encourages critical thinking and practical solutions. In many instances, students participating in these modules acquire transferable skills and can directly implement sustainable practices.
3. Experiential and transformative teaching methods pivot the focus from traditional passive learning to engaging, real-world applications.

Numerous studies emphasize improved sustainability competencies, including a reduction in ecological footprints and enhancements in low-carbon skill sets. Assessment methods, including pre- and post-surveys as well as qualitative case studies, consistently demonstrate an increase in green skills. Notably, none of the studies reported any negative or neutral outcomes, underscoring that active, integrative teaching strategies are the most effective means of instilling green skills into the undergraduate curriculum.

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The State of the Engineering Labor Market in Germany

Ingo Rauhut, VDI

Table of Content

1 Introduction

The engineering sector is a cornerstone of Germany's economic strength and innovation capacity. However, challenges such as demographic shifts, technological advancements, skill shortages, and geopolitical uncertainties have raised concerns about the future supply of engineers. Additionally, Germany is undergoing a structural transformation due to digital transformation, green transformation, and a growing impact of deglobalization. These factors are redefining the skill sets required in engineering professions and altering global supply chains, leading to a greater emphasis on domestic production and technological sovereignty.

Industry 4.0, characterized by intelligent factories, automation, and interconnected production processes, is significantly shaping the labor market. Simultaneously, the transition towards sustainability in general and climate-friendly technologies in specific is creating new demands for engineers specializing in energy efficiency, resource conservation, and circular economy principles. The shift toward reshoring – bringing manufacturing and high-tech production back to Germany to reduce reliance on international supply chains – has further increased the need for skilled engineers in fields such as semiconductor manufacturing, robotics, and renewable energy.

The VDI discussion paper "Securing Skilled Labor in Times of Economic Downturn" (2020) highlights that economic fluctuations have a measurable impact on engineering employment. However, the demand for engineers remains consistently high due to the structural need for technical expertise in future-oriented fields such as digitalization and climate protection. The paper emphasizes that policy interventions must ensure the long-term availability of skilled engineers, regardless of short-term economic downturns.

Furthermore, the latest VDI/IW Engineering Monitor (Q3 2024) confirms that, despite economic slowdowns, the number of engineering job vacancies in Germany remains at pre-COVID levels, with persistent shortages in key disciplines. The monitor reports approximately 129,000 open positions in engineering and IT professions in the first quarter of 2024, representing a 21.8 percent decrease from the previous year. Nevertheless, severe staff shortages continue in energy and electrical engineering, with a bottleneck ratio of 4.4 vacancies per unemployed engineer in Germany. These findings emphasize that while economic cycles influence short-term hiring trends, the underlying demand for skilled engineers remains strong due to structural industry needs and the increasing push for national technological independence amid deglobalization trends.

The objective of this paper is to provide a structured analysis of the current state of the German engineering labor market by reviewing existing literature and data sources. This analysis will assess employment trends, skill demands, and policy implications to offer a comprehensive understanding of the evolving engineering landscape in Germany.

2 Findings: Demand for engineers remains high

2.1 Demographic change

Germany's aging workforce presents one of the most pressing challenges for the engineering sector. According to estimates, by 2029 over 710,000 engineers from the baby boomer generation will retire, significantly reducing the available labor force (Koppel 2015). The number of engineering graduates entering the labor market is not sufficient to compensate for these retirements, leading to persistent skill shortages. The VDI/IW Ingenieurmonitor 2024/III highlights that the shortage ratio in engineering professions remains at 442 vacancies per 100 unemployed engineers, indicating a structural imbalance between supply and demand. Without targeted measures such as incentives for young professionals, retraining programs, and international recruitment, the gap is expected to widen further.

2.2 Digital transformation

The increasing integration of artificial intelligence (AI), automation, and smart manufacturing technologies is transforming the engineering landscape. Industry 4.0 requires engineers to develop expertise in robotics, data science, cybersecurity, and IoT applications. However, many companies report that university curricula are not keeping pace with industry needs, leading to a mismatch between skills taught and those required on the job market. The demand for engineers with strong digital competencies is particularly high in software engineering, industrial automation, and IT security, where companies struggle to fill vacancies.

2.3 Green transformation

The shift towards renewable energy, energy efficiency, and sustainable infrastructure is another key driver for demand for skilled-labor. Germany's commitment to achieving climate neutrality by 2045 requires an expansion of green technologies, including wind and solar energy, hydrogen infrastructure, and electric mobility. As a result, demand for electrical engineers, energy engineers, and environmental engineers has surged. The shortage ratio for energy and electrical engineering professions has reached up to almost 8 vacancies per unemployed engineer in 2022 (VDI/IW Ingenieurmonitor 2022/IV), making this one of the most affected fields. Additionally, the push for sustainable construction and circular economy principles is increasing the need for civil engineers and material scientists with expertise in eco-friendly designs and resource-efficient production.

2.4 Deglobalization

The global shift towards reducing dependence on international supply chains and strengthening domestic production capabilities has had a direct impact on the engineering labor market. In response to recent geopolitical tensions, Germany is prioritizing reshoring high-tech manufacturing, particularly in semiconductors, battery production, and automation technology. This trend has fueled demand for engineers in mechanical engineering, industrial robotics, and process optimization, as companies work to establish new production facilities and reduce reliance on imported technologies. According to the VDI/IW report, the mechanical and automotive engineering sector currently has a shortage ratio of 290 vacancies per 100 unemployed engineers, illustrating the high demand for talent in these fields. To address these challenges, policymakers are promoting investment in R&D, tax incentives for domestic production, and specialized training programs to prepare engineers for a more localized and resilient industrial landscape.

Overall, despite economic uncertainties, the demand for engineers in Germany remains strong across multiple sectors. The combined effects of demographic change, digitalization, green transformation, and deglobalization are reshaping the labor market, requiring targeted policy measures and industry initiatives to ensure a sufficient supply of skilled professionals in the years to come.

3 Implications

3.1 Getting more young people interested in engineering

To address the persistent shortage of engineers, Germany must take further steps to promote STEM education among young people. Pre-schools/nursery schools/kindergartens, schools and extracurricular programs for children should focus on fostering enthusiasm for technical subjects from an early age. Initiatives such as coding workshops, robotics competitions, and STEM mentorship programs can play a crucial role in increasing the number of students pursuing engineering careers.

3.2 Increasing the number of international students

Attracting more international students to German HEIs can help mitigate skill shortages. Policies should focus on simplifying visa processes, providing scholarships, and offering English-language engineering programs to make Germany a more attractive destination for global talent. Studying engineering in Germany is already very attractive worldwide. More than 150,000 foreign engineering students help compensate for the generally decreasing numbers of engineering students (DAAD/DZHW 2022-2024).

Additionally, stronger HEI-industry partnerships must improve job placement rates for international graduates, encouraging them to stay in Germany after completing their studies. There is a need for supporting programs, which assist in developing necessary German language skills, the access to professional networks, and mentoring programs to ease settling into the German labor market and culture.

3.3 Strengthening domestic potential

Beyond traditional engineering education, Germany must invest in re-skilling and up-skilling programs for professionals in related fields. Encouraging career changers to enter engineering through fast-track training programs and industry-funded apprenticeships can help address labor shortages. However, there is more:

- Keeping employees in the workforce beyond retirement: Companies should implement measures to extend the working lifetime of experienced engineers. This can include flexible retirement models, part-time employment options, and targeted training programs to help experienced professionals stay updated to ever-faster technological advancements.

- Better utilizing the potential of women: Women remain underrepresented in engineering professions. Increasing female participation in STEM careers requires targeted outreach programs, mentoring initiatives, and structural workplace changes, such as family-friendly policies and equal pay measures. Women can also profit from mentoring programs, e. g. VDI-WoMentorING to find and enhance career pathways in an evolving work environment.

- Ensuring work-life balance: To make engineering careers more attractive, employers must focus on enhancing work-life balance. Strategies such as remote work options, flexible hours, and support for childcare can help retain talent and make engineering roles more appealing to a broader workforce.

3.4 Promoting skilled immigration in engineering professions

The number of foreign engineers in Germany has risen significantly in recent years. There are about 400,000 foreign engineers living and working in Germany, which is about 17 percent of the total engineering workforce. Still, the demand continues to exceed supply. As German HEIs and domestic training programs struggle to keep up with the increasing need for technical professionals, targeted immigration policies must be expanded. Possible actions are:

- Expanding immigration pathways: Streamlining work visa and residence permit processes for skilled engineers from non-EU countries can accelerate integration into the labor market.
- Recognition of foreign qualifications: Simplifying and expediting the recognition of international engineering degrees will enable highly qualified professionals to work in Germany without unnecessary bureaucratic delays.
- Mentoring programs for integration: Initiatives such as VDI-Xpand, which connects foreign engineers with experienced professionals in the field, play a crucial role in easing the transition into the German labor market. These programs provide networking opportunities, technical training, and career guidance to enhance long-term retention.
- Partnerships with talent-rich countries: Establishing cooperation agreements with countries that have a surplus of STEM graduates can help attract skilled engineers and mitigate shortages in critical sectors.

By enhancing education reforms, international recruitment, and integration support, Germany can secure a sustainable engineering workforce to maintain its technological and industrial leadership.

4 Conclusion

The German engineering labor market is undergoing profound changes due to digitalization, technological advancements and demographic shifts. While there is a high demand for engineers in energy, electrical, and digital fields, the supply of skilled professionals is not keeping pace with industry needs. The shortage of skilled workers, coupled with declining student enrollment in engineering disciplines, underscores the importance of up-skilling, lifelong learning, and international recruitment efforts.

To sustain Germany's engineering excellence, policymakers and industry leaders must take proactive measures. Strengthening STEM education, easing immigration pathways for skilled workers, and investing in reskilling initiatives will be crucial in ensuring that the engineering workforce remains competitive in the era of Industry 4.0 and the green transformation.

5 Literature

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