Circular Economy Innovation
Ecosystems REdesigning Skills

CERES

D1.1

REPORT ON CIRCULAR ECONOMY MARKET LABOUR EDUCATIONAL NEEDS AND SET OF RECOMMENDATION TOWARDS VET AND HE SECTOR

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D1.1

Report on CE market labour educational needs and set of recommendation towards VET and HE sector

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Short abstract: The document will describe which are the market trends in the CE field; it will report the training needs emerging from industrial actors consultation; it will contain recommendations addressing educational actors, advising them regarding new CE curricula content.

Deliverable Status

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0.1	Structure of the deliverable
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0.3	Second version (market analysis results)
0.4	Third version (survey results)
0.5	Fourth version (interviews results)
0.6	Fifth version (discussions)
0.7	First version (overall discussion and comparison with D2.1)
0.8	Updated deliverable after internal review
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Executive Summary

The Circular Economy Innovation Ecosystems Redesigning Skills (CERES) project wants to contribute to support the just transition of European society towards the Green Deal accomplishment. To achieve the European objectives, CERES points to two main categories of users belonging to Vocational Education and Training (VET) and Higher Education (HE). To reach and effectively empower them, the project will implement and deploy in a collaborative way a new set of assets (curricula, learning material, and services), resilient and adaptable to future knowledge developments in the circular economy (CE) domain and fostering the cross-fertilization among different industries and stakeholders across the European Union (EU). Educational institutions are uniquely positioned to enhance young people's personal development and consequently society improvements. In particular, to effectively foster the transition towards the European Green Deal, CERES will develop transnational, structured, and result-driven education initiatives and training curricula.

The results presented in this deliverable (grounded on a literature analysis from a theoretical perspective, complemented by a market investigation and a survey and interviews with practitioners) will be exploited to develop these education initiatives and training curricula in the CERES project. These courses, dedicated to HE and VET levels, will be made available in the new Circular Economy Digital Innovation Hub (CE-DIH) to be developed in CERES. In particular, the objective of this deliverable, belonging to the Work Package (WP) 1, is multi-faceted, aiming to:

- investigate market and resilience needs for competences and skills to better address the challenges of CE transition and the European Green Deal,
- review existing VET and HE training in CE,
- provide accessible insights to feed HE/VET/Market actors' competence development and promote the field of CE education,
- inform the training materials developed within the project.

The document presents the results coming from the activities performed in CERES WP1 (i.e., the Systematic Literature Review (SLR) in the CE skills and competence research domain, the market analysis of the available courses on the market for HE and VET levels, the online survey, and the interviews to investigate the actual needs of companies in terms of skills and job profiles to effectively implement CE practices in their processes). In this way, existing gaps between market needs and the available educational offer are discussed. In addition, the most useful training courses are proposed and their potential impacts on the job market are evaluated. These courses should provide accessible insights to feed HE/VET/Market actors' competence development and promote the field of CE education, providing key facts and insights as well as recommendations for the development of CE education in organizations.

The systematic analysis performed was aimed to identify the main skills and market needs in terms of professional qualifications for the transition towards CE. Its results revealed that future professionals need to develop skills that are not only technical but also multi-systemic,

encompassing interpersonal skills and those associated with digital transformation. In other words, CE encompasses a multifaceted labour market with individuals requiring continuous educational development. The findings also demonstrate that a highly qualified workforce is crucial to meeting the current challenges posed by the green and digital transition (i.e., the twin transition). Lack of skills may evolve into barriers hindering a successful transition. Given this context, it will be necessary to establish active teaching and learning approaches that promote multi-disciplinarity and encourage the development of critical and systemic thinking.

The market analysis provides valuable insights into the current opportunities for individuals and organizations at both HE and VET levels. Comparing the educational programs among HE and VET levels, it emerged that HE courses tend to address the topics linked to CE without focusing on a specific industry, unlike VET courses which, in general, explain the main concepts and then go into detail by industry (e.g., agri-food, construction, fashion). Furthermore, more frequently than VET courses, HE educational programs provide many theoretical concepts and, in many cases, they deepen the themes of monitoring and assessing relevant Key Performance Indicators (KPIs), also offering a broad overview of the main technologies that can support the circular transition. However, they lack practical teaching, thus making it difficult to put the theoretical concepts learned into practice.

The purpose of conducting the survey was to identify the industrial and practical needs associated with the required professional roles, necessary to address the transition towards a CE model as well as training needs and preferred training forms. From a theoretical perspective, the survey contributed to unveil which are the skills, job profiles, and types of education more needed to foster education in the CE research domain. Practical gaps and barriers hampering an easy transition have been also collected, together with priorities and regulations adopted by organization to climb their CE maturity levels, unveiling key areas of improvement and of further research in the domain of CE education. From a practical point of view, the results obtained through the survey enabled to clarify the state of practice about the current needs of companies in pursuing a transition towards circularity especially in the field of new skills needed. This can be supportive both for educational institutions in helping them to develop more effective courses and training sessions and *curricula* and for companies willing to approach CE in understanding what could be the key topics to be addressed to upskill and reskill their managers and operators.

The results obtained throughout the interviews are discussed highlighting the peculiarities that emerged from each industry and comparing the various needs across the three industries (i.e., Waste from Electrical and Electronic Equipment (WEEE), automotive, textile).

Finally, the outcomes of Deliverable (D) 1.1 (composed of the analysis of the available literature on skills and competences needs in the CE domain, a market analysis of the courses currently offered for HE and VET, and the survey and interviews conducted with practitioners and industrialists to understand their practical needs in terms of competences and skills for the adoption of the CE paradigm) will flank the results of the analysis conducted with D2.1 in WP2 (which were delivered at month 10). For this reason, a comparison with the results previously obtained in D2.1 is also provided.

List of Abbreviations

Abbreviations	Descriptions
BFRs	Brominated Flame Retardants
BoL	Beginning-of-life
CA	Consortium Agreement
CMs	Core Modules
CPD	Continuing Professional Development
CE	Circular Economy
CE-DIH	Circular Economy Digital Innovation Hub
CERES	Circular Economy innovation ecosystems REdesigning Skills
CET	Central European Time
CSCs	Circular Supply Chains
CV	Curriculum Vitae
D	Deliverable
DE	Dissemination Expert
DfX	Design for X
DigComp	Digital Competence Framework
DIH	Digital Innovation Hub
DIY	Do-it-yourself
DL	Deliverable Leader
DMS	Document Management System
DoA	Description of Action
DPO	Data Protection Officer
DTs	Digital Technologies
EC	European Commission
EEE	Electrical and Electronic Equipment
EI	Emotional intelligence
EntreComp	Entrepreneurship Competence Framework

EoL	End-of-life
EQF	European Qualifications Framework
ESG	Environmental, Social, Governance
EU	European Union
F2F	Face to Face
GA	Grant Agreement
GAM	General Assembly Meeting
GDPR	General Data Protection Regulation
GHG	Greenhouse Gas
GreenComp	Sustainability Competence Framework
HE	Higher Education
HEI	Higher Education Institution
I4.0	Industry 4.0
LCA	Life Cycle Assessment
KPI	Key Performance Indicator
M	Month
MCQ	Multiple-Choice Question
MoL	Middle-of-life
MOOCs	Massive Open Online Courses
N/A	Not Available
NQF	National Qualifications Framework
OPSS	Office for Product Safety & Standards
PC	Project Coordinator
PMT	Project Management Team
PO	Project Officer
POPs	Persistent Organic Pollutants
PU	Public
QE	Quality Expert
QMR	Quarterly Management Reports

R	Report
RM	Review Meeting
SDGs	Sustainable Development Goals
SC	Steering Committee
SLR	Systematic Literature Review
SMs	Specialized Modules
SEN	Sensitive
TBL	Triple Bottom Line
TL	Task Leader
TPM	Transnational Project Meeting
VAM	Virtual, Augmented and Mixed
VE	Vocational Education
VET	Vocational Education and Training
WEEE	Waste from Electrical and Electronic Equipment
WP	Work Package
WPL	Work Package Leader
3DP	3D Printing

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1 Document Summary

1.1 Project Overview

The Circular Economy (CE) paradigm, accelerated within the context of Industry 4.0 (I4.0), has been increasingly applied both inside and outside the manufacturing domain. The set of new capabilities, skills and competencies developed through I4.0 need to be augmented and enhanced to conform to the Triple Bottom Line (TBL) perspective (profit, people, planet). These enhancements initially affect supply chain management and then expand towards entrepreneurship, business model development, innovation management and societal development.

Research shows that there is a significant potential to address the complex challenges towards a more sustainable and resilient society by cross-fertilizing these disciplines through the CE perspective, via provisioning new courses and practical cases.

For this reason, the joint CE-I4.0 evolution needs to be grounded on a new set of knowledge and best practices to be provided through both high education (HE) and vocational education and training (VET), demanding systemic ways for sustainable development.

Circular Economy Innovation Ecosystems Redesigning Skills (CERES) project recognizes the need to shift the restricted focus of CE from firms to a more extended and system-level view that considers skills, competences, and knowledge needs (provided from various business sectors such as e-waste, textiles, renewable energy, etc.) to be supplied to HE and VET.

This would catalyse the embracement of CE under a social development perspective from the preliminary stage of training and education.

In this context, CERES innovation ecosystem, the Circular Economy Digital Innovation Hub (CE-DIH), is aimed to promote connectedness among the stakeholders and to generate a systematized set of services, skills, competences, and knowledge able to support the multi-faceted CE domain. The CE-DIH can be strategic not only to raise awareness but also to provide the most suitable and complete set of services able to support the circular enrichment and transition of both companies on the market and individuals in society.

1.2 Deliverable Purpose and Scope

The results presented in this deliverable (grounded on a literature analysis from a theoretical perspective, complemented by a market investigation and a survey and interviews with practitioners) will be exploited to develop dedicated courses in the CERES project. These courses, dedicated to HE and VET levels, will be made available in the new CE-DIH to be developed in CERES (Sassanelli et al., 2023b).

In particular, the objective of this deliverable is multiple:

- To investigate market and resilience needs for competences and skills to better address the challenges of CE transition and the European Green Deal,
- To review existing VET and HE training in CE,
- To provide accessible insights to feed HE/VET/Market actors' competence development and promote the field of CE education,
- To inform the development of training materials later in the project.

1.3 Impact and Target Audiences

There are different target audiences that could be impacted by the results of this deliverable.
A first category is composed by educators, and courses and training providers, who can exploit the detected and systematized 40 skills required in the twin transition era, divided in three main dimensions (resiliency, digital technologies (DTs), specialized/technical), the three macro-categories of extant courses provided on the market (CE transition, Sustainability transition, Twin transition) and their main characteristics and the practical needs provided from the practitioners through the survey and interviews results. For CE educational instructors, this study provides crucial guidance for establishing educational courses and programs perfectly aligned with market demands. This allows students to be more prepared to deal with the challenges of I4.0 and circular transition. Given that the twin transition reflects a constant evolution of production systems, educators can adjust their teaching approaches and adapt to changes to provide high-quality education, bridging theoretical knowledge and practical applications.
Also companies and organizations could better understand the skills and training needed to upskill professionals in the manufacturing sector. Also, knowing the critical skills allows managers to have greater clarity about which aspects need to be fostered within the organizational team, developing strategies to recruit and train new talent. The study shows that organizational structures require training program implementation skills. Therefore, this work also contributes to the development of internal technical training plans and the development of interpersonal skills.
For policy makers, standardization of skills needed for CE and digital transition can be triggered by this work. Governments can create mechanisms to promote different skills, such as complementary professional training programs and establishing collaboration networks among the public, industry sector and society. Policymakers can act positively through initiatives that encourage teaching skills from basic educational formation.

1.4 Deliverable Methodology

To address the main objectives of WP1, a dedicated research methodology has been developed and enacted (Figure 2). Both theory and practice have been investigated using different research approaches. A systematic literature review (sub-section 4.1) has been conducted to explore and systematize the knowledge related to the CE skills and competences research domain. On the other side, a market analysis (sub-section 4.2), an online survey (sub-section 4.3), and a set of interviews (sub-section 4.4) have been conducted to investigate the market and resilience needs for competences and skills to better address the challenges of CE transition and the European Green Deal, to review existing VET and HE training in the CE domain, and to provide accessible insights to feed HE/VET/Market actors' competence development and promote the field of CE education and to inform the training materials which we develop in the project.

1.5 Document Status

This document is a public report. The Quality and Evaluation Strategy for its review has been created by the Project Coordinator (PC) and fine-tuned with the cooperation of the Steering Committee (SC), the Project Management Team (PMT), and the Quality Expert (QE).
The deliverable's Table of Contents (ToC) was shared with partners for contributions. After, a consolidated version of the deliverable was shared for review. Once a final version was reached, it was distributed to the Consortium. Once distributed, it is binding on all partners.

1.6 Dependencies and Supporting Documents

Dependencies with other activities and deliverables of the project are shown in Figure 2 in Section 4. This deliverable exploited as inputs the results coming from D2.1 (i.e., the summary competences in the CE domain and the two competency maps for HE and VET levels). A comparison of the results obtained with this input is also provided in sub-section 6.7.
Through the multiple analyses performed, this deliverable unveils, from a theoretical, market, and practical perspective, the gap existing between current formative market offer and industrial needs. The results of this deliverable will be presented and validated with selected experts in the first webtalk of the CERES project.

As a result, in the CERES project, this deliverable constitutes the starting point to develop CERES training curricula and implement CERES courses (respectively in WP2 and WP3) appropriate to the demand of the CE market and to be deployed in the CE-DIH of CERES (WP4).

2 Introduction

The twin transition, which can be understood as "an intertwined and simultaneous green and digital transition to offset companies' carbon footprint" (Rehman et al., 2023, p. 1), is attracting the attention of managers, scholars and policymakers. Previous studies have already pointed out the benefits of adopting DT for enhancing circular economy (CE) strategies (e.g., Liu et al., 2022; Sassanelli et al., 2023; Kumar et al., 2024). For instance, DT enable the optimization of operational processes alongside the empowerment of strategic decision-making (Kristoffersen et al., 2020). However, the manufacturing sector needs to change the paradigm to achieve results aligned with circular principles, and this requires innovation, process improvement and specific skills (Whitehill et al., 2022). For example, designing and implementing circular design strategies is not an easy task, as it requires in-depth expertise and adequate training (Spreafico and Landi, 2022). Also, adopting DT such as artificial intelligence and big data requires digital skills to extract value from information (Acciarini et al., 2023; Kinkel et al., 2022). Thus, it is increasingly crucial for professionals and organizations to have the skills required for the simultaneous transition. Skill refers to "the ability to use one's knowledge effectively and readily in execution or performance" (Merriam-Webster Dictionary, 2024). According to Akyazi et al. (2022), the manufacturing sector will need a multi-skilled workforce that translates the twin transition's challenges into opportunities for innovation.

Extant research has found that a highly qualified labour force is essential for the manufacturing sector to become competitive and sustainable in the long term (Akyazi et al., 2023, 2022). Highly qualified workers need to have not only technical skills but also socio-behavioural abilities to deal with the complexities arising from the transition (Cannavacciuolo et al., 2023). For example, Beducci et al. (2024) identified competencies for different areas within the circular manufacturing domain, including transversal skills like system thinking, creativity and permanent curiosity. Acerbi et al. (2022) developed a model to evaluate the workforce's readiness for the demands of I4.0. The model presents maturity levels considering hard and soft skills, although not focusing on circular transition. Also, a maturity model has been developed to understand if an organization is capable to process and manage data to foster the adoption of circular manufacturing (Acerbi et al., 2024). Knudby and Larsen (2017) addressed how to educate engineers to operationalize circularity-oriented supply chains and provided a set of skills and teaching methods. Straub et al. (2023) found six categories of skills related to circular business model implementation.

Nevertheless, despite the valuable insights into skills and professional growth offered by prior scholarship (e.g., Watkins et al., 2021; Acerbi et al., 2022; Pinzone and Taisch, 2023), theoretical endeavours are fragmented and have not given sufficient attention to skills in light of recent green and digital transformations (i.e. twin transition) in the manufacturing sector. Due to rapid socioeconomic change in the digital era (Dąbrowska et al., 2022), skills need to be constantly updated (Sumter et al., 2021), especially with regard to the adoption of DTs to foster circular practices. A deep and current understanding is essential for establishing new teaching methods that are aligned with contemporary requirements and also for providing practical guidelines for upskilling workers. As evidenced by Watkins et al. (2021), a key challenge in higher education lies in ensuring that academics are adequately trained with specialized expertise to effectively impart knowledge to students. This study argues that without understanding of the skills required by the job market, academics may fail to deliver quality education to enhance the inclusion of human intellectual resources and boost employability in the twin transition. Also, policymakers will not have the scientific support to guide the development of social policies to reduce the adverse effects of job digitalization.

The results presented in this deliverable (grounded on a literature analysis from a theoretical perspective, complemented by a market investigation and a survey and interviews with practitioners) will be exploited to develop dedicated courses in the CERES project. These courses, dedicated to HE and VET levels, will be made available in the new CE-DIH to be developed in CERES (Sassanelli et al., 2023b).

In particular, the objective of this deliverable is multiple:

- To investigate market and resilience needs for competences and skills to better address the challenges of CE transition and the European Green Deal,
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- To provide accessible insights to feed HE/VET/Market actors' competence development and promote the field of CE education,
- To inform the training materials developed within the project.

Therefore, in sub-section 5.1, this deliverable aims from a theoretical point of view to explore and understand which skills are essential for a CE in the manufacturing sector, including those needed to leverage DTs for a circular approach. The section provides comprehensive synthesis of skills based on a systematic literature review combining bibliometric analysis and content analysis. As a result, 40 skills have been identified categorized into three dimensions: (1) Resilience skills, (2) DTs skills, and (3) Specialized/technical skills. Responding to a constant call from the scientific community (e.g., Sumter et al., 2021; Pinzone and Taisch, 2023), this study contributes to current scholarship revealing the skills and multidisciplinary nature of knowledge required for a successful twin transition. By providing this evidence, the paper not only offers insights for increasing the resilience of production systems, but also provides guidelines for developing training programs grounded on high-quality education that encompasses digital, technical, and resilience skills.

Despite the growing number of comprehensive studies addressing competencies for CE (e.g., (Akyazi et al., 2023; Burger et al., 2019; Watkins et al., 2021)), the literature so far does not provide a synthesis of the most relevant paths to be followed in future investigations in this area. Without an academic assessment of the current research gaps, the literature may fail to offer the necessary theoretical and practical support for a successful transition. To overcome this challenge, this study, grounded on a systematic literature review, aims to develop a strategic research agenda that offers study direction to scholars to better focus their future scientific endeavours. Sub-section 5.1.4 complements the extant literature and provides major contributions to the field of skills and competencies for CE. Firstly, six main research avenues constituting a complex landscape during the transition to a CE were synthesized. Second, a list of guiding research questions was elaborated for each identified avenue in the research agenda. Third, the necessity of changing traditional teaching methods to adopt digital and circular transformations was explored and documented. Finally, in line with Akyazi et al., (2023), the paper contributes to the practice by providing insights

into developing intellectual capital training programs that meet actual market demands and skills needs.
Without an understanding of the current state of practice, it would not be possible for educational institutions to provide educational and training courses capable of meeting industry demand for courses which support this transition. Indeed, new job profiles with extended or updated skills are needed in companies' organizations to implement their transition from linear to circular business models (Straub et al., 2023). Moreover, employees with different job roles outside of the CE or typical environmental role may be required to address the different activities related to CE (from organization, business model and research and development, through technology, supply chain and customer involvement, up to performance evaluation and regulations). To enable the right competences related to each of these facets of the CE, a different type of training will be required. In addition, for each stage of the lifecycle of the circular solution required, a specific kind of skill could be necessary. In addition, it is also needed to understand if companies are capable to find and select extant training courses and to reach and exploit them to qualify their workforce, enhance their CE readiness level, and to cope with the obstacles occurring throughout the twin transition. Furthermore, being strategic to complement the need of new CE-related skills, collaboration with external stakeholders has to be investigated to unveil which type of actors could better assist companies to become more circular (Pohlmann et al., 2020). Finally, models have been recently introduced in literature to help companies to self-assess their maturity in terms of CE (Acerbi et al., 2024; Demko-Rihter et al., 2023). To be able to climb the CE maturity levels, companies should be aware of the barriers they could face and which public strategies, action plans, and regulations could be supportive in coping with them (Taddei et al., 2024). To overcome this challenge and get a full understanding of the state of market and of practice, a multiple-perspective analysis (composed of a market analysis, a survey, and interviews) has been conducted. The market analysis (sub-section 5.2) was performed to map the formative and training opportunities already available in the educational scenario related to the CE domain. The survey (sub-section 5.3) has been conducted to identify the industrial and practical needs associated with the required skills and professional roles, necessary to address the transition towards a CE model. The interviews (sub-section 5.4) have been employed to grasp the concrete needs and unveil the already put in place actions to align the skills and job profiles required in the circular transition from experts working in textile, waste from electrical and electronic equipment (WEEE), and automotive sectors.

The deliverable is organized as follows. Section 3 summarises the results from D2.1, reporting the competency maps of the CERES project. Section 4 provides an overview of the research methodologies employed to conduct the activities. Section 5 presents the results, Section 6 includes the discussion and, finally, Section 7 provides conclusions, highlighting the links of the results obtained with future activities of the project in the different deliverables.

3 Skills in Circular Economy (CE): the context

The outcomes of D1.1 (composed of the analysis of the available literature on skills and competences needs in the CE domain, a market analysis of the courses currently offered for HE and VET, and the survey and interviews conducted with practitioners and industrialists to understand

their practical needs in terms of competences and skills for the adoption of the CE paradigm) will flank the results of the analysis conducted with D2.1 in WP2 (which were delivered at month 10).
D2.1 offered a comprehensive review and analysis of existing definitions and standards in various policy documents and recommendations linked to European learning and qualification and competence frameworks. Based on them, it laid the groundwork for creating the innovative CERES competency maps, including a dedicated focus on circularity-related competences, and aligning with the European Qualification Framework (EQF), National Qualification Framework (NQF), and micro-credentials to foster cross-country recognition, ensuring a global perspective on CERES required skills and qualifications.

The in-depth analysis of the European competence frameworks performed in D2.1 has proven instrumental in identifying and categorizing the necessary skills for CERES competency maps. The job market overview and analysis of the skills needed helped to better understand the workforce's evolving demands and trends and to identify the future leading roles. The review of Lifelong learning provided a nuanced understanding of eight key competences, bringing the imperative for digital and entrepreneurship skills to the forefront. These key competences laid the ground for VET, aligning mostly with EQF levels 4 and 5, making clear that to continue with the educational path for professionals, supporting the development of recognized certifications at EQF levels 6 and 7 in VET is essential. D2.1 thus directed the definition of CERES proficiency levels and the selection of four overarching skill categories: entrepreneurship skills, green skills, digital skills, and resilience and soft skills, for establishing the CERES comprehensive skill set. The CERES necessary skills were identified and categorized into fourteen distinct areas, each representing a specific facet crucial for comprehensive skill development. Moreover, the detailed breakdown reveals 38 competences that will play a pivotal role in guiding the nuanced and compelling design of the CERES curricula (D2.2). Table 1 serves as a comprehensive reference to summarize the competences identified in D2.1 for the CERES project. This comprehensive summary provides a holistic overview, serving as a strategic guide for the dynamic design and refinement of CERES curricula. Including these competences ensures a nuanced consideration of various facets, fostering a well-rounded and tailored approach to skill and knowledge development within the CERES educational journey.
Recognizing the ever-evolving nature of the CE domain, the CERES Competency Map (Figure 2) has been conceived to exhibit flexibility and adaptability. It is a dynamic process aiming to accommodate evolving trends and good practices. This framework forms the foundational cornerstone to build and deploy the CERES curricula and learning materials, equipping the target audience with the means to acquire and enhance these essential skills. As a result, the approach remains responsive to the evolving demands and opportunities in the CE domain.
Moreover, integrating the CE as a transversal theme underscores its importance across the framework, ensuring that the principles of circularity are interwoven seamlessly throughout the competency maps, fostering a holistic understanding and application of circular practices. The structure of the two competency maps (VET and HE) is characterized by a foundation of four core modules (CMs) augmented by Specialized Modules (SMs) tailored for HE and VET. This dual approach acknowledges the diverse learning needs of students pursuing different educational paths. Furthermore, the development process will be guided by four overarching skills categories — entrepreneurship, green, digital, and soft skills — providing a structured framework for shaping the CMs. Notably, creating SMs for HE and VET will be enriched by insights from WP1, incorporating inputs for further development. This sequential and collaborative approach ensures

a nuanced and well-informed development process, aligning the competency maps with the evolving needs of learners and the broader educational landscape.

Table 1: Summary Competences CERES.

Overarching categories	Areas	Competences
Entrepreneurship	**Ideas and opportunities (Entrecomp)**	Spotting opportunities
		Creativity
		Vision
		Valuable Ideas
		Ethical and sustainable thinking
	Into action (Entrecomp)	Taking the initiative
		Planning and management
		Coping with uncertainty, ambiguity, and risk
		Working with others
		Learning through experience
	Resources (Entrecomp)	Mobilizing resources
		Financial and economic literacy
		Mobilizing others
	Embracing complexity in sustainability (Green Comp)	System thinking
		Critical thinking
Resilience and Soft skills	**Personal**	Self-regulation
		Flexibility
		Wellbeing
	Social	Communication
		Collaboration
	Resources (Entrecomp)	Self-awareness and self-efficacy
		Motivation and perseverance

Overarching categories	Areas	Competences
Digital Technologies (DTs)	**Communication and Collaboration**	Sharing through DTs
		Engaging citizenship through DTs
		Collaborating through DTs
	Digital content creation	Copyright and licenses
		Programming
	Safety	Protecting the environment
	Problem Thinking	Identifying needs and technological responses
		Creatively using DTs
		Identifying digital competence gaps
Green transition	**Embracing complexity in sustainability (Green Comp)**	Problem framing
	Envisioning sustainable futures (Green comp)	Future literacy
		Adaptability
		Exploratory thinking
	Acting for sustainability (Green comp)	Political agency
		Collective action
		Individual initiative

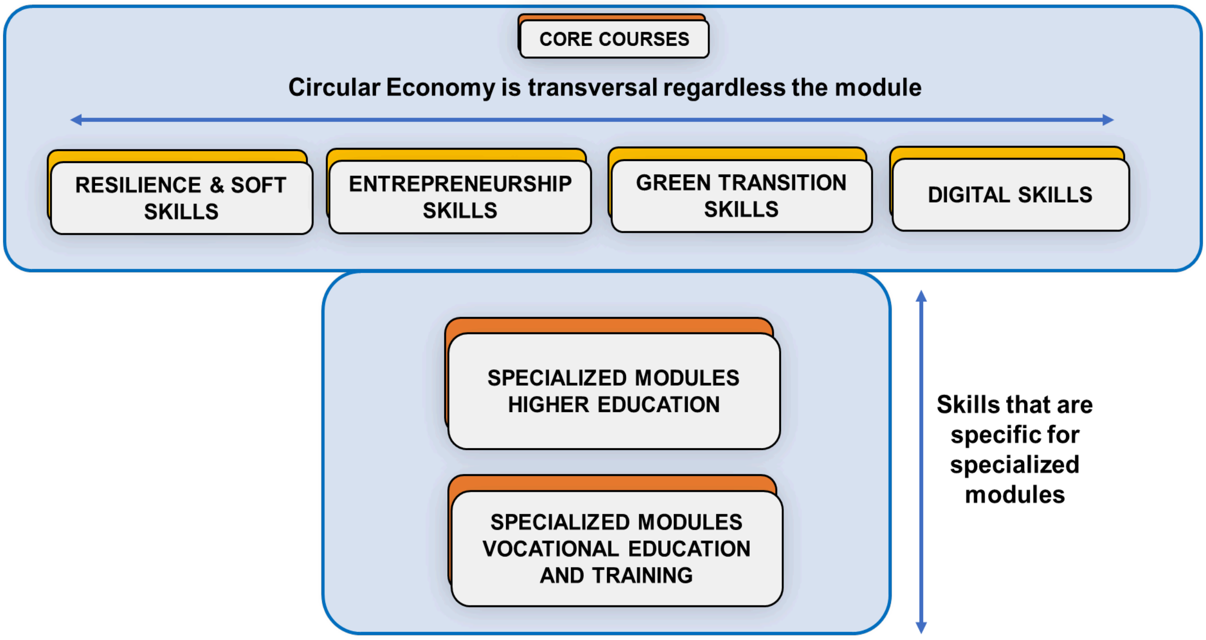


Figure 1: CERES Visual Competency Maps

3.1 Skills in CE

The circular transition requires diverse skills to increase the number of professionals who build and master green technologies. Central to this is sustainability, which is pivotal in advancing the growth of the CE. Competences in CE may include understanding the impact of sustainability practices that align with sustainable development goals (SDGs), digital, circular products, services, and business models, creating innovative nature-based solutions, helping minimize activities' environmental footprint, and advocating for sustainable waste and resource management (European Commission (EC), 2020).

In this sense, the CERES curricula considered the Sustainability Competence Framework (GreenComp), Digital Competence Framework (DigComp), Entrepreneurship Competence Framework (EntreComp), and Personal, Social, and Learning-to-learn Competence Framework (LifeComp) to support the identification of competences to address during the modules.
Considering the insights from the GreenComp, the CERES curricula will refer to competencies that are particularly pertinent and systematically closely aligned with the principles and practices of the CE to embrace complexity in sustainability, envisioning sustainable futures and actions for sustainability. Green skills encompass a set of abilities and knowledge tailored to address environmental sustainability challenges and promote eco-friendly practices. Possessing green competences will contribute to sustainable solutions, address environmental challenges, and participate in the global effort to build a greener and more resilient future. The green skills in the CERES curricula will represent a sophisticated integration of academic knowledge and practical expertise in environmental sustainability. Individuals will understand the complexities of green practices and applications. Learners will develop foundational green skills for future contributions

to sustainable practices in different manufacturing sectors. Mastering green skills will involve applying advanced knowledge to address complex environmental challenges. The emphasis on green skills reflects the evolving importance of sustainability across diverse academic and professional domains, preparing individuals to contribute meaningfully to a more environmentally conscious and resilient global community.

Building on the insights from EntreComp, the CERES curricula will include competencies that are aligned with the principles and practices of the CE to create ideas and opportunities, put into action activities in complex environments, and manage resources. The CERES curricula consider entrepreneurial skills to encompass a dynamic set of attributes that empower individuals to identify opportunities, take calculated risks, and transform innovative ideas into tangible ventures, emphasizing a proactive mindset, creativity, and a willingness to adapt in the face of uncertainty. Effective problem-solving, strategic thinking, and a keen sense of initiative are integral to entrepreneurial skills. In a rapidly evolving global landscape, stakeholders increasingly recognize entrepreneurial skills as essential for fostering innovation, driving economic growth, and cultivating a mindset of continuous learning and adaptation across various domains. Entrepreneurial skills are highly significant and represent a fusion of academic prowess and practical insight. Individuals will not only master advanced knowledge in their respective fields but also exhibit entrepreneurial dexterity. This entails identifying opportunities, navigating complexity, and applying innovative thinking to real-world challenges. Learners will cultivate foundational entrepreneurial skills, laying the groundwork for future professional endeavours. A deeper integration of entrepreneurial skills will require individuals to conceive innovative solutions and strategically implement and manage projects. The emphasis on effective communication, strategic thinking, and leadership reflects the broader recognition that entrepreneurial skills are pivotal for success in diverse academic and professional contexts, fostering a mindset of innovation, adaptability, and proactive engagement with the evolving landscape. Also, communication and leadership abilities are crucial in facilitating collaboration and resource mobilization to bring ideas to fruition.

Following the DigComp framework, the CERES curricula considered communication, collaboration, digital content creation, safety, and problem thinking. Digital skills will encompass diverse competences essential for navigating the contemporary technological landscape. These skills go beyond basic computer literacy, encompassing proficiency in utilizing digital tools, platforms, and technologies. Key aspects of digital skills include information literacy, the ability to critically assess and interpret digital information, and proficiency in using software applications for diverse purposes. Digital skills include coding, data analysis, cybersecurity, and digital communication. Individuals with robust digital skills will leverage technology for professional tasks and contribute meaningfully to the digital transformation shaping various industries and sectors. The module in digital skills will improve foundational digital literacy and proficiency in complex digital tools and technologies, developing a more comprehensive understanding of digital skills and laying the groundwork for more advanced applications that will enable the digital transition. Knowledge of digital skills will involve assessing and applying digital information critically, engaging in advanced data analysis, and contributing to digital transformation. The emphasis reflects the evolving importance of technology across diverse academic and professional contexts.

Finally, in the CERES curricula, resilience and soft skills have been strategically divided into three distinct areas: personal and social (derived from the LifeComp) and resources (derived from the

EntreComp). Possessing effective communication, Emotional intelligence (EI), and interpersonal abilities is integral. Cultivating resilience and soft skills is vital in shaping individuals who can excel academically and professionally. Resilience is a fundamental quality that empowers individuals to bounce back from setbacks, adapt to change, thrive in the face of challenges, persevere through adversity, maintain a positive mindset, and have the strength to navigate uncertainties. In the professional context, individuals often intertwine resilience with a repertoire of soft skills, including interpersonal, communication, and EI. Soft skills are the interpersonal attributes that enable effective collaboration, communication, and problem-solving. They contribute significantly to workplace success by fostering positive relationships, teamwork, and adaptability.

4 Research Methodology

To address the main objectives of WP1, a dedicated research methodology has been developed and enacted (Figure 2). Both theory and practice have been investigated using different research approaches. A systematic literature review (sub-section 4.1) has been conducted to explore and systematize the knowledge related to the CE skills and competences research domain. On the other side, a market analysis (sub-section 4.2), an online survey (sub-section 4.3), and a set of interviews (sub-section 4.4) have been conducted to investigate the market and resilience needs for competences and skills to better address the challenges of CE transition and the European Green Deal, to review existing VET and HE training in the CE domain, and to provide accessible insights to feed HE/VET/Market actors' competence development and promote the field of CE education.

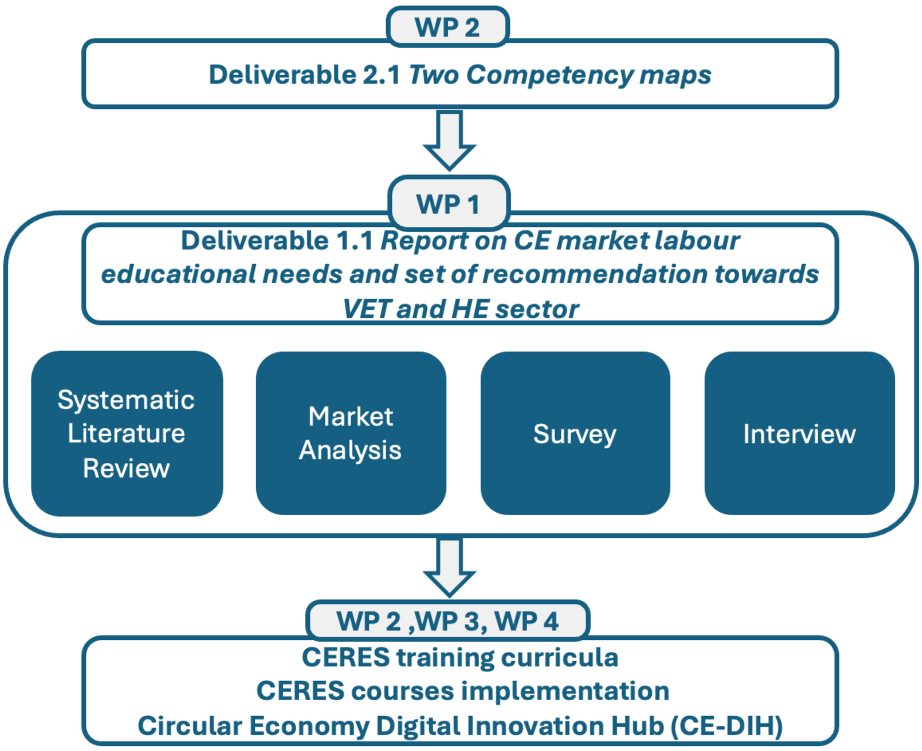


Figure 2: Research methodology scheme.

4.1 Systematic literature review (SLR)

To identify the critical competencies and skills essential for enabling the adoption of a CE in the manufacturing sector, a systematic literature review (SLR) was conducted. The SLR method was adopted following the guidelines of Tranfield et al. (2003) and Moher et al. (2009), and the process began with the selection of databases and the development of the search string. The Scopus and Web of Science search platforms were chosen for being internationally recognized (Rosa et al., 2020) and for containing a vast number of articles on the study's topic. The search string combined terms related to skills, competencies, and education with CE and manufacturing. Figure 3 presents the transparent and replicable approach, including the documents' inclusion and exclusion criteria.

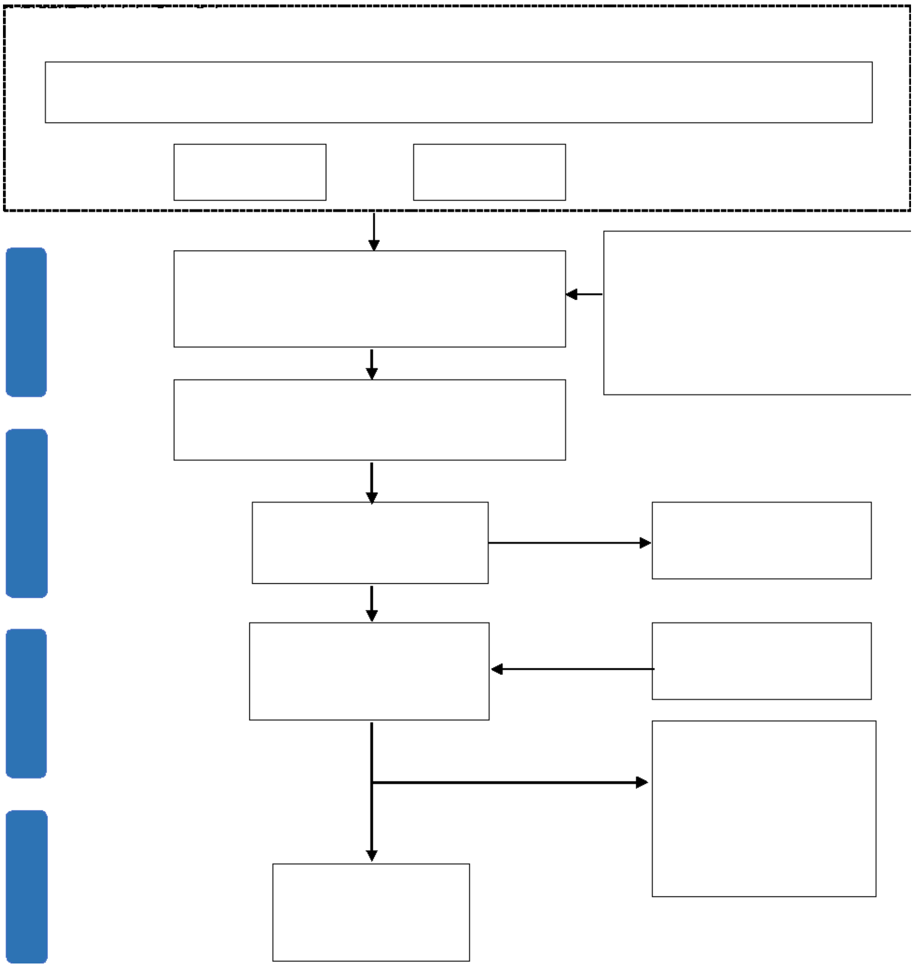


Figure 3: Research strategy (adapted from the PRISMA guidelines (Moher et al., 2009))

The searches were conducted on September 14, 2023, and only articles published in English and available in peer-to-peer journals and conferences were considered. Additionally, only papers published after 2012 were selected, as this marks the publication year of the first report by the Ellen MacArthur Foundation (The Ellen MacArthur Foundation, 2013), which globally popularized the term CE. Since that year, the quantity of articles exploring the principles of CE has exponentially increased (Kirchherr et al., 2017b), contributing to confining the sample of articles most relevant to our analysis. In total, 669 records were identified after removing duplicates, which were first screened based on Title, Abstract, and Keywords.

During the first screening stage, articles addressing mathematical models and algorithm development unrelated to the CE research field were eliminated. Papers using the term "circular" in contexts unrelated to circular manufacturing and design, such as circular cylinders, circular milling technology, or circularity errors, were also excluded from consideration. In the second evaluation stage, articles were read thoroughly, and only those focusing on skills, capabilities, and competencies for the CE were selected. The final sample resulted in 58 papers, including five additional papers found through a backward snowballing process. This method involved utilizing the reference lists of the initially selected papers to uncover supplementary relevant documents (Wohlin, 2014). The entire screening process was carried out simultaneously and autonomously by two authors to reduce bias.

Consistent with previous studies (i.e., Acerbi and Taisch, 2020; Sassanelli et al., 2020), the dimensions extracted in the selected articles included: year of publication, research type (categorized as Action Research/Application Case; (Multiple) Case studies; Mixed methods; Surveys; Literature review; other), publication source (Journal or Conference), nation of the first author, and industries. In addition, skills mentioned in each paper were also extracted. To support the data analysis process, the authors utilized both Microsoft Office's Excel spreadsheets and the qualitative analysis software Maxqda®. Following the recommendations of Miles et al. (2014) and Elo and Kyngäs (2008), a meticulous content analysis process was conducted for the identification of skills categories, considering coding and categorization of the data (Figure 4).

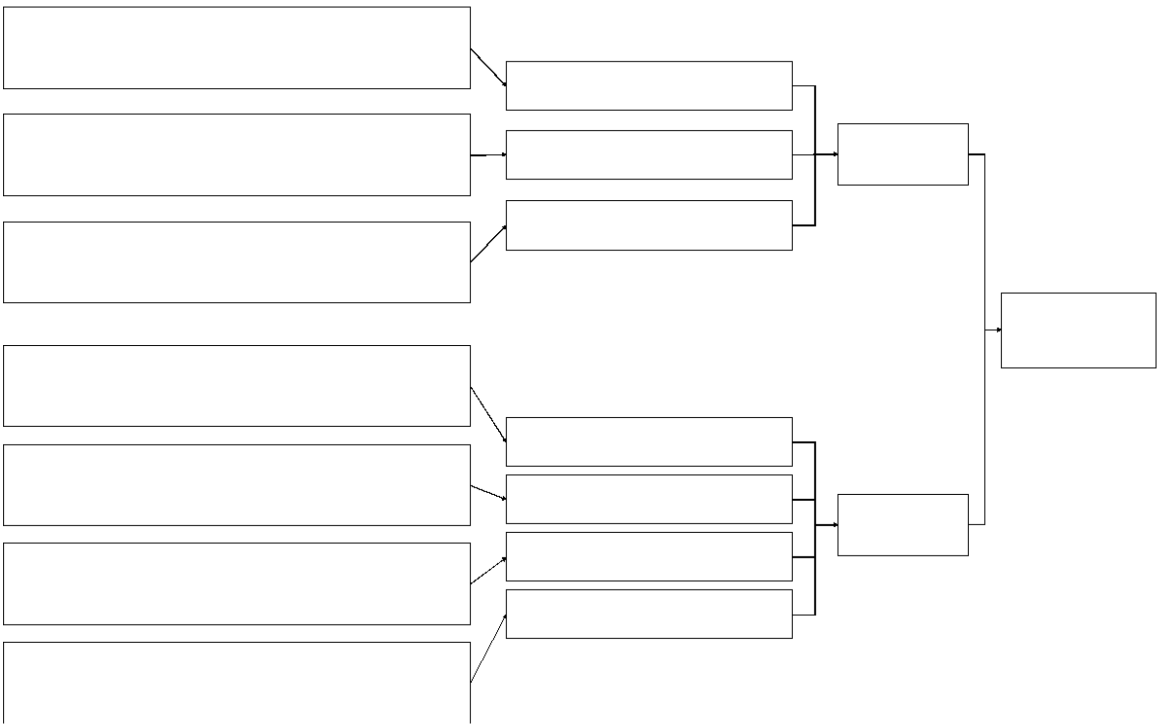


Figure 4: An example of the coding process adopted.

In the first coding cycle, texts were extracted based on "in vivo" codes, representing short phrases (skills) mentioned in the analysed articles (Miles et al., 2014). At this stage, three different authors identified 498 textual segments (representative quotes), which were grouped into 40 first-order codes. For example, the textual segments "*Ability to work with data*" (de Miranda et al., 2021) and "*In this digital era, knowledge of big data analytics (BDA) […] has proven to be a tacit resource*" (Bag et al., 2021a) were grouped under the code "Data management and analytical skills". Subsequently, the authors looked for patterns in the second coding cycle and created 7 second-order codes that best represented the analysed data. After extensive discussions and consensus-building among the authors, the second-order codes were aggregated into 3 macro-dimensions (categories), encompassing all the skills identified in the literature. The 3 aggregated dimensions were (1) Resilience skills, (2) DTs skills, and (3) Specialized/Technical skills. Figure 4 provides an example of the code structure related to the aggregated dimension "DTs skills". In sub-section 5.1.2, a detailed description of the three aggregated skill dimensions is presented.

4.2 Market Analysis

The market research was carried out to map the formative and training opportunities already available in the educational scenario related to the CE domain. The analysis started in September 2023, and was structured into 3 main steps:

1. research of learning and training courses offered on the market and data collection,
2. analysis of the information gathered,
3. critical discussion of the results obtained.

The first step has been conducted classifying the courses by educational levels (i.e., HE and VET). Therefore, dedicated queries were performed on the web browser for gathering information related to the extant courses at HE level ("course circular economy" and "master degree course Circular Economy"), and at VET level ("course on circular economy for vocational and training education VET").

This research uncovered 108 courses in total (27 at VET level (mostly related to specific projects dedicated to their development) and 81 at HE level). Going into detail, each course was then analysed according to 25 drivers, split according to three primary goals: to gather the information describing the sample of courses detected and selected (e.g., provider/teaching institution, language of the course); to analyse the content of courses and of their modules (e.g., methodological approach of teaching, course delivery methods); and, based on this analysis, to classify the selected courses into macro-categories (e.g., keywords, main topics). In Table 2, a detailed list of these drivers of analysis is provided.

Table 2: Drivers used for the market analysis of CE courses.

Scope	Drivers
Descriptive information about the course (and the eventual related project)	a. Provider/Teaching institution, b. Country of the provider/teaching institution, c. Language of the course, d. Belonging of the course provider to the CERES consortium, e. Title of the course, f. Learning objectives, g. Educational level (HE/VET/Other), h. Type (i.e., Project, Webinar, Training course, Pilot course, Workshop (only for VET)).
Analysis of the content provided in the modules of the courses	i. Methodological approach of teaching (theory-based, application-base, case study, analytical applications, simulation, serious games), j. Course delivery method (Online/Offline/Hybrid), k. Learning materials (MOOCs/Presentations/Other), l. Number of modules, m. Modules' title, n. Duration, o. Final assessment (if yes, which type), p. Price of the course, q. Target groups (e.g., managers, technicians, undergraduates, postgraduates, executives, companies, etc.), r. Prerequisites (i.e., conditions to meet before one can enroll or participate in a particular course or program (e.g., bachelor, master, none, etc.)), s. Required proficiency level (e.g., beginner, intermediate, expert), t. Course (or a module) of Master Degree/ Master Degree/Post-graduate course, u. Referring industry (e.g., all industries, agri-food, etc.), v. Public availability of learning material (i.e., learning materials already published on courses' platform/website or available for all).
Classification of the courses into macro-categories	w. Keywords, x. Main topics (identified through course's learning objectives and content of modules), y. Macro-category (i.e., Circular economy transition, Sustainability transition, Twin transition).

The classification of courses into macro categories was done through the application of the SLIP method (Maeda, 2006), which is a free-form methodology used to "Sort, Label, Integrate and Prioritize" concepts: after identifying the keywords for each educational program, and considering courses' main topics and learning objectives, 3 main macro-categories linked to CE, sustainability and digital transition were detected. These macro-categories are detailed in sub-section 5.2.

4.3 Survey

To identify the industrial and practical needs associated with the required professional roles, necessary to address the transition towards a CE model, a questionnaire was developed, and a related online survey was run. In it, respondents were asked to share personal information, data about the organization in which they are currently working for, and their experience about their understanding of CE and about the needs related to CE-related skills. The questionnaire was designed to be filled by employees of companies and organizations interested or involved in the CE

domain, to grasp their experience, issues, needs and expectations. The research method is composed of three main phases: survey development, survey execution, and analysis of results.
In the first phase, thirty questions were developed in English (and then translated also in Italian and Bulgarian) to ensure accessibility and inclusivity across diverse linguistic audiences. The complete list of questions is provided in Annex 7. The questionnaire consists of multiple-choice, open-ended, and ranking questions, split in four main sections. The first section (from question 1 to 9) aims at profiling respondents (asking their affiliation, their role within organizations, their level of involvement in the CE-related activities, and their areas of responsibility). The second part, comprising questions from 10 to 13, refers to information purely related to the respondents' organization (i.e., industry, size of the organization, geographical impact of the related business). The third section, from question 14 to question 17, aims to explore the company's understanding of CE, asking their level of maturity concerning CE, and identifying the main barriers in approaching its guiding principles. The fourth and final section includes questions from 18 to 30 and wants to investigate the organizations needs in terms of skills and competences, type of trainings, and the stakeholders capable of better supporting the CE transition. The survey was designed to require around 15 minutes for its completion.

Regarding the survey execution, the questionnaire, in the three different languages, was reported on a professional platform (https://freeonlinesurveys.com/). Each of the versions of the same questionnaire in the three languages corresponded to a different link to the same platform. The English version of the survey was shared for the first time in the first week of November 2023, and then also in Bulgarian and Italian were shared in the following week. Three waves of official dissemination of the survey's links were implemented (beginning of November 2023, of December 2023, and of January 2024) through the CERES project (in which the survey was performed) website and on its LinkedIn page. To enable the widest possible reach, the links were also shared via each project partner private and public social channels. Additionally, the link to the questionnaire in Italian was also shared through Erion's newsletter and the questionnaire in English was pushed by REPIC and Politecnico di Bari through direct e-mail contacts to different companies. At the beginning of February, the survey was closed, and all the data were retrieved and translated in English (when needed).

The third phase was the analysis of results. It began with the verification of answers and leading to eliminating 50 not significant (not fully filled) answers from the English-language questionnaire and 24 from the questionnaire in Italian, leading to a total number of 102 useful answers. The answers to the open questions were collected and analysed, grouping similar ones and grasping recurring themes.

4.4 Interviews

To address the main objectives of this deliverable, interviews have also been conducted, requiring the development of a semi-structured interview protocol. The interviews (together with the survey) have been employed to grasp the concrete needs and existing actions to align the skills and job profiles required in the circular transition from experts working in textile, WEEE, and automotive sectors. It's indeed worth mentioning that this study complements parallel analyses previously descripted (deployed through the systematic literature review and the market analysis performed on universities, business schools, national and international projects websites) (Sassanelli et al., 2023b), which served as the theoretical background for the development of the interview protocol and the interpretation of the results, as suggested by (Yin, 2018).

The interview protocol (Annex 8) has been developed following the guidelines provided by Yin (2018), and it is based on twenty questions covering seven areas of analysis addressing the CE transition of the three different sectors, which are reported below:

1. *Interviewees profiling and company information*: questions aiming to frame the role of the interviewee and the profile of the related company, as well as the sustainability-related activities already put in place.
2. *Industry peculiarities*: questions aiming to explore the perceived peculiarities of each specific industry in addressing the circular and/or sustainable transition.
3. *Job profiles needed*: questions to explore the perceived needs in terms of new job profiles or changes in the already existing job profiles to cope with the circular transition.
4. *Skills and competencies needed*: questions to perceive needs in terms of new hard and soft skills (also digital skills) needed to support the current transition phase.
5. *Training programs developed*: questions aiming to detect the training programs already proposed by the companies to align employees' skills with those regarded as needed for the proper management of the circular transition, and to perceive skills' gaps detected within the sectors.
6. *External partnerships established*: questions aiming to identify potential partnerships established by the interviewed companies and the reason behind this choice in terms of added value for their circular transition.
7. *Future outlook*: questions aiming to evaluate how companies perceive this circular evolution and which kind of support they consider fundamental from governments.

After developing the interview protocol, an invitation e-mail has been prepared presenting the activities of the project of which this analysis is a relevant part (Sassanelli et al., 2023b) as suggested by (Yin, 2018). This email has been sent between the 9th January and 6th March 2024 to 10 expert professionals from the three identified sectors. They have been selected based on their experience in sustainability or circularity projects (both internal initiatives to the company and external like European funded projects). Among them, one expert from the WEEE sector, two experts from the textile sector and four experts from the automotive sector have responded positively. Therefore, 8 separate semi-structured interviews have been conducted (online) involving at least one person to two from the company and at least 2 out of 7 researchers.
Table 3 reports the information about the interviews.

Table 3. Details about the seven interviews conducted.

#	Company	Industry	Location	N° interviewers	N° Interviewees	Role	Duration	Date
1	A	Textile	Italy	3	2	Sustainability Specialist, Sustainability Director and Company President	30 min	09/01/24
2	B	Textile	Italy	3	1	Sustainability Manager	37 min	12/01/24
3	C	WEEE	UK	2	1	Development Engineer	53 min	16/01/24
4	D	Automotive	Italy	5	2	Materials Department	60 min	07/02/24
5	E	Automotive	France	7	1	Mechanical Department Manager	49 min	19/02/24
6	F	Automotive	Spain	7	1	Environmental Innovation Manager	25 min	20/02/24
7	G	Automotive	Germany	7	1	Power department	30 min	04/03/24
8	H	WEEE	UK	2	1	Managing Director	50 min	17/01/24

4.5 Gap analysis

Exploiting all the results obtained through the previous activities, a gap analysis has been designed to identify the gaps existing between current formative offer (i.e., AS IS) and market needs (i.e., TO BE) in terms of skills related to CE. Consequently, the output of this analysis constitutes the starting point to develop new curricula appropriate to the demand of the CE market in WP2. In particular, a twofold framework has been developed to allow a visual comparison among the AS IS configuration of skills in CE (coming from the market analysis results and put at the centre of the framework as a baseline for the benchmark) and the theoretical and practical TO BE configurations (composed on top by the results coming from the empirical investigation performed (i.e., the survey and the industrial interviews) and on the bottom by the theoretical results of the SLR).
In particular, the declination of the CE skills provided on the market were detailed at both the HE and VET levels. The market analysis results shown in sub-section 5.2. all the topics (and related sub-topics) were analysed, and then linked and translated in the related needed skills (following the categorization developed and proposed through the SLR results presented in sub-section 5.2).
These two sets of CE-related skill offer have been compared on one side with the needs coming from survey and interviews (named “empirical skills requirements – need TO BE there”) and on the other side with those coming from the literature (named “theoretical skills requirement – need TO BE there”).
Concerning empirical skills requirements, from the survey results, the most prioritized 6 skills, ranked from the eleven answer options of question 18 were taken in consideration, after being linked and expressed in the related skills categorized through the SLR. On the same line of empirical requirements at the top of the framework, results from interviews were also considered, taking into account the set of skills explicitily indicated by industrial experts as those needed for CE adoption.

Dealing with the theoretical skills requirements, results fom the SLR were considered and split in two lines at the bottom of the framework. The first line is composed by the 5 most cited skills in literature per each macro-category of skills defined in the SLR and the second one with the remaining (less cited) ones.
The final aim was to verify if the courses provided on the market actually address the empirical demand and requirements (at the top of the framework) and the theoretical needs (at the bottom of the framework). In particular, the empirical and top ranked skills from SLR not addressed from the market offer represent the skills that are required to be added in new courses related to the CE. Instead, looking at the skills less cited in the literature, new specific topics and streams could be raised if they are not addressed by the market, and niche topics streams could be detected if they are already covered by the market offer.
The development of the twofold gap analysis framework for HE and VET levels, involves all the results coming from the previous researches. If skills are present or not in the list of those addressed by course analysed in the market analysis, they have been kept on the framework respectively in green (needed skill) or red (already covered skill).
The frameworks are presented in sub-section 5.5 of this deliverable and represents a visual starting point able to provide useful recommendations about which skills the CE education should focus on.

5 Results

In this section, the results obtained through the different research methods adopted are reported. Sub-section 5.1 shows the output of the SLR, conducted to explore, and systematize the knowledge related to the CE skills and competences research domain. On the other side, the results related to the practice are presented as follows: market analysis (sub-section 5.2), online survey (sub-section 5.3), and set of interviews (sub-section 5.4).

5.1 Systematic literature review

5.1.1 Descriptive analysis

In this section, the descriptive analysis of the 58 selected papers is presented. The results were structured according to historical publication trend by year; research method used; distribution of papers by source of publication; publishing countries; collaboration analysis of co-authorship; industry type; co-occurrence of keywords; and educational levels presented in the papers.

The historical publication trend (Figure 5) shows a growing interest in the theme of skills for the CE. However, despite the EMF report being published in 2012, it was only in 2015 that scholars began discussing education and skill development, which is crucial for the circular transition. The year 2021 contains the highest number of publications (12 in total), and this can be attributed to the increased likelihood of DT adoption (digitalization) by companies driven by the COVID-19 pandemic (Bai et al., 2021). With the rise of digitalization, there is a shift in the demand for skills and a need to upskill workers for industrial transformation (Ghobakhloo et al., 2023). Most articles (61.9%) discussing skills associated with the dimension of DTs were published after this date. The year 2023 had a lower publication rate than 2021 because only articles published until September were analysed.

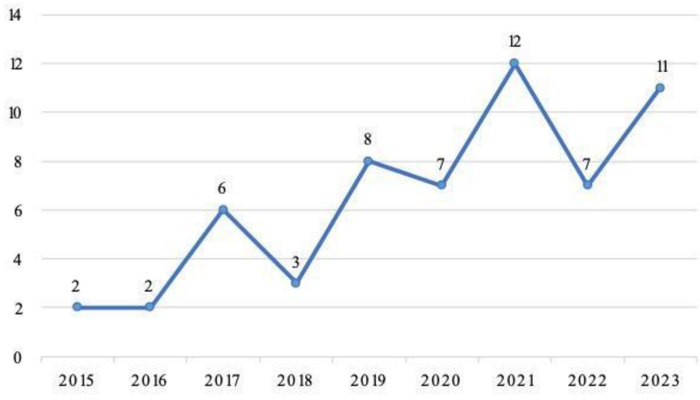


Figure 5: Historical publication trend by year.

Regarding the research method used by the papers (Table 4), the majority of them adopted a more practical methodological approach by employing action research (25,9%), where results stem from educational processes or projects developed to foster the skills of undergraduate students. (Multiple) case studies also showed an elevated adoption (20,7%), followed by mixed methods that combine more than one methodological approach (15,5%). Surveys and literature reviews represent 10,3% and 8,6%, respectively, and eleven articles (19%) adopted other methods such as workshops, panel discussions, system dynamics, and others.

Table 4: Research type.

Used methodologies	Nº of papers
Action Research/Application Case	15
(Multiple) Case studies	12
Mixed methods	9
Surveys	6
Literature review	5
Other*	11

* Workshops, panel discussion, system dynamics, agent-based approaches, analyses of programs, courses, and education data.

The publication sources of the papers were quite diverse (41 identified sources), distributed among journals and conferences. The most relevant publication sources (Figure 6) were Sustainability MDPI (8), followed by Journal of Cleaner Production (7). One conference, the European Society for Engineering Education (SEFI) Conference, appeared in the top five ranking with 2 publications.

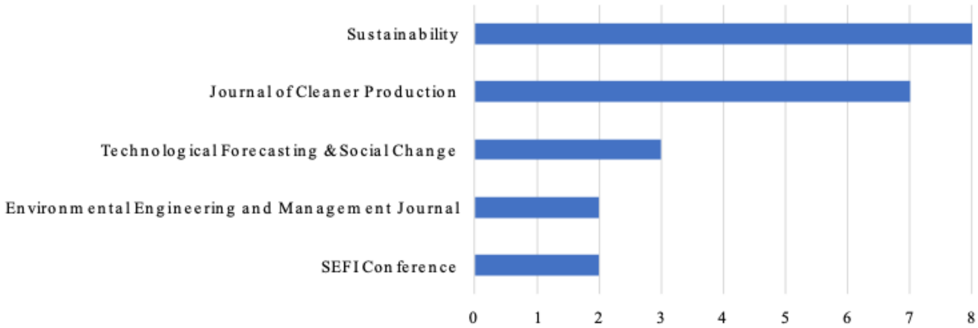


Figure 6: Paper distribution across journals and conferences (Top 5).

A more in-depth analysis to detect the geographic distribution of publications and collaboration among authors from different nations was conducted (Figure 7 and Figure 8). In terms of the distribution of papers by nationality, the majority of contributions came from the European continent, with Italy (10) holding a prominent position, followed by the United Kingdom (9), Spain (5), and the Netherlands (4). The African continent, South Africa, and in the American continent, the United States, presented each 3 publications. Other countries showed fewer publications (between 1 and 2), indicating that this theme has not yet become a priority in those nations. Through a bibliometric analysis using VosViewer software, it was possible to identify four main clusters of collaboration among authors, as in Figure 6. Authors establish partnerships between different countries and institutions. The large nodes symbolize nations with significant influence on the topic, while the connections between nodes represent collaborative relationships among universities and institutes.

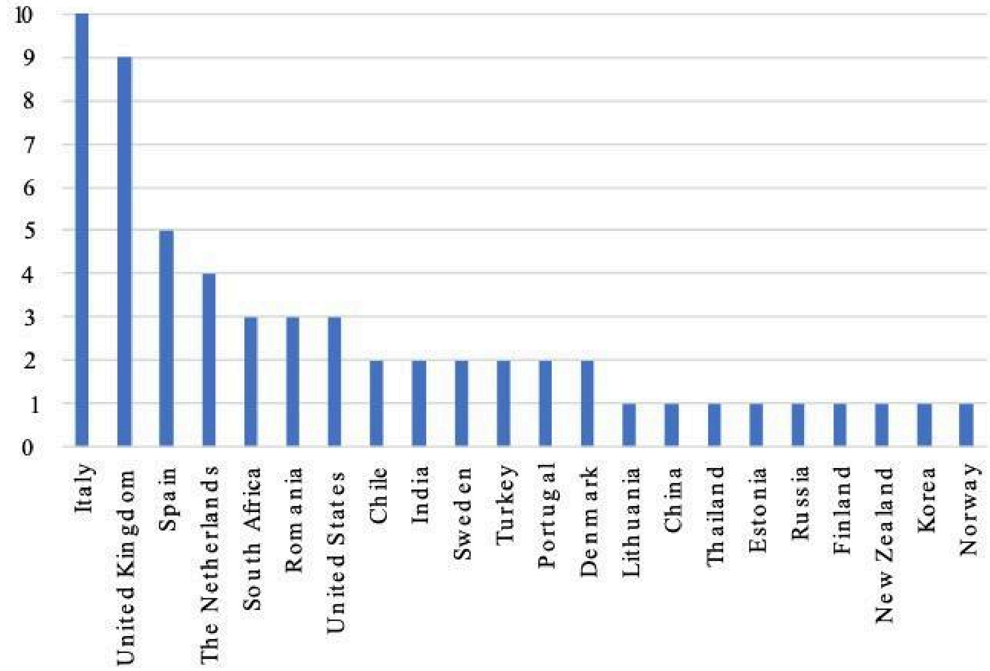


Figure 7: Distribution of papers by the main author's country of origin.

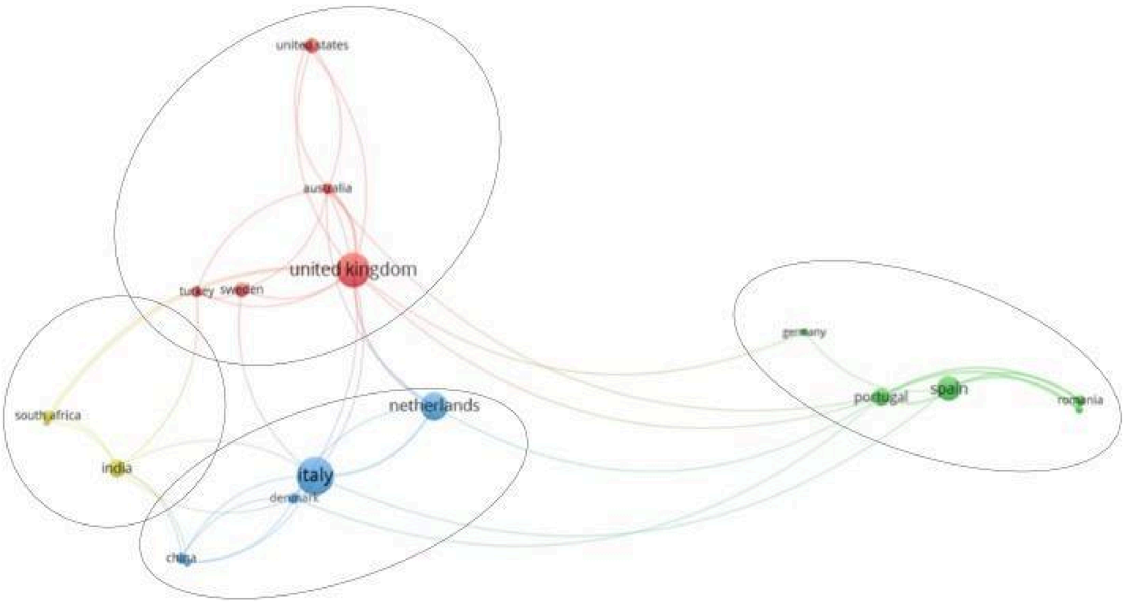


Figure 8: Country co-authorship network (Collaboration analysis) developed through the software VosViewer.

In terms of the industrial sectors covered in the selected sample (Figure 9), practically half of the documents (26 articles) do not specify the type of sector or industry of focus. In this context, the CE skills mentioned are comprehensive and applicable to different industries. In the analysed papers, seven articles investigated multiple industrial sectors. For example, De los Rios and Charnley (2017), explored a variety of industries, such as electronics, automobile, fast moving consumer goods, and furniture. Regarding the papers that focused in a specific sector, the textile, footwear, and fashion segments presented the highest number of publications (7), followed by the chemical manufacturing (4) and automotive (3) and construction and cement industry (3).

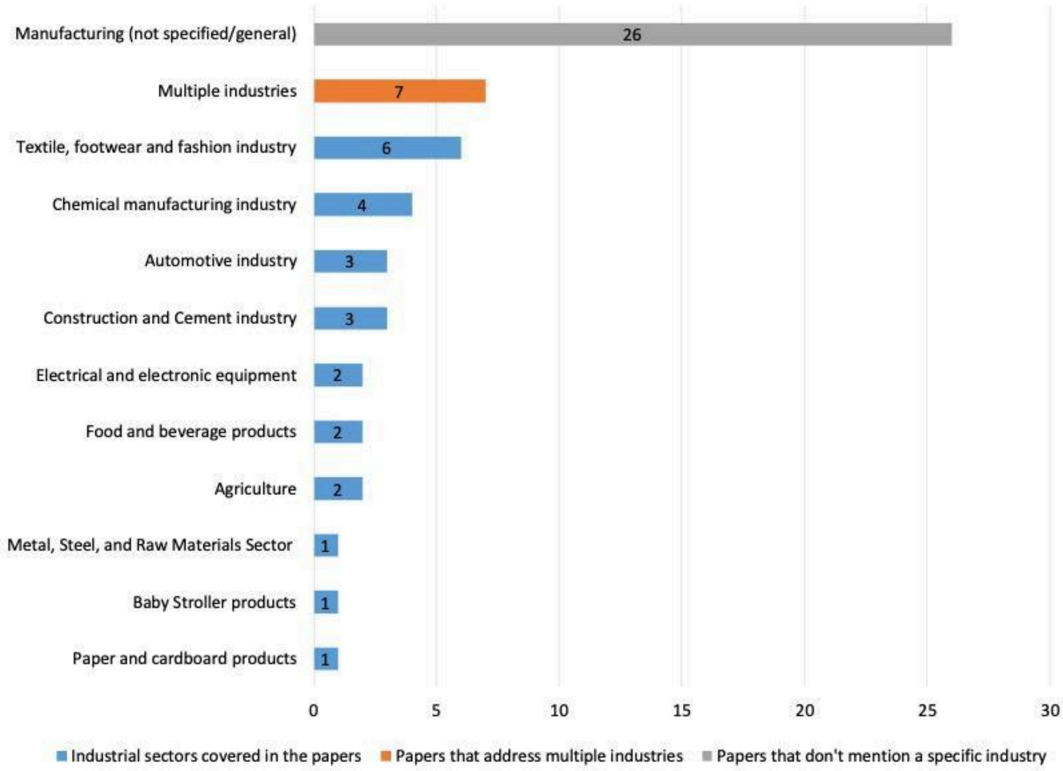


Figure 9: Industries

In Figure 10, a keyword co-occurrence analysis was performed, which provides an overview of the most relevant hotspots within the field of knowledge (Ranjbari et al., 2021). The co-occurrence network was created with the same keywords that appeared at least in three papers of the SLR sample. This analysis shows that topics such as “product design”, “students”, and “engineering education” have already attracted attention in the past, but that currently research is more focused on “I4.0”, “sustainable manufacturing”, “skills”, and “economic conditions”. The most frequent keyword was “circular economy”, with 39 occurrences. The second most was sustainability/sustainable development, with 30, followed by product design, with 13 occurrences.

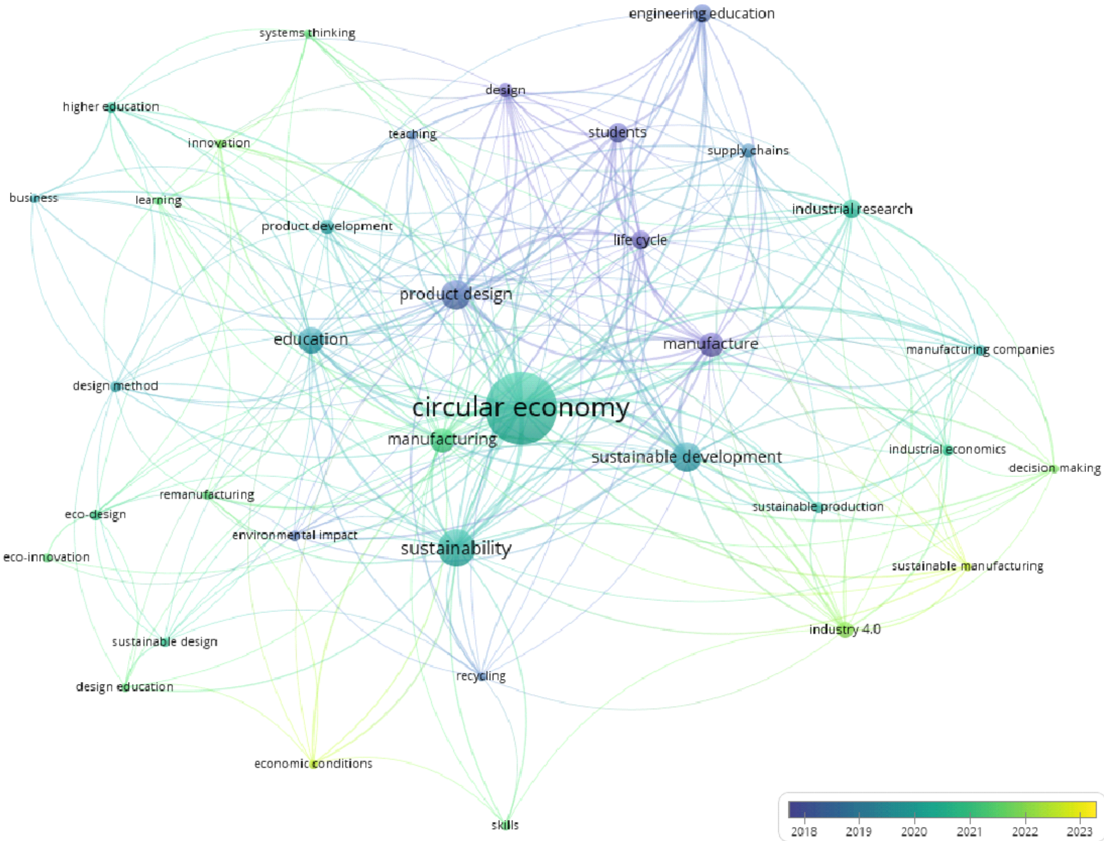


Figure 10: Co-occurrence of keywords developed through the software VosViewer

In terms of educational level discussed in the papers, this study founds 7 categories: primary, secondary, HE undergraduate, HE post-graduate, HE in general (or tertiary, as some of the papers do not specify the level), PhD/researcher/teacher level, and VET. Some of the implemented or proposed courses were obligatory while others were voluntary.

Figure 11 shows the distribution of educational levels across the papers. As it can be seen, out of those that address the educational level, the highest number of papers refer to VET. Some of these educations are targeting specific profession/sector, such as designers (Andrews, 2015; Spreafico and Landi, 2022; Sumter et al., 2021; Vihma and Moora, 2020), textile and clothing sector (Avadanei et al., 2021, 2020), while others refer to owners/managers of small companies (Cassells and Lewis, 2017) or industry in general (Akyazi et al., 2023; De los Rios and Charnley, 2017). Similarly, the courses proposed for undergraduate students are related to specific study, such as chemical engineering (Reichmanis and Sabahi, 2017) or design studies (Kim and Lee, 2022), or have been planned for wider range of studies, such as practice-focused engineers, mechanical, marketing, business, data management, and manufacturing engineers (Knudby and Larsen, 2017). Looking at the graduate level programs, some were dedicated to chemical engineering students (Reichmanis and Sabahi, 2017), others were specific for industrial design studies (Fernandes et al., 2018; Raeva et al., 2021), while most were more general.

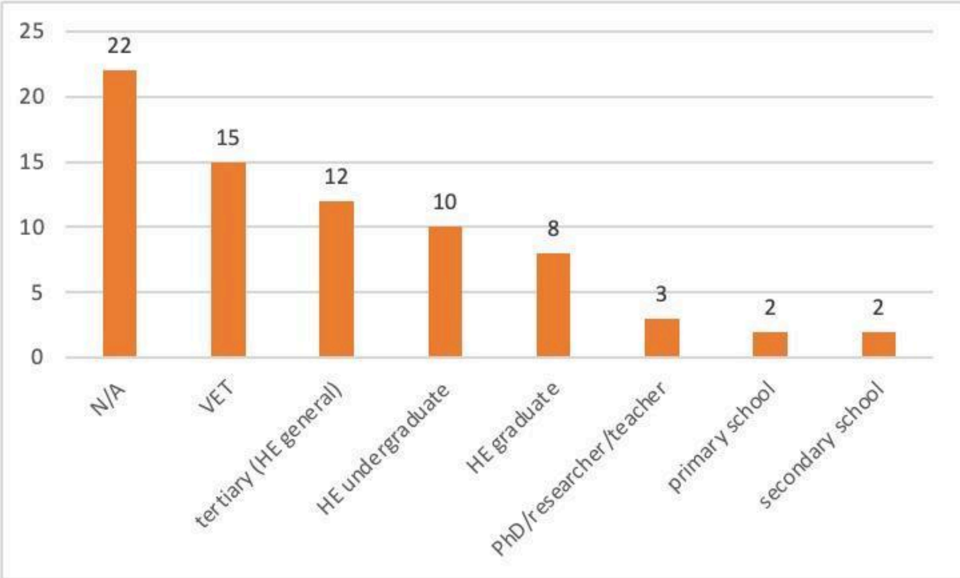


Figure 11: Educational levels presented in the papers

5.1.2 Circularity skills analysis

Grounded on the systematic literature review, 40 skills were identified, divided into three main categories: (1) Resilience skills, (2) DTs skills, and (3) Specialized/technical skills. The resilience category addresses twenty-three skills that support restructuring current socio-technical regimes towards more resilient production systems, such as designing circular business models and exploring systemic thinking. The DTs category encompasses seven skills directly related to business digitalization processes, such as implementing I4.0 technologies and proficiency in programming and developing digital solutions. Finally, in the specialized/technical category, ten skills related to in-depth knowledge of the CE are provided, including life cycle management, resource use, and efficient management.

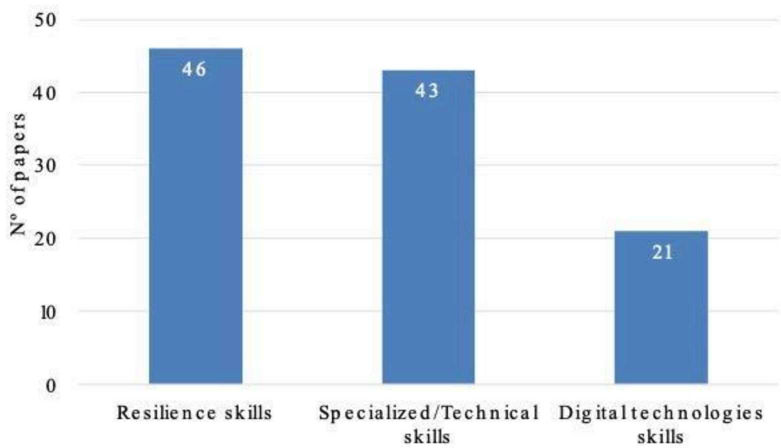


Figure 12: Distribution of categories per number of analysed papers

Figure 12 shows the distribution of the number of articles analysed (58 in total) by category. Most of the papers addressed skills associated with the three domains investigated. Notably (79.3% of the sample) mentioned some type of resilience skills, followed by 74.1% discussing some type of technical skill, and less than half of the papers (36.2%) presented skills relating to DTs.

Regarding the most mentioned skills (Figure 13), there is a highlight for the technical skill of circular product design, which is mentioned in 24 papers. This skill is directly associated with the manufacturing industry, which, in seeking to develop more sustainable products, should consider the development of solutions that incorporate circular principles from the initial design stage. Another skill deserving attention is the design of circular business models and circular supply chains (CSCs), mentioned in 19 articles. The literature on CE sheds light on the demand for professionals with the ability to propose and implement successful business models that are economically viable, supported by environmentally appropriate actions, and respecting social aspects.

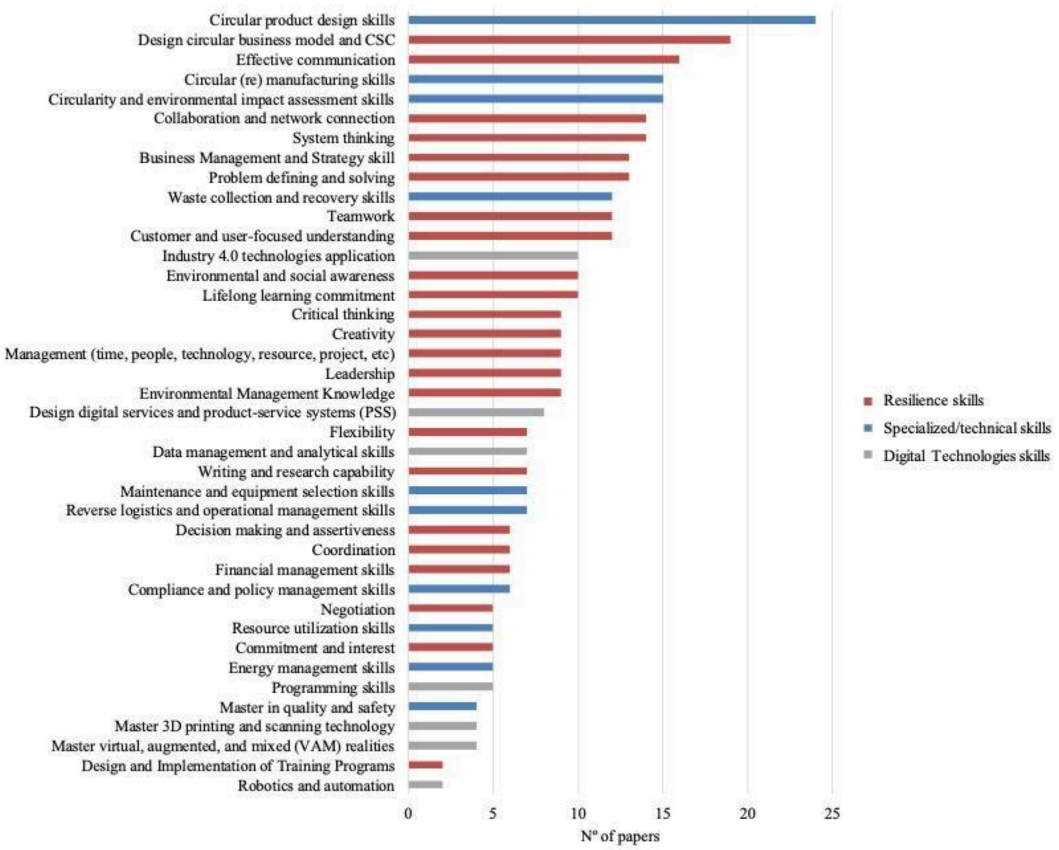


Figure 13: Distribution of skills per number of analysed papers

DT skills, as observed in Figures 10 and 11, were the least mentioned by the literature. Skills such as programming, 3D printing and scanning technology, virtual and augmented reality (VAM), and robotics and automation were discussed in fewer than five articles each. However, it is noteworthy that these skills have gained more emphasis in recent literature, particularly since the year 2020. New studies are exploring the impact of DTs on enabling circularity-oriented initiatives and the required knowledge. In the following sections, each skill identified in the literature will be detailed, along with its implications for theory and practice.

5.1.2.1 Resilience skills analysis

This category encompasses 23 skills divided into two subcategories: *cross-cutting* and *soft skills* (Table 5). The cross-cutting subcategory includes fundamental skills for developing business models, establishing strategic partnerships, and managing different essential aspects in a CE model. The soft skills subcategory contains all the interpersonal skills necessary in the workplace, allowing greater engagement, flexibility, and creativity regarding circular practices.

a. Cross-cutting skills

Business management and strategy refer to the skills a professional must possess when successfully managing a solution. This skill includes properly understanding team roles and responsibilities (Reichmanis and Sabahi, 2017), analysing, and evaluating the market to gain a comprehensive overview of sustainability issues (Sumter et al., 2018), creating sustainable marketing plans (Pinzone and Taisch, 2023; Summerton et al., 2019), and managing risks while engaging in entrepreneurial actions (Giannoccaro et al., 2021; Watkins et al., 2021).

The *collaboration and network connection* skill is widely discussed in CE literature. Professionals with this type of skill can build business partnerships (Akyazi et al., 2022), apply collective intelligence facilitation tools (Akyazi et al., 2023), work in multidisciplinary groups (Sanchez-Romaguera et al., 2016), make horizontal and vertical integrations of value partners (Ghobakhloo et al., 2023), as well as engaging in the co-creation of circular solutions (Walker et al., 2023). According to Can Saglam (2023), this skill is critical as it makes it easier to overcome barriers and enjoy benefits, that a firm would not achieve alone.

Another essential skill within cross-cutting is *coordination*. The CE requires alignment and coordination of partners towards the same goals. This skill reinforces the importance of coordination among the workforce of a single company but also among actors in the supply chain (Bag et al., 2021a) and the entire innovation ecosystem. Furthermore, the ability to coordinate is not only limited to the actors but also includes operational, communication, and training activities (Akyazi et al., 2022) that should be synchronized to reduce possible conflicts.

Sub-category	Skills	Reference
Cross-cutting skills	Business Management and Strategy skill	(Akyazi et al., 2022; Alonso-Muñoz et al., 2021; Giannoccaro et al., 2021; Knudby and Larsen, 2017; Kopnina, 2019; Lanz et al., 2019; Pinzone and Taisch, 2023; Raeva et al., 2021; Reichmanis and Sabahi, 2017; Summerton et al., 2019; Sumter et al., 2018; Vihma and Moora, 2020; Watkins et al., 2021)
	Collaboration and network connection	(Akyazi et al., 2022; Burger et al., 2019; Can Saglam, 2023; Chen, 2022; Fernandes et al., 2018; Ghobakhloo et al., 2023; Mondal et al., 2023; Onpraphai et al., 2021; Pinzone and Taisch, 2023; Sanchez-Romaguera et al., 2016; Sumter et al., 2021, 2018; Walker et al., 2023; Watkins et al., 2021)
	Coordination	(Akyazi et al., 2023, 2022; Bag et al., 2021a; Burger et al., 2019; Can Saglam, 2023; Sumter et al., 2021)
	Customer and user-focused understanding	(Akyazi et al., 2022; Alonso-Muñoz et al., 2021; De los Rios and Charnley, 2017; Giannoccaro et al., 2021; Sanchez-Romaguera et al., 2016; Spreafico and Landi, 2022; Sumter et al., 2021; Vihma and Moora, 2020; Vogt Duberg et al., 2020; Walker et al., 2023; Watkins et al., 2021; Whitehill et al., 2022)
	Design and Implementation of Training Programs	(Akyazi et al., 2022; Ghobakhloo et al., 2023)
	Design circular business model and CSC	(Akyazi et al., 2022; Avadanei et al., 2021, 2020; Bag et al., 2021a; Burger et al., 2019; Giannoccaro et al., 2021; Isaksson et al., 2018; Knudby and Larsen, 2017; Lanz et al., 2019; Pinzone and Taisch, 2023; Sanchez-Romaguera et al., 2016; Summerton et al., 2019; Sumter et al., 2021, 2018; Walker et al., 2023; Watkins et al., 2021; Whitehill et al., 2022)
	Environmental and social awareness	(Akyazi et al., 2023, 2022; Avadanei et al., 2020; Burger et al., 2019; Kim and Lee, 2022; Llorens et al., 2019; Sanchez-Romaguera et al., 2016; Torreggiani et al., 2021; Watkins et al., 2021; Whitehill et al., 2022)
	Environmental Management Knowledge	(Akyazi et al., 2023, 2022; Can Saglam, 2023; Cassells and Lewis, 2017; Esparragoza and Mesa-Cogollo, 2019; Giannoccaro et al., 2021; Llorens et al., 2019; Pinzone and Taisch, 2023; Watkins et al., 2021)
	Management (time, people, technology, resource, project, etc.)	(Akyazi et al., 2022; Alonso-Muñoz et al., 2021; Burger et al., 2019; Chen, 2022; Fernandes et al., 2018; Lanz et al., 2019; Sanchez-Romaguera et al., 2016; Watkins et al., 2021)

	System thinking	(Akyazi et al., 2023, 2022; Alarcón et al., 2019; Cappelletti et al., 2022; Cozma et al., 2020; Kopnina, 2019; Leal et al., 2020; Mayer, 2020; Pinzone and Taisch, 2023; Reichmanis and Sabahi, 2017; Summerton et al., 2019; Sumter et al., 2021; Watkins et al., 2021; Whitehill et al., 2022)
	Writing and research capability	(Akyazi et al., 2022; Burger et al., 2019; Onpraphai et al., 2021; Sanchez-Romaguera et al., 2016; Summerton et al., 2019; Vihma and Moora, 2020; Watkins et al., 2021)
	Financial management skills	(Akyazi et al., 2023, 2022; Burger et al., 2019; Knudby and Larsen, 2017; Sanchez-Romaguera et al., 2016; Watkins et al., 2021)
Soft skills	Decision making and assertiveness	(Ada et al., 2023; Akyazi et al., 2023, 2022; de Miranda et al., 2021; Sanchez-Romaguera et al., 2016; Watkins et al., 2021)
	Commitment and interest	(Ada et al., 2023; Akyazi et al., 2023; Alarcón et al., 2019; Ul-Durar et al., 2023; Walker et al., 2023)
	Effective communication	(Akyazi et al., 2022; Bag et al., 2021b, 2021a; Burger et al., 2019; Can Saglam, 2023; Chen, 2022; Ghobakhloo et al., 2023; Giannoccaro et al., 2021; Kopnina, 2019; Reichmanis and Sabahi, 2017; Sanchez-Romaguera et al., 2016; Summerton et al., 2019; Sumter et al., 2021; Torreggiani et al., 2021; Watkins et al., 2021; Whitehill et al., 2022)
	Creativity	(Ada et al., 2023; Alarcón et al., 2019; Giannoccaro et al., 2021; Kim and Lee, 2022; Mondal et al., 2023; Pinzone and Taisch, 2023; Vihma and Moora, 2020; Watkins et al., 2021; Whitehill et al., 2022)
	Critical thinking	(Akyazi et al., 2023, 2022; Burger et al., 2019; Kopnina, 2019; Pinzone and Taisch, 2023; Summerton et al., 2019; Torreggiani et al., 2021; Watkins et al., 2021; Whitehill et al., 2022)
	Flexibility	(Ada et al., 2023; Akyazi et al., 2023, 2022; de Miranda et al., 2021; Ghobakhloo et al., 2023; Pinzone and Taisch, 2023; Ul-Durar et al., 2023)
	Leadership	(Akyazi et al., 2022; Bag et al., 2021b; Ghobakhloo et al., 2023; Isaksson et al., 2018; Mondal et al., 2023; Torreggiani et al., 2021; Vihma and Moora, 2020; Watkins et al., 2021; Whitehill et al., 2022)
	Lifelong learning commitment	(Akyazi et al., 2023, 2022; Burger et al., 2019; de Miranda et al., 2021; Ghobakhloo et al., 2023; Isaksson et al., 2018; Lanz et al., 2019; Pinzone and Taisch, 2023; Vihma and Moora, 2020; Watkins et al., 2021)
	Negotiation	(Akyazi et al., 2022; Burger et al., 2019; Ghobakhloo et al., 2023; Sanchez-Romaguera et al., 2016; Watkins et al., 2021)
	Problem defining and solving	(Akyazi et al., 2023, 2022; Burger et al., 2019; De los Rios and Charnley, 2017; Ghobakhloo et al., 2023; Kim and Lee, 2022; Knudby and Larsen, 2017; Lanz et al., 2019; Mondal et al., 2023; Pinzone and Taisch, 2023; Reichmanis and Sabahi, 2017; Summerton et al., 2019; Watkins et al., 2021)
	Teamwork	(Akyazi et al., 2022; Bag et al., 2021b; de Miranda et al., 2021; Ghobakhloo et al., 2023; Knudby and Larsen, 2017; Onpraphai et al., 2021; Pinzone and Taisch, 2023; Raeva et al., 2021; Sanchez-Romaguera et al., 2016; Summerton et al., 2019; Torreggiani et al., 2021; Watkins et al., 2021)

Table 5: Skills regarding the Resilience category

Customer and user-focused design is also crucial to develop circular solutions. Professionals with this skill can understand users' experience and their expectations and perception of value (De los Rios and Charnley, 2017). They can comprehend market needs (Walker et al., 2023) and have knowledge about consumer behaviour (Giannoccaro et al., 2021). It is a skill that supports the co-creation of value with clients and the acquisition of feedback to improve products and services.
Throughout the implementation of a CE model, it is essential to evaluate the performance of corporate employees (Akyazi et al., 2022). For this reason, the *design and implementation of training programs* skill is applied. This skill is not frequently mentioned in the literature, being addressed in only two articles (Akyazi et al., 2023; Ghobakhloo et al., 2023). However, it is core for keeping employees engaged, developing employee retention programs, and promoting professional improvement in response to new market demands.

One of the skills that deserves to be highlighted within the cross-cutting subcategory is the *design of circular business models and supply chains*. This skill covers knowledge related to innovation and business transformation (Burger et al., 2019; Sanchez-Romaguera et al., 2016), prototyping, testing of solutions (Watkins et al., 2021), the management of CSCs (Giannoccaro et al., 2021), and ideation of value proposition with impact in the social, economic, and environmental domain (Walker et al., 2023). Collaborators with these skills can understand the organizational context to develop business models integrating different DTs and multidisciplinary knowledge (Giannoccaro et al., 2021).
However, to structure a CSC and design new businesses, an indispensable skill is *environmental and social awareness*. In line with Akyazi et al., (2023), this skill concerns consciously using resources such as energy and materials, including the choice of more environmentally friendly production processes and technologies. Also, the social and ethical aspects cannot be neglected when strategically applying circular practices (Sanchez-Romaguera et al., 2016). This includes not only looking at the external organizational context but also at health safety and working conditions (Avadanei et al., 2020).

Another required skill is extensive *environmental management knowledge*. This skill refers to understanding key concepts such as sustainability and CE as their main strategies (including closing and slowing down resource flows) (Esparragoza and Mesa-Cogollo, 2019). Knowledge oriented towards recycling, reducing waste and increasing energy efficiency is expected from a professional (Cassells and Lewis, 2017). Knowledge about industrial symbiosis, production and responsible consumption is also part of the scope of this skill (Akyazi et al., 2023; Llorens et al., 2019).

Circular manufacturing processes mostly require *management* skills. This skill encompasses four critical aspects. First, time management is essential for developing products and services aligned with current market demands (Burger et al., 2019). Second, resources, including human, physical, and natural resources, must also be managed (Akyazi et al., 2022; Watkins et al., 2021). Third, it is necessary to manage knowledge, whether associated with a

technology or the market, as well as develop project management plans to implement or improve existing solutions (Alonso-Muñoz et al., 2021; Sanchez-Romaguera et al., 2016). Finally, self-reflection (Lanz et al., 2019) helps improve the worker's actions and behaviours, leading to initiatives that are more consistent with CE.
Given that the implementation of a circular model involves complex activities and requires a holistic view of processes and resources, it is crucial for professionals to have *system thinking*. This skill enables individuals to make predictions about future scenarios, understand internal and external contexts, as well as grasp emerging trends (Pinzone and Taisch, 2023). Furthermore, it allows the entire product lifecycle to be considered when operationalizing circular practices, going beyond a single specific stage such as the beginning of life or end-of-life (EoL) (Cappelletti et al., 2022; Watkins et al., 2021).

The skill to *write and conduct research* also demands attention, whether for data collection, investigating new practices to be implemented or for effective communication of environmental issues (Onpraphai et al., 2021; Sanchez-Romaguera et al., 2016; Vihma and Moora, 2020). Professionals must be able to prepare reports in a technical yet comprehensive manner, according to each public (audience) they intend to reach (Akyazi et al., 2022; Burger et al., 2019).
Finally, the last skill within the cross-cutting subcategory is *financial management.* When transitioning to the CE, it is crucial to have a clear understanding of the financial impacts, the costs associated with each strategy, and the return-on-investment time (Akyazi et al., 2022; Knudby and Larsen, 2017; Watkins et al., 2021). Financial planning ensures that potential constraints do not emerge along the way, preventing them from becoming significant bottlenecks during the transition.

b. Soft skills

Within the subcategory of soft skills, product designers are required to possess *decision-making and assertiveness* skill. This demands that professionals have the ability to think logically (Akyazi et al., 2023) and to identify and evaluate business opportunities (Akyazi et al., 2022). They need to develop decision-making criteria and not merely make choices based on personal and pre-established biases.
To know the best choices to make, it is important for the professional also to have *commitment and interest* in exploring new areas of knowledge. CE requires changes throughout the value chain (Ada et al., 2023), and this demands commitment, support from senior management (Walker et al., 2023), and motivation to transform ideas into actions (Akyazi et al., 2023). According to Akyazi et al., (2023, p. 5), this skill "*helps inspire stakeholders to become more involved and committed*" during the business transformation stages.
Another skill that is highly highlighted in the literature is *effective communication*. This skill refers to the exchange of information, opinions, knowledge, and ideas in a clear way, where interlocutors can understand the dialogue and the message that they want to transmit (Akyazi et al., 2023). To do this, the individual needs to master communication

techniques, such as storytelling, where it is possible to create a vocabulary to involve stakeholders and disseminate the circular practices applied (Sumter et al., 2021).

Creativity also stands out as a soft skill to be fostered. Given that significant organizational changes need to be implemented, workers need to leave their comfort zones (Ada et al., 2023) and be able to use their imagination to devise new solutions and processes (Akyazi et al., 2023). Contrary to what common sense believes, Torreggiani et al. (2021) argue that creativity is not restricted only to an inherently inherited talent. Using simple strategies (e.g. do-it-yourself (DIY)), it is possible to provoke individual creative thinking.
Professionals also need to be able to adapt quickly to changes in the work environment (Ghobakhloo et al., 2023). *Flexibility* helps the team to face unexpected challenges quickly and assertively that may emerge along the way (Akyazi et al., 2023). Therefore, being open to new adaptations and changes in the work routine is a key factor for companies that are seeking to integrate circular principles.

Leadership skill is also frequently mentioned by CE scholars. This skill is significantly related to adopting I4.0 DTs (Bag et al., 2021b). It covers aspects such as providing constructive feedback to the team and identifying, in addition to allocating, appropriate human capital (Akyazi et al., 2022). In accordance with Mondal et al. (2023, p. 6), "*strong leadership and supportive organizational culture can inspire employees to embrace sustainability*".

Lifelong learning commitment is a skill that enables professionals to learn from their mistakes (Lanz et al., 2019). The continuous and active search for knowledge allows them to update themselves and acquire new skills constantly. This ability also encompasses active listening (Burger et al., 2019), in which the individual learns by paying careful attention to what other people say, understanding, agreeing, or disagreeing with the points of view presented.
By paying attention to others and the external environment, professionals can better apply *negotiation* tactics. Expertise in negotiation helps to change behaviour and strategically direct actions that need to be implemented. Negotiation applies not only to commercial transactions but also to establishing work agreements that satisfy both parties (Akyazi et al., 2022).

An additional and crucial skill in a CE is *problem defining and solving*. This skill is applied to solve complex and new problems that emerge in industrial systems (Burger et al., 2019). It encompasses identifying, analysing, and establishing strategies to address the challenges and difficulties that arise. It is necessary to devise intelligent ways to solve problems, optimizing the use of resources and reducing the time required.

Finally, *teamwork* deserves attention within the soft skills subcategory. This skill is "*characterized by a unified commitment to achieving a given goal, participating equally, maintaining open communication, facilitating effective usage of ideas*" (Akyazi et al., 2023). Teamwork requires profoundly strengthening collaborative ties, as individuals must build cross-disciplinary teams (Knudby and Larsen, 2017) and create a trust-based structure (Ghobakhloo et al., 2023).

5.1.2.2 Digital technologies (DTs) skills analysis

This category encompasses seven skills grouped into two subcategories: *Digital transformation of businesses* and *Technology innovation in the CE* (Table 6). The subcategory of digital transformation of businesses covers skills associated with digitalization and business data management processes. The innovation technology subcategory includes skills relating to applying specific DTs that promote circularity, such as 3D printing and virtual, augmented, and mixed realities, among others.

a. Digital transformation of business

The first skill within this subcategory refers to *data management and analytical skills*. The digital transformation associated with implementing circular strategies demands to professionals the knowledge of working with large data sets, from generation, collection, storage, sharing, cybersecurity, applications, and visualizations (Akyazi et al., 2022; de Miranda et al., 2021). According to Bag et al. (2021b), this ability is already recognized as an implicit resource coming from the workforce. Professionals who master data analysis tools and techniques (e.g., machine learning and AI technologies) may be able to extract valuable insights (Akyazi et al., 2023) that support decision-making.

Furthermore, an ability that the market has increasingly demanded is *programming skills* integrated with developing new software and platforms (Isaksson et al., 2018). This skill is connected with several other digital applications and purposes (Burger et al., 2019), such as the adoption of industrial robots (Luo and Qiao, 2023), artificial intelligence (Bag et al., 2021b), digital models and 3D printing (Chen, 2022).

Data and algorithm knowledge is also crucial for the *design of digital services and product-service systems (PSS).* Understanding how the service experience is provided and how to enable dematerialization is a key skill in circularity-oriented business model innovation (De los Rios and Charnley, 2017; Ghobakhloo et al., 2023). This skill is not only associated with delivering a product as a service or incorporating additional services into a product offering. It also refers to the possibility of creating multiple lifecycles and increasing resource use efficiency in product-services (Pinzone and Taisch, 2023).

b. Technology innovation in the CE

Knowledge of *I4.0 technology applications* has become vital in the digital age. The existing technologies are vast, such as the Internet of Things, cloud, artificial intelligence, etc. (Akyazi et al., 2022). Therefore, it is necessary to create employee skills to integrate DTs into daily activities and the functions performed by workers (Ghobakhloo et al., 2023). Otherwise, the lack of this skill can create a barrier to technological innovation (Dwivedi et al., 2022), making it impossible to exploit digital functions and make real-time decisions (Akyazi et al., 2023).

Another skill within the technological innovation subcategory is *mastery of 3D printing and scanning technology*. According to Chen (2022), this skill also requires designers to understand software and methods and know which materials can be used as consumables for 3D printing, observing the types of products generated depending on the input. Understanding the composition of virgin and recycled materials and the best way to use them (Despeisse et al., 2017) helps minimizing waste and maximize sustainable initiatives.

Mastery of *VAM realities* is also a required skill. Virtual and augmented reality can simulate manufacturing environments and allow interaction with the system to perform different types of analyses and even predictive maintenance (de Miranda et al., 2021). Using these technologies to simulate product development (Watkins et al., 2021) and factory environments is also possible.

Finally, a digitalized environment requires engineers to have knowledge of *automation and robotics*. In line with Luo and Qiao (2023, p. 6), "*the adoption of industrial robots increases the demand for skilled labour who have high levels of technical expertise and skills in fields such as engineering, computer science and robotics to operate and maintain these machines*". The individual is expected to develop human-robot collaboration, remote control, and construction and operation skills (Akyazi et al., 2022)

Table 6: Skills regarding the DTs category

Sub-category	Skills	Reference
Digital transformation of businesses	Data management and analytical skills	(Akyazi et al., 2023, 2022; Bag et al., 2021b, 2021a; de Miranda et al., 2021; Ghobakhloo et al., 2023; Luo and Qiao, 2023)
	Programming skills	(Bag et al., 2021a; Burger et al., 2019; Chen, 2022; Isaksson et al., 2018; Luo and Qiao, 2023)
	Design digital services and product-service systems (PSS)	(Burger et al., 2019; De los Rios and Charnley, 2017; Ghobakhloo et al., 2023; Giannoccaro et al., 2021; Pinzone and Taisch, 2023; Sumter et al., 2021; Vogt Duberg et al., 2020; Watkins et al., 2021)
Technology Innovation in the CE	I4.0 technologies application	(Akyazi et al., 2023, 2022; Alonso-Muñoz et al., 2021; Burger et al., 2019; de Miranda et al., 2021; Dwivedi et al., 2022; Ghobakhloo et al., 2023; Giannoccaro et al., 2021; Pinzone and Taisch, 2023; Watkins et al., 2021)
	Master 3D printing and scanning technology	(Akyazi et al., 2022; Chen, 2022; Despeisse et al., 2017; Leal et al., 2020)
	Master VAM realities	(Akyazi et al., 2022; de Miranda et al., 2021; Reichmanis and Sabahi, 2017; Watkins et al., 2021)
	Robotics and automation	(Akyazi et al., 2022; Luo and Qiao, 2023)

5.1.2.3 Specialized/Technical skills analysis

This category embraces 10 distinct skills, which have been grouped into three categories: *Circular lifecycle management*, *Cleantech and advanced materials*, and *Waste management*. The *Circular lifecycle management* category includes skills that enhance circularity aspects in different phases of product lifecycle (such as product design or (re)manufacturing), as well as skills that enable participants to assess circularity and environmental impact. *Waste management* category covers skills needed to manage the reverse flows of materials, such as waste collection, reverse logistics management, and utilization of resources out of the waste. Finally, the *Cleantech and advanced materials* category includes building competences needed to process the recovered materials, including the energy recovery of the waste, but also developing new materials from the recovered resources, and related product, environment regulatory aspects and certifications.

a. Circular lifecycle management

Circular product design is a category of skills addressed in the largest number of the papers (Figure 10). This is justified by the fact that around 80% of the environmental impact of a product is decided at the early stages of the product development (Watkins et al., 2021). These skills equip students and practitioners (designers, engineers, operators) to consider different sustainable product and process design strategies and methods to reduce the environmental impact of a product (Spreafico and Landi, 2022; Watkins et al., 2021). Some of the skills relate to design for longevity of products from durability perspective (Andrews, 2015) or from timeless design perspective (Spreafico and Landi, 2022). This can include skills for understating of product wear (De los Rios and Charnley, 2017) and material properties (Avadanei et al., 2020), as well as design simplification (Watkins et al., 2021). Other groups of skills are about design and development of products using waste material (Avadanei et al., 2020; Rizzo et al., 2017) which includes developing new (composite) materials (ibid.) to enable composting (Manfredi et al., 2019; Mottese et al., 2021) and biodegradability (Spreafico and Landi, 2022) of the products/packaging. It is also evident from the literature that the skills of designers should embrace knowledge about the effects of the product design on the subsequent phases of the lifecycle, such as recovery and multiple use cycles (Sumter et al., 2021), remanufacturing (Bag et al., 2021b), disassembly process complexity (Burger et al., 2019; Kim and Lee, 2022) and related technology support (Cappelletti et al., 2022).

Circular (re)manufacturing category covers skills needed in the transition and implementation of circular and sustainable production. Students and practitioners should be able to design (Monyaki and Cilliers, 2023), select and develop innovative transformation technologies and circular processes (Knudby and Larsen, 2017; Vogt Duberg et al., 2020) (such as moulding, shredding, 3D printing (3DP), etc. (Fernandes et al., 2018)) and systems to optimize sustainability impacts (Pinzone and Taisch, 2023)). This is challenging since process designers need to work with production using new innovative or waste materials as raw materials (Fernandes et al., 2018) or wide range of quality of return products. Additional skills needed are designing and understanding material flows in remanufacturing (Lanz et al., 2019), remanufacturing facility location (Vogt Duberg et al., 2020), commercial production (Whitehill et al., 2022), but also identifying and understanding skills that are required by remanufacturing processes (Ghobakhloo et al., 2023; Vogt Duberg et al., 2020). In addition, skills related to management of daily operations are necessary to be built (Knudby and Larsen, 2017), including production planning and scheduling skills (Akyazi et al., 2023).

Circularity and environmental impact assessment category covers skills that enable evaluation of the environmental impact of diverse circularity strategies (Sumter et al., 2018) and audit (including energy, CO_2, material circularity indicator, etc.) of circularity scenarios (Pereira and Fredriksson, 2015). This can be done on a system level (considering multiple lifecycles) (Sumter et al., 2018), on a site level (Akyazi et al., 2022) (considering health, safety and hazard aspects of (chemical) processes) (Reichmanis and Sabahi, 2017), or on a product level (through the Life Cycle assessment (LCA) method) (Giannoccaro et al., 2021; Mayer, 2020; Sanchez-Romaguera et al., 2016; Vihma and Moora, 2020). Besides the environmental impact, understanding and using economic sustainability indicators in assessing and comparing circular systems and interventions is also important (Esparragoza and Mesa-Cogollo, 2019). To conduct these assessments effectively, specific environmental management methods and tools are employed, such as LCA, ISO 14001 certification, and sustainability reporting frameworks. Mastering these tools is crucial (Giannoccaro et al., 2021; Walker et al., 2023; Watkins et al., 2021). Additional skills in this category relate to tracking relevant key performance indicators (KPIs) (Akyazi et al., 2022; Giannoccaro et al., 2021) and implement environmental protection measures (Giannoccaro et al., 2021).

b. Clean tech and advanced materials

Compliance and policy management category of skills should enable individuals to effectively develop environmental policies, implement environmental action plans, and monitor them (Akyazi et al., 2022). This should be based on having knowledge (Reichmanis and Sabahi, 2017) and appreciation/awareness (Akyazi et al., 2022; Summerton et al., 2019) on regulations and regulatory processes, as well as on ability to monitor and analyse legal developments (Akyazi et al., 2022; Vihma and Moora, 2020). This knowledge and awareness should be related to specific product registration and commercialization (Reichmanis and Sabahi, 2017) but also to overall EU environmental legislation, national action plans and certifications (Avadanei et al., 2020).

Energy management category encompasses a wide range of skills and knowledge that allow individuals and organizations to use energy efficiently and sustainably. This includes understanding the use of energy and related costs (Akyazi et al., 2023), knowledge on monitoring systems of energy consumption (Akyazi et al., 2022). It also involves familiarity with different energy sources such as renewable energy (Akyazi et al., 2022; Sanchez-Romaguera et al., 2016), as well as ways of energy conservation (ibid.). Knowledge on different approaches and technologies to achieve energy efficiency in a production system and/or through industrial symbiosis enables informed decision making about investments in energy-saving measures (Akyazi et al., 2023; Lanz et al., 2019). Additional skills and knowledge are related to system optimization and process analysis that can be used to improve understanding of how the industrial symbiosis (IS) process operates, and to determine potential targets for IS process improvement and increased efficiency (Akyazi et al., 2023).

Maintenance and equipment selection category relates more to skills needed for implementing CE principles through slowing resource cycles (for example, via maintenance, repair, etc.) (Giannoccaro et al., 2021). This involves understanding different failure modes of products and processes (De los Rios and Charnley, 2017; Watkins et al., 2021) and developing and implementing preventive and predictive maintenance methods and procedures (Akyazi et al., 2022; Burger et al., 2019; De los Rios and Charnley, 2017; Watkins et al., 2021). This should be supported by knowledge on different equipment and procedures for monitoring of operations to make sure machines work properly (Burger et al., 2019; Giannoccaro et al., 2021). Additional skills related to correcting malfunctions of technological systems include capability for equipment selection (Burger et al., 2019) which is about determining needed tools and equipment to perform the work needed, or to support the deconstruction (Mayer, 2020).

Master in quality and safety embraces skills needed due to variable and uncertain quality of return products and materials in CE context and the safety issues these might cause. This category focuses on the application of quality and safety principles to materials, parts, products, processes, and systems within the CE. This includes skills for performing quality control analysis (Burger et al., 2019), knowledge on quality assurance methodologies (Akyazi et al., 2022), but also performing deconstruction processes in a way that maintains salvaged values (Mayer, 2020). Safety related skills embrace ability to verify that products sold do not pose health hazard, or knowledge of best practices for deconstruction site safety with an emphasis on structural stability and hazardous material handling (ibid.)

Table 7: Skills regarding the Specialized/Technical category.

Sub-category	Skills	Reference
Circular lifecycle management	Circular (re)manufacturing	(Akyazi et al., 2022; Avadanei et al., 2021; Burger et al., 2019; Fernandes et al., 2018; Ghobakhloo et al., 2023; Giannoccaro et al., 2021; Knudby and Larsen, 2017; Lanz et al., 2019; Monyaki and Cilliers, 2023; Onpraphai et al., 2021; Pinzone and Taisch, 2023; Sumter et al., 2021; Vogt Duberg et al., 2020; Watkins et al., 2021; Whitehill et al., 2022)
	Circular product design	(Akyazi et al., 2022; Andrews, 2015; Avadanei et al., 2021; Bag et al., 2021b; Burger et al., 2019; Cappelletti et al., 2022; De los Rios and Charnley, 2017; de Miranda et al., 2021; Favi et al., 2016; Fernandes et al., 2018; Kim and Lee, 2022; Leal et al., 2020; Llorens et al., 2019; Manfredi et al., 2019; Mottese et al., 2021; Reichmanis and Sabahi, 2017; Rizzo et al., 2017; Sanchez-Romaguera et al., 2016; Spreafico and Landi, 2022; Summerton et al., 2019; Sumter et al., 2021; Vihma and Moora, 2020; Walker et al., 2023; Watkins et al., 2021)
	Circularity and environmental impact assessment	(Akyazi et al., 2023, 2022; Esparragoza and Mesa-Cogollo, 2019; Giannoccaro et al., 2021; Knudby and Larsen, 2017; Mayer, 2020; Pereira and Fredriksson, 2015; Pinzone and Taisch, 2023; Reichmanis and Sabahi, 2017; Sanchez-Romaguera et al., 2016; Sumter et al., 2021, 2018; Vihma and Moora, 2020; Walker et al., 2023; Watkins et al., 2021)
Clean tech and advanced materials	Compliance and policy management	(Akyazi et al., 2023, 2022; Avadanei et al., 2020; Reichmanis and Sabahi, 2017; Summerton et al., 2019; Vihma and Moora, 2020)
	Maintenance and equipment selection	(Akyazi et al., 2023, 2022; Burger et al., 2019; De los Rios and Charnley, 2017; Giannoccaro et al., 2021; Mayer, 2020; Watkins et al., 2021)
	Energy management	(Akyazi et al., 2023, 2022; Avadanei et al., 2020; Lanz et al., 2019; Sanchez-Romaguera et al., 2016)
	Master in quality and safety	(Akyazi et al., 2023, 2022; Burger et al., 2019; Mayer, 2020)
Waste management	Reverse logistics and operational management	(Bag et al., 2021b; Burger et al., 2019; De los Rios and Charnley, 2017; Halfdanarson and Kvadsheim, 2020; Knudby and Larsen, 2017; Mayer, 2020; Watkins et al., 2021)
	Waste collection and recovery	(Akyazi et al., 2022; Alarcón et al., 2019; Avadanei et al., 2021; Burger et al., 2019; Demartini et al., 2023; Giannoccaro et al., 2021; Leal et al., 2020; Llorens et al., 2019; Mayer, 2020; Mondal et al., 2023; Sanchez-Romaguera et al., 2016; Whitehill et al., 2022)
	Resource utilization	(Akyazi et al., 2022; Alarcón et al., 2019; Avadanei et al., 2020; Burger et al., 2019; Leal et al., 2020)

c. Waste management

Eighteen papers deal with the skills required for effective waste management and resource utilization. This category of skills encompasses diverse aspects of the reverse value chain, covering the initial stages of waste collection and recovery, looking into reverse logistics and operational management skills, and ultimately, utilization of resources skills.
The area of *waste collection and recovery skills* enable participants to gain fundamental understanding of waste management principles and sustainability practices for example in textile sector (Whitehill et al., 2022), in manufacturing in general (Akyazi et al., 2022; Sanchez-Romaguera et al., 2016) and at multiple manufacturing industries (steel, ceramic, water, cement, etc.) (Burger et al., 2019). Furthermore, building these skills also covers more specialized knowledge related to the location of jobsite (i.e., the construction site) and mapping of supply chain, layout of job site (Mayer, 2020), and key steps and work sequence at a job site with a purpose of maximizing material yield (ibid). This work is mainly based on the building sector (Mayer, 2020). Finally, this area of skills encompasses building competences related to ways of waste transformation (Llorens et al., 2019), as well as techniques for identifying, deconstructing, handling of materials suitable for recovery and finding ways of their recovery (Leal et al., 2020; Mayer, 2020) or discovering materials deemed non-recoverable (Mayer, 2020).

The *reverse logistics and operations management* area offers specialized skillset and expertise necessary to design the reverse logistic system (Knudby and Larsen, 2017) that seamlessly integrates with the overall supply chain, ensuring efficient and effective handling (manufacturing and repair) of discarded materials (Watkins et al., 2021). In addition to this, there is a need for skills to manage the complex dynamics of reverse flows, including managing daily operations and control of sites (Burger et al., 2019; Knudby and Larsen, 2017), including understanding the skills needed (Halfdanarson and Kvadsheim, 2020) and the processes to manage reverse flows (De los Rios and Charnley, 2017). Furthermore, this area of skills enables the participants to understand the effect of bidding on the economic viability of dismantling/deconstructing operations (Mayer, 2020).

In terms of *resource* utilization, the expertise required entails knowledge of various waste recovery strategies, such as reuse, recycling, and reduction of waste (Akyazi et al., 2022). Furthermore, identification of types of waste, including organic and industrial waste (Alarcón et al., 2019), are important skills gained. Additional skills in this category involve prioritizing resources (Burger et al., 2019) and selecting (Leal et al., 2020) the most appropriate processes and practices for optimizing resource usage, maximizing resource recovery, and minimizing resource consumption (Avadanei et al., 2020).

5.1.3 Teaching methods for training delivery and duration of training analysis

This section presents findings related to the teaching methods used or proposed in the different papers of SLR as well as the duration of the educations. Given the novelty and continuous evolution of the CE, particularly when intertwined with DTs, the delivery of knowledge necessitates appropriate and flexible approaches. This section also explores various teaching methods that have been implemented or envisaged to cultivate knowledge and skills related to the CE in both students and practitioners. To ensure our categorization complies with existing views, we consulted 3 literature reviews on teaching methods, identifying established methods and characteristics (Fernando and Marikar, 2017; Martin et al., 2014; Safapour et al., 2019). Despite having distinct areas of focus, these reviews share overlapping (categories of) teaching methods. For example, Martin et al. (2014) focus on training methods, which are distinguished from course delivery at higher and continuous education. Safapour et al. (2019) analyse non-traditional teaching methods, which are differentiated than traditional textbook-based methods.

Here we elaborate briefly the 11 categories of teaching methods identified in the papers. 30 of the papers did not mention any teaching method, while rest of the papers mention/used between one and ten methods.

Case study "provides the participants an opportunity to develop skills by presenting a problem, without a solution, for them to solve, or with a solution, as an exemplar of how to solve it" (Martin et al., 2014). Due to similarity, we added *problem-based learning* (PBL) into a same category. This was the most frequently used/addressed method in the analysed papers.

Although there are similarities (self-direction and collaboration) between problem-based and project-based learning, some authors have noted the specifics of *project-based learning*: closer to professional reality, more time-demanding, more focus on application rather than acquisition of knowledge, management of time and resources, tasks and roles are more important (Mills and Treagust, 2003). This method was addressed in 8 of the papers.

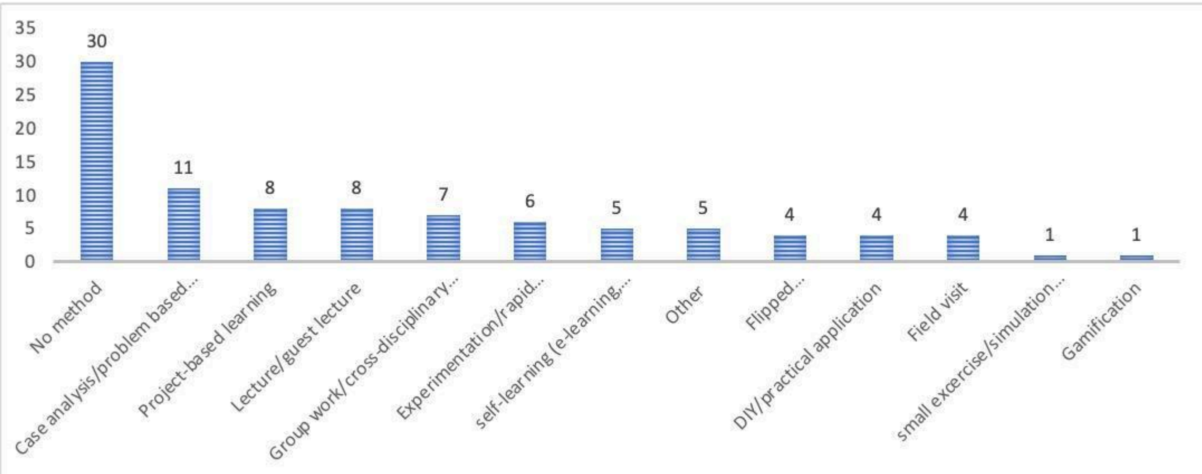


Figure 14: Teaching methods addressed in the papers

Groupwork/cross-disciplinary teams appeared in seven of the papers. Similarly to team-training (Martin et al., 2014) the benefit is that it helps participants develop social and teamwork skills, time-management and planning skills. Groupwork is often a way of conducting the learning/work in the previous two methods (PBL and project-based learning) that increases the level of interaction while learning (Martin et al., 2014). The way it is used for CE education is also for small exercises and evaluating other groups' solutions (Lanz et al., 2019). Due to the cross-disciplinary nature of CE, some of the papers propose cross-disciplinary team projects (Giannoccaro et al., 2021; Knudby and Larsen, 2017).

In a *Flipped classroom*, students watch short video lectures or read online articles prior to class sessions, and then use class time for active learning activities, such as discussions, problem-solving, and group projects. Although none of the reviewed papers defines *workshop* as an education method, and little has been written about workshops as an educational strategy (Steinert et al., 2008), it seems to partly overlap with flipped classroom due to it is "a usually brief, intensive … in a given field that emphasizes participation in problem solving efforts" (ibid.). *Tutorials* were added in this category because their main characteristic is to trigger discussion and inquiry-based learning in connection to a lecture or material presented prior to the tutorial, and help students develop important conceptual understanding and reasoning skills. However, they are normally conducted in a smaller group (Darasawang and Srimavin, 2006). Four of the reviewed papers addressed these teaching methods.

With the acceleration of new media, *self-learning* becomes more attractive education method for wider population. It is defined as education method which empowers learners to use different tools and resources in a way that fits them best to enhance their knowledge, abilities, and skills, and achieve their objectives (Safapour et al., 2019). This method was addressed in five of the papers, operationalized in different ways, such as: literature search and reading (Knudby and Larsen, 2017; Kopnina, 2019; Lanz et al., 2019), videos (Knudby and Larsen, 2017) and digital training platform including quizzes, forums etc. (Avadanei et al., 2020).

Lecturing "involves the dissemination of training material by a trainer to a group of trainees, by means of verbal instruction" (Martin et al., 2014). This is also considered as traditional teaching method and it was the second most frequently addressed method (in 8 of the papers). An alternative of it is a guest lecture (Onpraphai et al., 2021) where practical experiences are presented in addition to the theories. Interesting approach to preparing a lecture is presented by Esparragoza and Mesa-Cogollo (2019) who made a diagnosis of the students' understanding on CE models and then tailored their lecture to address confusion and misconceptions.

Simulation exercise was used in one of the papers (Lanz et al., 2019). It was built on discrete-event simulation software and presented a closed-loop material flow of technical materials, demonstrating different end-of-life scenarios (reuse, remanufacture etc.). This exercise created a problem-solving context for the students where through trial-and-error the students advanced in their learning and towards reaching a solution (ibid).

DIY approach was incorporated in 4 of the papers. Alarcón et al. (2019) propose a 7-phase approach for conducting DIY in education and find out that this hands-on learning experience effectively contributes to students understanding and awareness of the need to create product lifecycles that align with CE principles.

Field visit is recommended in four of the papers. Focusing on the agri-food sector, Onpraphai et al. (2021) state that such visits give the students possibility to be exposed to the overall complexity of the system, to experience a variety of conventional vs. organic management settings, as well as differing scales of operation. Similarly, Whitehill et al. (2022) conducted full factory tour, besides other activities, for the students to expand their engagement and understanding on textile waste and CE.

Gamification is defined as "a continuous procedure of improving learning ability with motivational affordances to invoke gameplay experiences and achievements" (Safapour et al., 2019). Only one previous study suggested using gamification and developed board games specifically for pupils aged 10-18 (Torreggiani et al., 2021).

Experimentation/rapid prototyping was proposed in six of the papers. Rizzo et al., (2017), for example, used experiments "aimed to analyse the possibility to use a variety of industrial wastes as substrates for plants growing in soilless systems". Despeisse et al., (2017) explore the potential of 3DP technologies to reshape how individuals learn existing concepts. For example, rapid prototyping enables accelerated design cycles and direct experimentation with new materials and processes, fostering deeper understanding.

5.1.3.1 Teaching methods per skill sub-category

Table 8 shows the fraction of methods out of total papers per skill sub-category. The 4-5 most used methods are highlighted in bold. It can be seen that *Case analysis/problem-based learning* is in the top three most used methods and also used in all categories of skills. It is followed by *Project-based learning* (in 6 of the sub-categories of skills), *Group work/cross-disciplinary teams* (in 5 sub-categories of skills) and *Lecture/tutorial/guest lecture* (in 4 sub-categories of skills). *DIY/practical application* is in the top 5 used methods for teaching *Waste management* skills, while *Experimentation/rapid prototyping (3DP)/physical tests* is in the top 3 methods used for *Technology innovation in the CE* skills. *Self-learning* (e-learning, providing reading material) is in the topmost used methods for teaching *Waste management*.

a. Resiliency category

Soft skills. Out of 32 papers discussing this category of skills, 14 papers reported the teaching method while 8 reported the teaching duration. The most frequently used teaching method is *Case analysis/problem-based learning* (in 8 out of 14 papers), followed by *Project-based* *learning*, *Group work/cross-disciplinary teams*, and *Lecture/tutorial/guest lecture* (each represented in 6 papers). *Field visit* was reported as a teaching method in 4 out of 14 papers, *Flipped classroom/workshop* and *Self-learning* (e-learning, providing reading material) in 3 papers each. Rest of the methods were represented in one or two papers. Most frequent duration reported was a whole course of 2-5 months (in 6 of the papers). Six of the papers used between 4-7 teaching methods, while the rest (7 papers) used between 1-3 teaching methods.

Cross-cutting skills. Out of 42 papers addressing this category of skills, 22 reported the teaching method, while 12 reported the duration. *Case analysis/problem-based learning* is the most frequently used teaching method (in 9 out of 22 papers), followed by *Project-based learning* and *Lecture/tutorial/guest lecture* (each in 8 papers). *Group work/cross-disciplinary teams* is used in 6 of the papers, followed by *Self-learning* (e-learning, providing reading material). *DIY/practical application* and *Field visit* are used in 4 papers respectively. Rest of the methods are represented in 1 to 3 papers each. The most frequently used duration was 2-5 months (in 7 of the papers), followed by few lectures (in 4 of the papers).

b. DTs category

Digital transformation of business. Only two papers (Giannoccaro et al., 2021; Watkins et al., 2021) out of 16 reported their teaching method, and only one of those reported the duration. Watkins et al. (2021)) used a variety of (7-8 different) teaching methods in a duration of a whole course, while Giannoccaro et al. (2021) used *Problem-based learning* and *Multi-disciplinary teams*. *Case analysis/problem-based learning* was used in both papers.

Technology innovation in the CE. Out of 15 papers discussing this category of skills, 5 report the teaching method. Having in mind the low amount of teaching methods reported, *Project-based learning* is the most frequently used method (in 3 out of 5 papers). Most papers used 1 or 2 methods, only one paper used variety (7-8) teaching methods. As in the above category of skills, only one paper reported duration of a whole course.

c. Specialized/Technical category

Circular lifecycle management. Out of 38 papers reporting *Circular lifecycle management* skills 22 stated their teaching method(s) used, while 12 stated the duration of the teaching. *Case study/problem-based learning* is the most frequently used teaching method (in 10 papers out of 22 that stated method), followed by *project-based learning* (in 7 out of 22), *groupwork/cross-disciplinary teams* and *lecture/tutorial* (each in 6 papers respectively). Fewer papers use *flipped classroom/workshop* (4 out of 22), *self-learning and experimentation* (each represented in 3 papers), and less from the rest of the methods. Only 5 papers used 3-5 methods, the rest used one or two teaching methods. In 7 of the cases the duration is in the category of 2-5 months, in 4 cases the duration was few lectures, while in one case it was longer (2 years).

Waste management. Eleven of the 18 papers covering this skill category stated the teaching method(s), while only 5 stated the education duration. The most used teaching method *was case analysis/problem-based learning* (4 out of 11 papers that stated method), followed by *project-based learning, group work/cross-disciplinary teams, self-learning and DIY/practical application* (each represented in 3 papers), and other methods represented in one or two papers each. Only one paper used 7 different teaching methods, other two papers used 4 and 3 methods respectively, while most of the papers used 1 or 2 teaching methods. The most common duration of education dealing with waste management was in the category of 2-5 months (4 out of 5 that stated duration), while only one paper covered this topic through several lectures.

Cleantech and advanced materials. Out of 13 papers related to this skill, 8 reported their teaching methods. *Case analysis/problem-based learning* is the most used method (in 5 out of 8 papers), followed by use of *group work/cross-disciplinary teams* (in 4 out of 8 papers). *Project-based learning*, *flipped classroom/workshop* and *lecture/tutorial/guest lecture* each are represented in three papers (out of 8). Four papers use between 4-7 teaching methods, while the rest use 1 or 2 methods. Three of the papers stated duration of 2-5 months, while one paper stated duration of few lectures.

Table 8: Fraction of method out of total number of papers discussing a skill category (not all papers report their teaching method)

		1. Case analysis/problem based learning	2. Project-based learning	3. Group work/cross-disciplinary teams	4. Flipped classroom/workshop	5. Self-learning (e-learning, providing reading material)	6. Lecture/tutorial/guest lecture	7. Small exercise/simulation exercise	8. DIY/practical application	9. Field visit	10. Gamification	**11. Experimentation/rapid prototyping (3DP)/physical tests**	**12. Other**
Resilience skills category	*Soft skills*	**0,25**	**0,19**	**0,19**	0,09	0,09	**0,19**	0,03	0,06	**0,13**	0,03	0,06	0,06
	Cross-cutting skills	**0,21**	**0,19**	**0,14**	0,07	0,12	**0,19**	0,02	0,10	0,10	0,02	0,05	0,10

DTs category	*Digital transformation of business*	**0,13**	0,06	0,06	0,06	0,00	0,06	0,00	0,00	0,06	0,00	0,06	0,06
	Technology innovation in the CE	**0,13**	**0,20**	0,07	0,07	0,00	0,07	0,00	0,00	0,07	0,00	**0,13**	0,07
Specialized/Technical category	*Circular lifecycle management*	**0,26**	**0,18**	**0,16**	0,11	0,08	**0,16**	0,00	0,05	0,05	0,00	0,08	0,05
	Waste management	**0,22**	**0,17**	**0,17**	0,06	**0,17**	0,06	0,00	**0,17**	0,11	0,00	0,11	0,11
	Cleantech and advanced materials	**0,38**	**0,23**	**0,31**	**0,23**	0,15	**0,23**	0,08	0,08	0,08	0,00	0,08	0,15

5.1.3.2 Duration of educational courses

Twelve of the papers addressed the duration of the education. Seven of these stated a duration in the range of 2-4 months which in most cases corresponded to a whole course. Four of the papers stated integrating the CE topic in a number of modules/lectures as part of existing course or during the graduate studies (Summerton et al., 2019), while one paper presented a concept for co-design of a new curriculum with a duration of 2 years for developing students' sustainability skills (Onpraphai et al., 2021).

5.1.3.3 Technological support for training delivery

Different technologies have been used to support the education and training in CE, in 14 of the reviewed papers. One category relates to software and tools that support different analysis in the product design phase. This could be: software enabling calculation of energy, carbon emission and material circular indicator for different product designs in cradle-to-cradle context (Pereira and Fredriksson, 2015); CAD software supporting product-redesign to increase disassemblability (Favi et al., 2016); software for material decisions and analysis including analysis for reduction of environmental impact (Esparragoza and Mesa-Cogollo, 2019), life cycle inventory tools (Reichmanis and Sabahi, 2017), LCA tools (Watkins et al., 2021), discrete-event simulation software (Lanz et al., 2019). Another category of technology includes machinery and equipment that enables actual production of materials and test or evaluation of the use of the materials. This includes laboratory for materials (Alarcón et al., 2019), sensors, datalogger (Rizzo et al., 2017), diverse machinery and equipment (Fernandes et al., 2018). Furthermore, different e-learning tools have been addressed, such as internet (youtube videos) (Knudby and Larsen, 2017), Massive Open Online Courses (MOOCs) platform (Avadanei et al., 2020; de Miranda et al., 2021), blogs and communication platforms, computer vision algorithms in MOOCs to compensate for the absence of human trainer (de Miranda et al., 2021).

5.1.3.4 Evaluation of the learning

Among the reviewed papers, ten assessed the effectiveness of the teaching/education effort using various methods, with most employing a combination of two to three approaches. More formalized assessments were practiced through multiple choice test that could be conducted online (Avadanei et al., 2021; Knudby and Larsen, 2017), pre- and post-workshop questionnaire to directly assess the learnings gained from a session (Summerton et al., 2019), individually graded final exam (Watkins et al., 2021). These assessments were mainly related to examining the theoretical knowledge of the participants. Another category of approaches was related to evaluation of a report of a project or exercise/assignment which is more about applying the knowledge learned in a course. In some cases, this included poster or student presentation (Knudby and Larsen, 2017; Reichmanis and Sabahi, 2017; Sanchez-Romaguera et al., 2016; Watkins et al., 2021). Reichmanis and Sabahi (2017) included industrial experts in the evaluation of the poster presentations, Fernandes et al. (2018) evaluated the level of applied knowledge from different courses into the developed project, Lanz et al. (2019) and Kopnina (2019) used grading of assignments and evaluating the quality of the exercise work. In addition to this, Kopnina (2019) used a sharing and comparing session where they asked the students to reflect on their learnings and share with the rest. Interestingly, Alarcón et al., (2019) observed the emotional reactions of the primary school students finding that tranquillity, happiness, curiosity was superior to antagonistic unrest, unhappiness, indifference when facing with the newly designed materials that have remarkable visual and tactile qualities.

5.1.3.5 Evaluation of the teaching

The most frequently used method for evaluating the courses was feedback form (Knudby and Larsen, 2017; Sanchez-Romaguera et al., 2016; Torreggiani et al., 2021; Whitehill et al., 2022). Several of the papers used scale from 1 to 5 to evaluate different aspects, such as: level of preparedness of the students to take the course (Reichmanis and Sabahi, 2017), amount and types of learnings (Fernandes et al., 2018; Lanz et al., 2019; Reichmanis and Sabahi, 2017), assignments that facilitated the learning (Reichmanis and Sabahi, 2017), assignments measured knowledge (Reichmanis and Sabahi, 2017), course effectiveness (Reichmanis and Sabahi, 2017), level of how interesting the project was (Fernandes et al., 2018), how willing the students were to continue with CE concepts implementation (Alarcón et al., 2019), course facilitators, course content, development of transferable skills (critical and holistic thinking) (Summerton et al., 2019). Another group of papers used actual outcome of the course/session to measure how good it was. For example, Favi et al. (2016) used disassembly time of four target components as an indicator, Mayer (2020) measured the results and impacts obtained, Leal et al. (2020) used test with few questions to evaluate the efficacy of the method, expert evaluation of the design results (Kim and Lee, 2022).

5.1.3.6 A Research Agenda Advancing Circular Economy (CE) Skills

Based on the current literature review, six research avenues have been identified (Table 9). They can be explored by scholars and serve as a guide for prioritizing new studies on skills and competencies required for a successful transition to CE. Therefore, these research opportunities represent topics underdeveloped by literature that deserve greater attention in future endeavours, as follows:

Research Avenue 1: Skill, Reskilling, and Upskilling for Circular Manufacturing. The rapid evolution of industrial systems results in a shift in the skills demand for workers, necessitating reskilling and, in many cases, upskilling. Future studies should focus on understanding the set of new skills, competencies, and even job positions that require qualified professionals (Akyazi et al., 2023; De los Rios and Charnley, 2017). According to (Giannoccaro et al., 2021), more in-depth empirical investigations are needed from an organizational perspective to understand the educational needs and provide a more targeted qualification for the circular transition. Additionally, the effective establishment of training programs significantly depends on understanding the current skills demanded by the market. Thus, it is crucial to comprehend how intellectual capital redistribution and collaboration across supply chains (Demartini et al., 2023) or even circular ecosystems can be done to provide educational programs for requalification and learning enrichment in circular manufacturing and design processes.

Research Avenue 2: Geographical and Cultural Understanding of Skills, Education, and Training Programs. The current research on education and competencies for sustainability and circularity often focuses on European countries, representing only the Eurocentric educational perspective. Consequently, the literature emphasizes the need for more comprehensive research considering global circular design education (De los Rios and Charnley, 2017; Watkins et al., 2021). In particular, studies discussing the peculiarities, differences, and similarities in teaching and learning in countries with diverse geographical locations are welcomed. Furthermore, understanding cultural differences in terms of teaching and perception of CE is also a potential future investigative pathway (Giannoccaro et al., 2021). The mapping of skills for an I4.0 in emerging countries, which have different economic realities, also represents a research gap that can be explored in new works (Bag et al., 2021b). Therefore, the development of training and education programs should also be formulated considering regional nuances that may influence the demand for specific competencies (Burger et al., 2019).

Research Avenue 3: Impacts of Digitalization and Required Skills. Given that industrial systems have been undergoing a revolution in recent years regarding digital and green transition (the so-called twin transition) (Chen et al., 2023), there is a growing demand for professionals with mutual digital and circular competencies. Therefore, future studies may focus on identifying the skills required for a smart CE (Bag et al., 2021a; Ghobakhloo et al., 2023). Furthermore, there is a need for a better understanding of how the human aspect is being addressed during the twin transition. According to (Ghobakhloo et al., 2023), the unprecedented adoption of DTs represents a double-edged sword in terms of the social dimension, as it enables automation, integrates stakeholders, connects the business environment, increases productivity but may also lead to job losses. As a result, in-depth research on developing policies that prioritize human well-being is necessary. Investigations into which skills and professions may become obsolete with digitalization also deserve greater attention from scholars (Burger et al., 2019). Finally, there is a significant opportunity for research in terms of interaction and educational programs that effectively bridge the collaboration between humans and machines, ensuring professional requalification (Ghobakhloo et al., 2023). This aspect is relevant once DTs not only support production operations but also the operators' training to improve their skills (Sassanelli et al., 2021).

Research avenue 4: Methods and Tools in CE Educational Programs. Due to the changes imposed by the twin transition, new methods and tools are necessary to support educational programs and professional (re)qualification. Understanding how DTs can be inserted into teaching environments represents an interesting path of study. The teaching of circular design, for example, can benefit from tools that help students comprehend in detail the material cycles (Pereira and Fredriksson, 2015). Furthermore, (Knudby and Larsen, 2017) argue that it is fundamental to investigate how teaching methods can enhance learning by facilitating the exchange of knowledge among students from different areas. There are also possibilities for research paths associated with the characteristics of teaching and learning programs offered through MOOC platforms (Giannoccaro et al., 2021) and how they differ from traditional higher education programs.

Research avenue 5: Soft and Hard Skills Integration in Multidisciplinary CE courses. Implementing circular practices requires professionals to integrate soft and hard skills. Educational institutions should offer multidisciplinary courses that encourage the development of individuals in different areas. Studies can be conducted to identify strategic approaches to incorporating topics such as social justice, unsustainable production, and consumerism, among others, into science, technology, engineering, and mathematics teaching curriculum (Kopnina, 2019; Reichmanis and Sabahi, 2017). Besides, there are opportunities to embed CE principles in arts, law, and humanities fields (Giannoccaro et al., 2021). In addition to new research, expanding knowledge in the CE domain can also occur through workshops and projects involving students, communities, and practitioners (Monyaki and Cilliers, 2023; Watkins et al., 2021). Project-based learning, where students can explore real context in circular manufacturing, is a powerful teaching approach (Kopnina, 2019). In this sense, investigating how to restructure CE teaching curricula to provide students with a holistic and multifaceted view of CE challenges and opportunities represents a valuable research area. This involves not only considering micro-level aspects but also taking a systemic view of the entire circular supply chain.

Research avenue 6: CE Skills and Professional Competency Levels. As firms make progress in the CE, it is necessary to monitor the skills required throughout the transition journey (Sumter et al., 2021). In this way, new research efforts can assess companies' maturity levels in terms of CE skills and competencies. Innovative studies are also recommended for developing artifacts, including digital ones, to describe and synthesize the levels of competence for each key skill in circular manufacturing (Pinzone and Taisch, 2023). To facilitate the effective development of training and educational programs centred on circularity, it is crucial to possess a comprehensive understanding of the specific competencies demanded by each functional role (for example, design role) (Sumter et al., 2018). This type of study can be conducted through empirical investigations of different business models and circular strategies adopted by firms (Sumter et al., 2018).

Table 9: CE skills: a research agenda

Research Avenue (related references)	Emerging research questions	Keywords
RA (1) Empirically validate and enhance skills identified in the literature; develop training programs for upskilling workers for circularity transformation (Akyazi et al., 2023; Can Saglam, 2023; De los Rios and Charnley, 2017; Demartini et al., 2023; Despeisse et al., 2017; Giannoccaro et al., 2021; Halfdanarson and Kvadsheim, 2020; Isaksson et al., 2018; Pinzone and Taisch, 2023; Sumter et al., 2018, 2021; Watkins et al., 2021).	How to provide workers belonging to the same organization with the correct set of skills and competences? How can suitable workforce redistribution be fostered in a company and along a circular supply chain/ecosystem? What teaching and learning approaches are needed to reskill and upskill workers in circular manufacturing? What are the key skills, competencies and job roles considering an empirical perspective and industrial demand?	New capabilities Skill-downgrading Life-long learning Intellectual capital Empirical data Professional qualification Circular design
RA (2) Focus on mapping the necessary skills and competencies for CE on a global scale and establishing educational programs that consider each region's geographic, cultural, and industrial differences (Bag et al., 2021a; Burger et al., 2019; De los Rios and Charnley, 2017; Giannoccaro et al., 2021; Halfdanarson and Kvadsheim, 2020; Watkins et al., 2021).	How are CE education programs structured locally, and how should they be globally? How can education programs be designed to reflect the diverse CE strategies across different countries and regions? How do cultural factors among countries influence the teaching and learning approaches in CE education? Do developed and emerging countries have the combination of competencies and workforce for sustainable manufacturing? In emerging nations, what skills, capabilities, and resources are critical for fostering both CE and I4.0? How can educational programs be tailored considering regional nuances and broad global economic disparities?	Educational programs Emerging economies Cultural perceptions Case studies Geographical disparities Eurocentric model
RA (3) Comprehend the impacts of new disruptive technologies on professional skills and the potential for substituting human labor (Bag et al., 2021a; Burger	What are the skills, and at what levels are they required for a smart CE?	Digitalization Not-yet-existent skills Socio-centricity

et al., 2019; Despeisse et al., 2017; Ghobakhloo et al., 2023; Kim and Lee, 2022).	Which human skills and capabilities stand to be replaced by DTs, and what are the consequential impacts of this transformation? To what extent do current skills and professions face the threat of obsolescence with digitalization? How should public policies and actions be structured to actively incorporate the social dimension in an era of growing digitalization? How can academics provide guidance in this sense? What emerging technologies will drive CE adoption, and what skills will be needed to harness their potential? How can students and employees be educated about the applications, benefits, and impacts of DTs in CE? How to ensure the prioritization of human centrality within I4.0? And how can we design educational programs that effectively foster human-machine collaboration in CE? Which technologies could be integrated into smart workplaces to foster the implementation of CE in companies? How can they enable the upskilling and reskilling of operators with their adoption?	Technologic innovation I4.0 and I5.0 Automation
RA (4) Focus on pioneering novel teaching methodologies, employing tools within the classroom for the analysis of linear and closed material cycles, and assessing multidisciplinary educational programs and platforms (Alarcón et al., 2019; de Miranda et al., 2021; Giannoccaro et al., 2021; Isaksson et al., 2018; Knudby and Larsen, 2017; Pereira and Fredriksson, 2015; Spreafico and Landi, 2022; Sumter et al., 2021).	Which DTs should be adopted in CE teaching? How to integrate them into new teaching methods? Which tools can facilitate the teaching and learning of circular design? What are the typical characteristics of courses and training modules in the CE domain? How could they change if delivered via massive open online course (MOOCs)? How to create a learning space for students with different competences to learn from each other? And how can incorporating do-it-yourself (DIY) approaches amplify creativity and enrich teaching and learning in CE? What methods, approaches, and tools could support solving future CE challenges in product development?	Methodologies HE programs Vocational programs Learning goals

RA (5) Expand the currently available academic disciplines, identify ways to integrate different knowledge areas and make learning more active that promotes sustainable and circular practices (Avadanei et al., 2021; Giannoccaro et al., 2021; Kopnina, 2019; Mayer, 2020; Monyaki and Cilliers, 2023; Onpraphai et al., 2021; Reichmanis and Sabahi, 2017; Summerton et al., 2019).	How can science, technology, engineering, and mathematics (STEM) courses be enriched to incorporate vital concepts like social justice, consumer needs, culture, and human behavior? How to integrate CE principles in other subject areas such as law, arts, and humanities? And how can CE teaching curricula be restructured to become more systemic and multifaceted? Which methods offer students a practical and holistic view of the circular supply chain domain?	Social impact Experimental learning Regional network Collaboration
RA (6) Explore skills fundamental for each stage of the CE transition and develop proficiency levels according to their importance and the roles performed by designers (Pinzone and Taisch, 2023; Sumter et al., 2021, 2018).	How to assess the maturity of an organization in terms of CE-related skills and capabilities? How to monitor the skill levels of different professionals throughout the CE journey? How to define proficiency levels and assess the relevance of each skill? What skills and competences are required by different organizational roles and divisions? How can an ontology of circular manufacturing competences be developed to organize competences in different contexts?	Design competences Skill monitoring Proficiency levels

5.2 Market Analysis

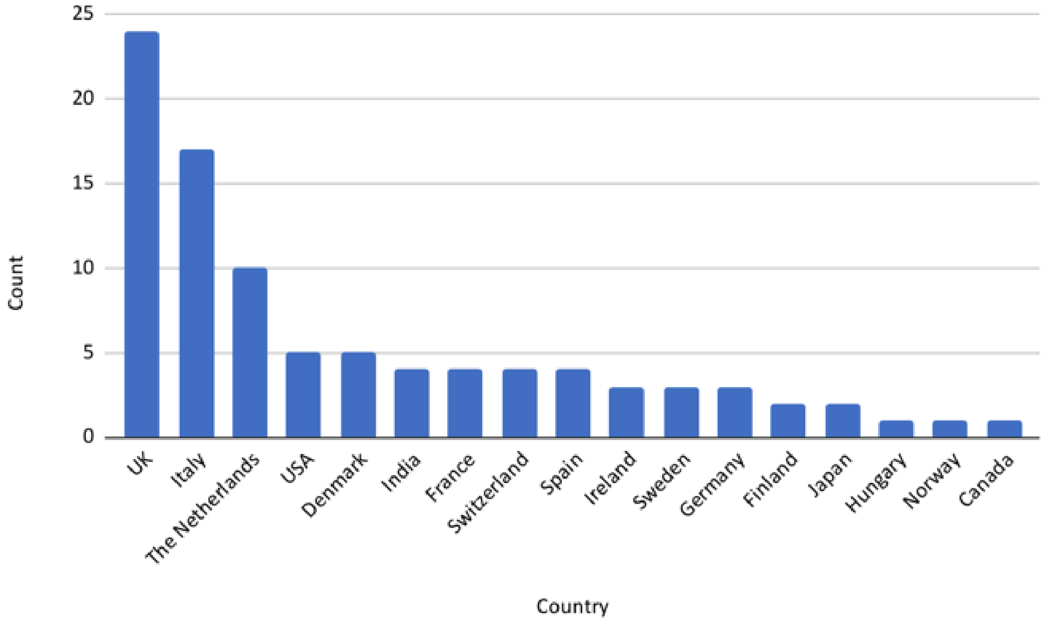
This sub-section reports the results of the market analysis performed. A mapping of the formative and training opportunities already available at European level has been performed. They have been analysed according to several variables (e.g., target audience, content, countries, educational level), also providing an overview in terms of modules and existing professional careers related to CE topic. In sub-section 2.1, the information describing the sample of courses has been gathered. In sub-section 2.2, the results of the content analysis, which led to the definition of the three macro-categories of courses, are reported.

5.2.1 Descriptive analysis

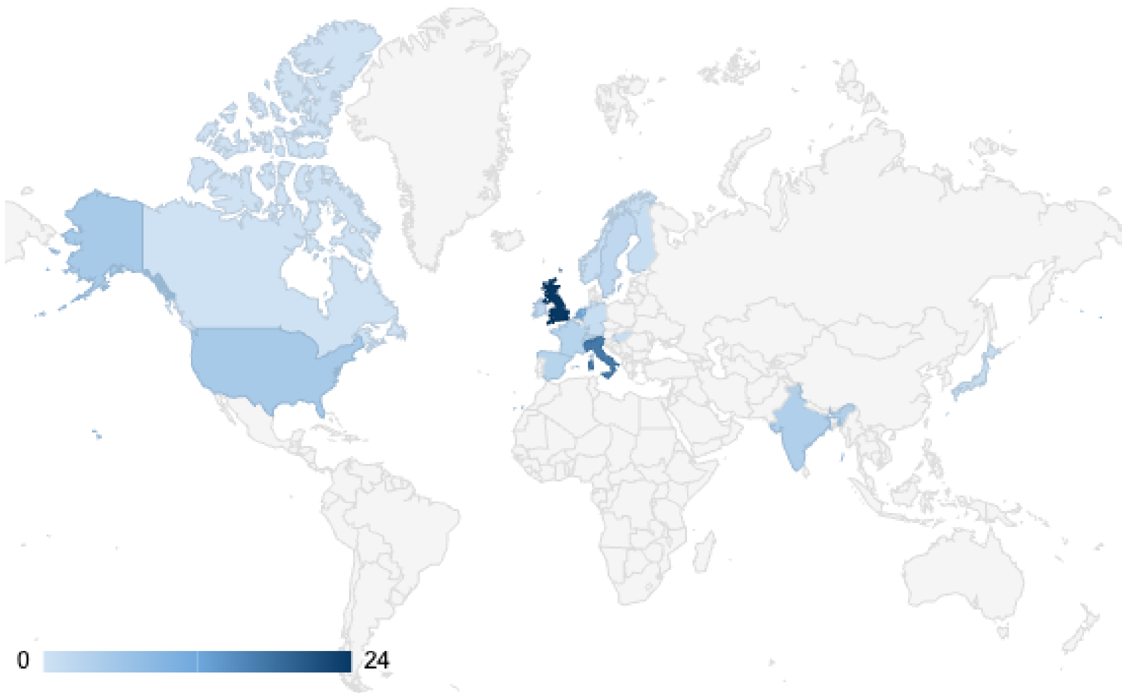
The market has been analysed separately for the HE and VET levels, being quite different samples in terms of characteristics and content.

5.4.3.1 Higher Education (HE) level

The analysis of the HE samples showed that almost all courses are provided by universities or business schools, which often rely on platforms for online courses. These teaching institutions are mostly concentrated in Europe, where the United Kingdom (UK), Italy, and The Netherlands are the first providers in terms of the number of teaching courses offered (Figure 15a and Figure 15b). Among them, a set of HE programs are provided by partners of the CERES consortium (i.e., *École des Ponts Business School*, *Politecnico di Bari*, and *Politecnico di Milano*).



(a)



(b)

Figure 15: (a) Countries contributing to HE courses, (b) Geographical distribution of providers and teaching institution

The courses' teaching modules were then examined in detail following the same drivers used for the VET sample. The drivers considered were the following.

The methodological approach of teaching: the theory-based approach is adopted in all cases; going into more detail, looking at Figure 16, it can be observed that:

a. 9.4% of the courses adopt only theory-based approaches;
b. 15.6% adopts also application-base approaches, case study, simulation;
c. 3.1% includes analytical application in addition to the previous;
d. 3.1% integrates all the approaches considered in the analysis (theory, application-base, case study, analytical approach, simulation, serious game);
e. 68.8% alternate the explanation of theory concepts with case studies.

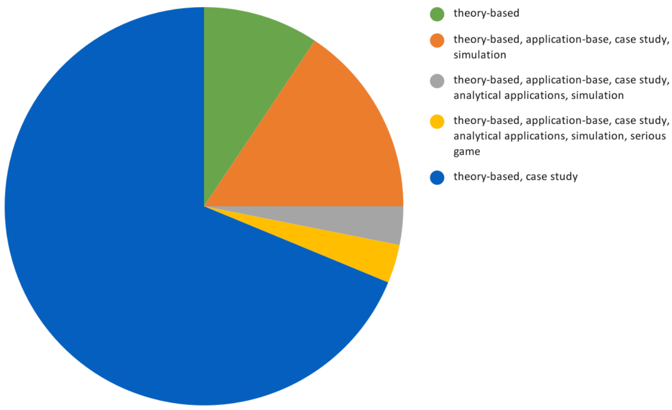


Figure 16: Methodology adopted in the HE courses

Course delivery method. As shown in Figure 17, by a large majority, the online delivery method is the most used due to its ease of implementation. Despite this, a hybrid approach (where lessons are mixed between online and offline) is practiced by 22.2% of the educational programs, and 18.5% of them are completely provided in person (offline).

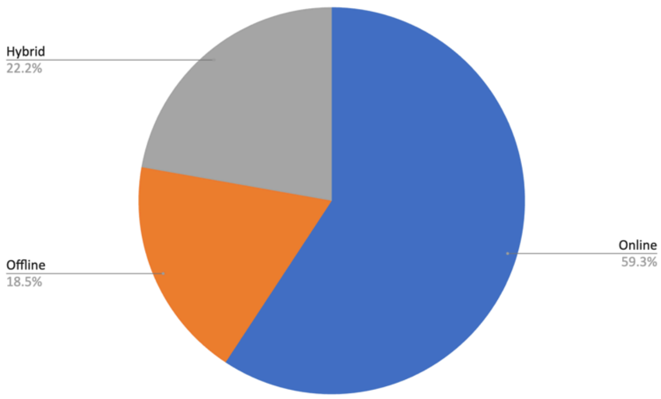


Figure 17: Delivery method in the HE courses

Prerequisites, target groups and proficiency level: since these educational programs mostly consist of degree- or master's-level courses, most of them require participants to have at least a bachelor's degree or its equivalent; in other cases, they additionally require

participants to have a minimum of work experience. Therefore, the target audiences are primarily managers, industry leaders, policymakers, business professionals, executives, students specialized in sustainability and CE matters, designers, and engineers.
The majority of courses required an Intermediate proficiency levels (51.3%) (Figure 18), meaning that students should already have studied fundamental concepts related to topics like sustainability and CE; 40% of the courses analysed do not require specific competencies (that are envisioned to be addressed in in detail in the various modules of the course offered); expert proficiency levels are required to enroll in seven teaching courses that are designed for candidates with relevant experience in the CE field or in areas such as R&D, manufacturing, supply chain in different sectors (e.g., agriculture, packaging).

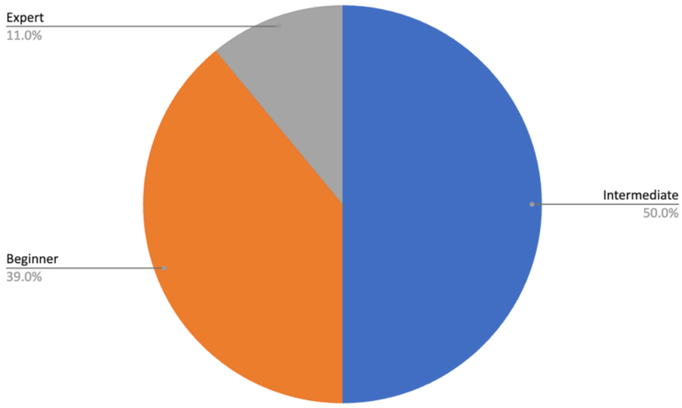
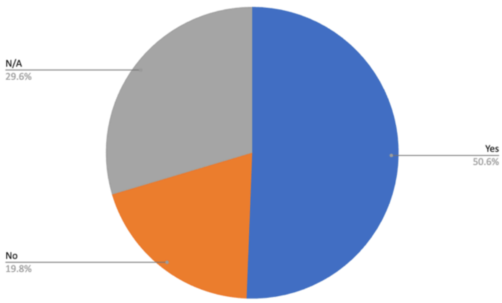


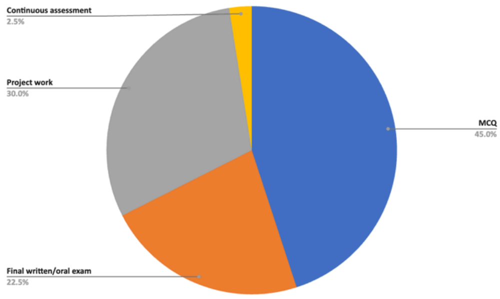
Figure 18: Required proficiency level

Number of modules and their average duration. Considering the information available on course websites, the analysis (Figure 19) showed that the average number of modules for HE courses is 5.9 and the median is equal to 5; their duration is at least 1 day (in general, there was no precise info about the duration of the modules).

Final assessment. Many courses disclose information about the presence or absence of final assessments (70.4%). Specifically, 50.6% have final assessments of competences, while 19.8% don't require final exams.
When there is a final exam, it takes place as a multiple-choice question (MCQ) exam in half of the cases, project work (which can be the development of an individual essay or group project), and a final written exam; only one course also includes continuous assessment.



(a)



(b)

Figure 19: (a) Final assessment, (b) Typology of final assessment

Language. The majority of the educational programs are offered in English, whereas 9 courses are also provided in other languages besides English (such as Norwegian, Spanish, French, Italian); in a few cases, some programs are fully taught in Italian (3) or Spanish (1) (Figure 20).

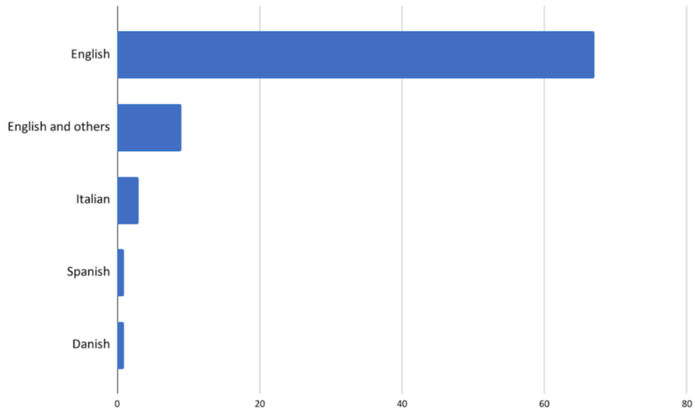


Figure 20: Language used in HE courses

Price. Price information was unavailable in 34% of the cases, but for 66% of them useful information could be obtained:

a. 17% of courses are free access,
b. 7.9% are free courses, but participants need to pay for obtaining the final certification (average price: €121.5),
c. 5.3% requires a tuition fee (e.g., universities),
d. the average price of the remaining educational programs is €1,863.48 (min: €13.38, max: €13,000).

Referring industry. Since these courses aim to prepare professionals with largely transversal abilities (they don't aim to teach people to shape technical figures), the concepts presented are often not industry-specific (86.8%). Nonetheless, there are some courses with a focus on the plastic, renewable energy, agri-food, built environment and metal industries (Figure 21).

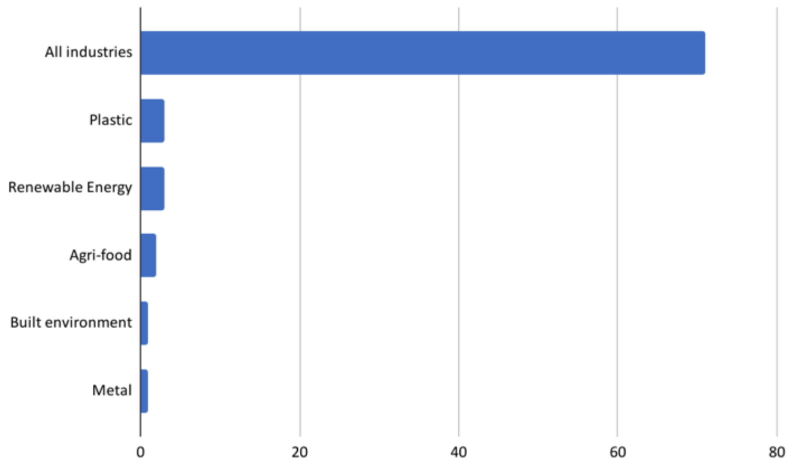
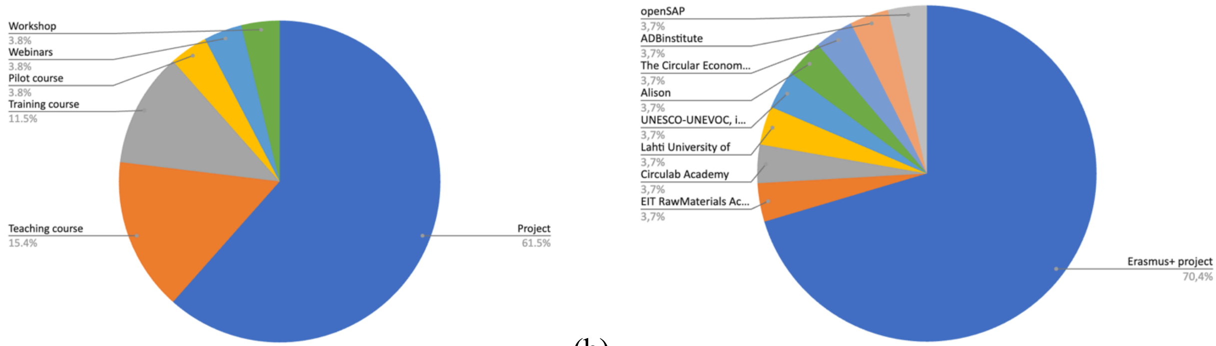


Figure 21: Referring industry in HE courses

5.2.1.2 Vocational and Training (VET) level

Concerning VET, the market analysis started with the classification of the educational programs by typology (Figure 22a) and provider/teaching institutions (Figure 22b). Considering the reference sample, 61.5% are projects, 15.4% are teaching courses, 11.5% training courses and the remaining 11.4% is split between workshop, webinar and pilot courses. It turns out that the first consideration that can be drawn is that the majority of them are Erasmus+ funded projects (70.4%), while 29.6% are courses provided by universities (i.e., *Lahti University of Applied Sciences*, *University of Gävle*, *University of Latvia*, *Itmo University*), non-profit organization (e.g., *Circle Economy Foundation*), online education platforms (*Circulab Academy*), and consortium (*EIT RawMaterials*). None of these courses is provided by a CERES partner.



(a) (b)

Figure 22: (a) Classification of the educational programs analyzed, (b) Provider/Teaching institution of VET projects and courses

Another element considered during the analysis regarded the countries involved in the supply of these educational programs. This enabled to highlight that the highest number are in Germany, followed by Italy and Spain (Figure 23a and Figure 23b).

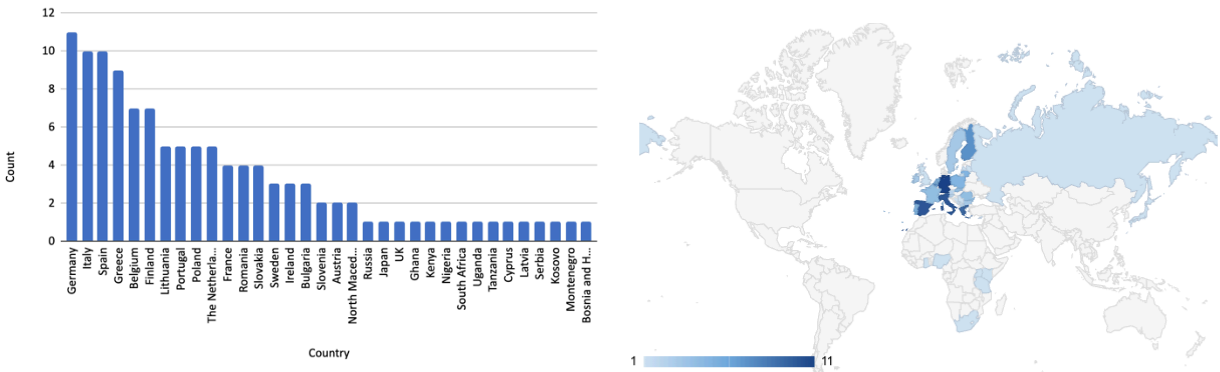


Figure 23: (a) Countries contributing to VET projects/training courses, (b) Geographical distribution of VET projects/courses

The teaching modules of the courses at VET level were also examined, considering:

1. **The methodological approach of teaching**: all the 27 educational programs adopt a theory-based approach; among them, 25.5% also adopt case studies as teaching

methodology, 11.8% gamification, 5.9% simulation and the remaining 3.9% application-based approach (Figure 24).

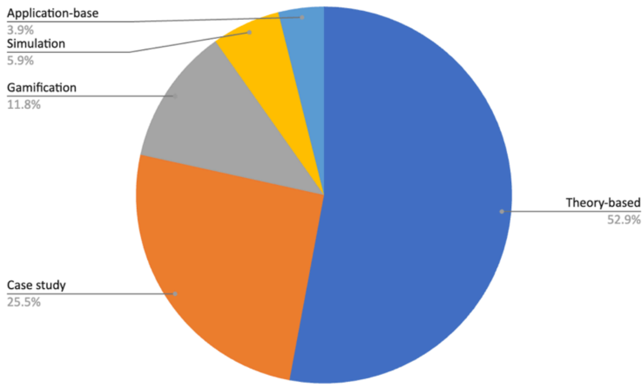


Figure 24: Methodology adopted

Course delivery method: the majority of the courses are delivered through online platforms (Figure 25), where students can access learning materials such as MOOCs, presentations (e.g., PowerPoint format), virtual reality sessions or live streaming lessons (in some cases, these learning materials are already published and available for all users, without needing a registration). Only 14.8% adopt a hybrid approach (which means both online and offline), and one course is held in presence (offline).

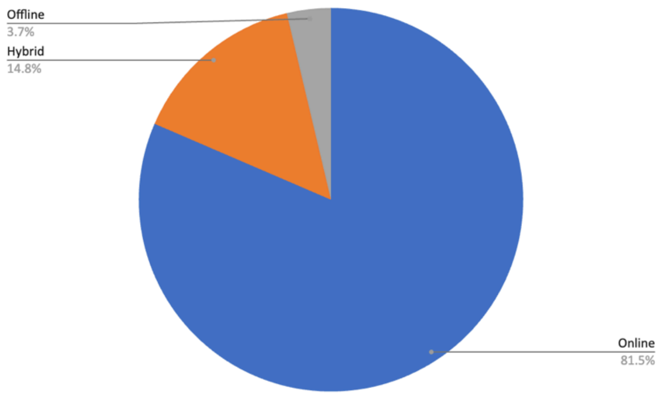


Figure 25: Delivery method

Required proficiency level. All the courses require a beginner proficiency level, which means that they provide teachings that start from the basic concepts and then possibly delve deeper into certain areas, so that they can be accessible to as many people as possible, even those who know little about the principles of the CE, for example.

Prerequisites and target groups. Most courses do not require prerequisites to participants, excluding only a few cases in which there are constraints in terms of age (e.g., 18+), or English proficiency level (at least B1). VET students and teachers are the main target groups, although in other cases the targets are technical professions (e.g., electricians, plumbers, carpenters, etc.), designers, entrepreneurs, and managers.

Number of modules and their average duration. Out of 27 educational programs, 20 report quite detailed information on their modules, which means it was possible to calculate that on average they offer 5.5 modules, the duration of which ranges from a minimum of 1 hour to a maximum of 30 working hours.

Final assessment. As shown in Figure 26, some courses don't have a final assessment (33.3%) and for 18.5% of them this information was not available (N/A). On the other hand, 48.1% of courses have final assessments, which include continuous assessment, MCQ, individual written exam, and group projects.

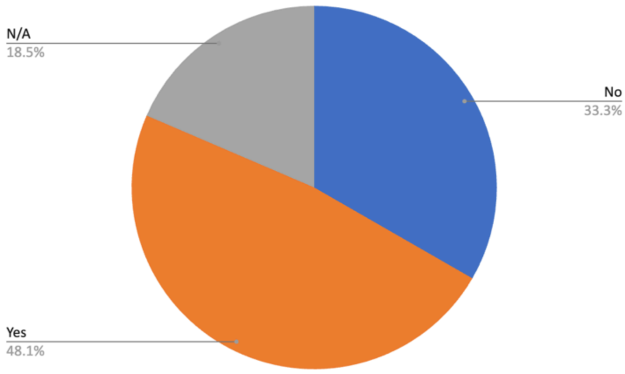


Figure 26: Final assessment

Language. All courses are taught primarily in English, which is also the only language offered in 59.3% of them. However, 40.7% of these courses allow students to follow lectures, in addition to English, also in additional languages (such as Italian, Spanish, Swedish) (Figure 27).

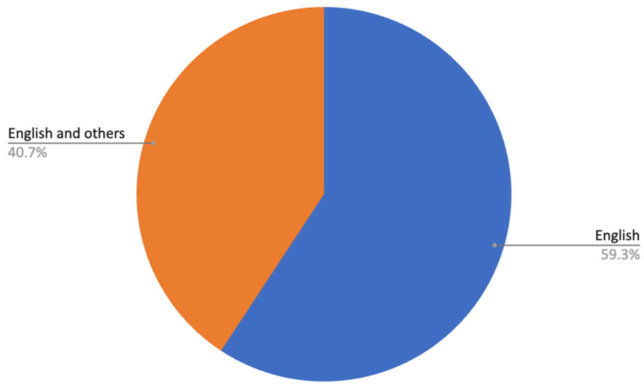


Figure 27: Language used in VET courses

Price. Most of the educational programs in the VET sample are free because they receive funding by the EC or other organizations (one course is funded by the Emilia-Romagna region in Italy, for example). There is just one course that needs to be paid for ($280,00); the other is accessible for free for a limited time, after which participants must pay €50 to have unlimited access to its content for a whole year.

Referring industry. While many courses offer lessons that can be useful in a variety of industries, some are either specialized in a specific one (construction, for example, or agri-food), or only offer a limited number of modules that are specifically focused on a particular sector. For example, the project "Building green skills for circular economy" offers some modules that are specialized in the plastic, fashion, and electronics industries (Figure 28).

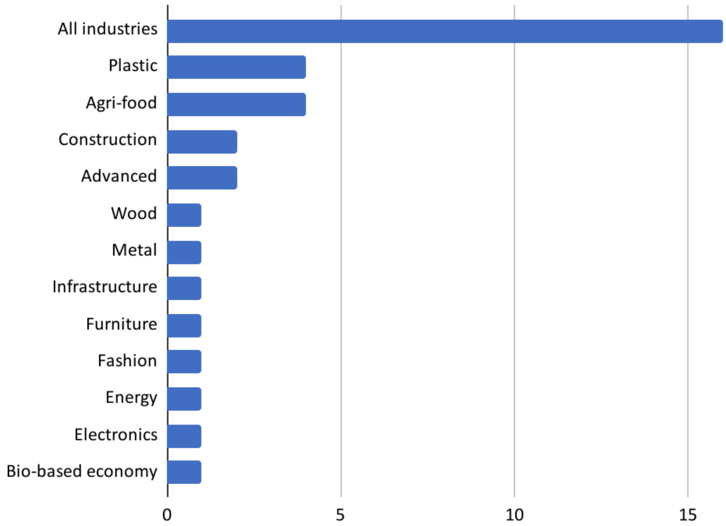


Figure 28: Referring industries in VET courses

5.2.2 Content analysis

The SLIP methodology (Maeda, 2006) allowed the classification of courses within the 3 macro-categories identified (CE transition, Sustainability transition, Twin transition), both at HE and VET levels.

5.2.2.1 HE: Macro-Categories

Almost all courses in the HE sample were classified into the "CE transition" macro-category, and a very few into the other ones (Figure 29). These are explained in detail below.

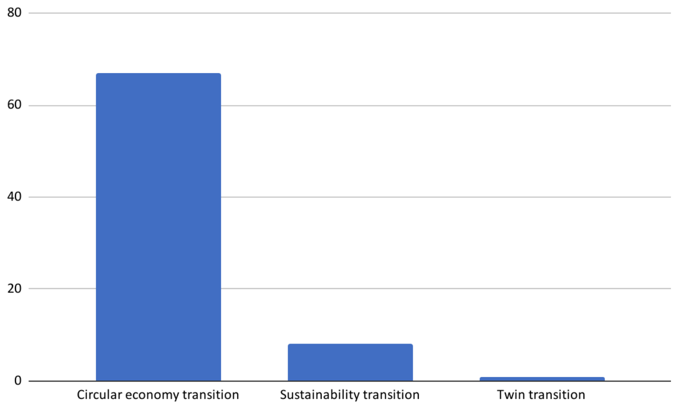


Figure 29: Macro-Categories at HE level.

The following table (Table 10) summarizes the relevant topics for each macro-category identified for HE, reporting the topics and sub-topics in which they are developed. In addition, topics have been translated in skills (following the framework proposed in the SLR), to support the conduction of the gap analysis presented in section 5.5.

Table 10: Relevant topics and sub-topics per macro-category

Macro-Category	Topic	Sub-topics	Skills
	Introduction to circular economy	- Definitions, principles of CE - Sustainability - Circular Business Models - Benefits & obstacles	· Sustainable development (ESG standards, SDGs) · Design Circular Business Models and CSC
	Strategy & Marketing	- Business resilient - Circular creation cycles - Marketing strategies - Ecosystems - Partnerships - Open innovation	· Marketing and Sales (Business Management and strategy skills) · Design Circular Business Models and CSC/Ecosystems · Collaboration and Network collection · System Thinking
	Circular Supply Chain	Procurement: - Raw materials & Sustainable alternative materials Operations: - Waste management - Energy management	· Design Circular Business Models and CSC · Master 3d printing · Circular product design · Waste collection and recovery skill · Energy management skills
Circular economy transition	Circular eco-design	- Design for reuse, repair, recycle - Design for demanufacturing, remanufacturing	· Circular Product Design Skills · Circular (re)manufacturing skills
	Policies & EU regulations	- EU policies - EU regulations	· Compliance and policy management skills
	Introduction to advanced technologies enabling CE implementation	- Blockchain - Digital platforms - Additive manufacturing - Advanced technologies for recycling and recovering - Advanced waste sorting & separation technologies	· Industry 4.0 Technologies application · Robotics and Automation
	Assessing & Monitoring	- Circular and sustainable finance - project financing - Budgeting - LCA - SDGs impacts	· Financial Management skills · Circularity and environmental assessment skills · Business Management and strategy skills
	Introduction to sustainability	- Definitions and principles - SDGs - ESG standards - Sustainability vision - Relation with circular economy	· Sustainable development (ESG standards, SDGs) · Design Circular Business Models and CSC
Sustainability transition	Sustainability management	- Sustainable business models - Leadership skills - Organizational change & design - Marketing strategies	· Sustainable development (ESG standards, SDGs) · Design Circular Business Models and CSC · Leadership skill · Design Circular Business Models and CSC · Marketing and Sales (Business Management and strategy skills)
	Assessing & Monitoring	- KPIs linked to Triple Bottom Line - KPIs linked to ESG standards - Sustainable finance	· Circularity and environmental assessment skills · Financial Management skills

Twin transition	Sustainability & Circular Economy	Sustainability & Circular Economy	· Sustainable development (ESG standards, SDGs) · Design Circular Business Models and CSC
	Energy management	- Renewable energies - Energy efficiency - Energy certifications	· Energy Management Skills
	Green technologies	- Energy storage technologies - Renewable heat technologies - Variable Renewable Energy Technologies	· Energy Management Skills

B. CE transition at HE level

This category is defined according to the same criteria used for the VET courses and projects. In fact, the category 'CE transition' for HE includes all those courses (belonging to the HE sample) that aim to provide teaching intended to develop knowledge and skills related to the CE. The topics tackled are the following: Introduction to CE, Strategy & Marketing, Circular Supply Chain, Circular Eco-design, Policies & EU regulations, Assessing & Monitoring, and also technological support (although this is not the core focus of these courses as in the case of the "twin transition" category). Considering these conditions, 67 HE courses were identified as part of this category (Annex 1).

Through the SLIP method (Maeda, 2006), the data gathered from the analysis of the courses was sorted, labeled, integrated, and prioritized according to 7 principal topics, explained in the following:

1. **Introduction to CE**. All the HE courses introduce their teaching offer starting from the basis of the CE, namely:

- **Definitions and principles of CE**. The main frameworks and paradigms (e.g., the 3R – Reduce, Reuse, Recycle) are explained, including the advantages CE can bring in addressing global challenges; in some cases, these concepts are described referring to specific industries – e.g., both the Delft University of Technology and the Oxford Management Center offer a course called "*Circular Economy for a Sustainable Built Environment*", which introduces CE theories by linking them to the built environment.
- **Sustainability**. Some courses introduce the CE concepts remarking the difference with sustainability and the relationship between them. For instance, the course "A Circular Economy of Metals: Towards a Sustainable Societal Metabolism Sustainability" introduces metals with reference to the pursuit of CE in complying with SDGs standards.
- **Circular business models**. Almost all courses include notions on traditional business models and how we can move towards a circular one; therefore, diverse typology of business models are explained, such as the product-as-a-service model or the sharing platform one, since more and more companies are adopting these as business opportunities.
- **Benefits and obstacles**. Among the topics proposed to introduce the CE, there is the explanation of the general benefits that CE can bring to the environment, to society (new job opportunities) and companies (e.g., cost savings, energy efficiency, waste reduction); however, some courses also discuss about the potential obstacles related to CE implementation (e.g., these topics are covered in the courses "*Circular Economy Specialist*" and "*Circular Economy Instructor*" by the Circular Economy Institute).

2. **Strategy & Marketing**. Deeper aspects of CE are then outlined in detail, regarding both business strategies aspects and marketing.

- **Business resilience**. The concept of resilience is often addressed with reference to business transformation; thus, courses offer a general understanding of what business resilience is, why it is important nowadays, and how companies can learn to be resilient.
- **Value creation cycles**. To implement a successful circular strategy, it's important to map circular initiative and identify circular opportunities: these can be supported by circular tools, such as "the butterfly diagram" proposed by The Ellen MacArthur Foundation in the course "*Circular Economy: The Big Idea*", which helps companies to visualize materials flow and value relationships.
- **Marketing strategies**. Understanding customers' needs and behaviours are fundamental for companies which, as a consequence, necessitate implementing marketing tools and developing communication skills to tell circular product/service features and avoid potential mistakes.
- **Ecosystems and partnerships**. Another significant aspect regards the stakeholder's management, how to identify key stakeholders (public and private) in the CE ecosystem, and understanding the importance of strategic partnerships for developing CE projects (e.g., the "*Circular Economy Management*" course, by LUISS Business School, explains these matters in detail). One course (i.e., "*Circular Economy Online Course*" developed by *Sant'Anna-Scuola Universitaria Superiore Pisa*) also introduces the theory of *Open Innovation*, which can help companies innovate thanks to the collaboration with external partners.

3. **Circular supply chain.** A recurring subject concerns the study of the current supply chain processes and how to make them shift to a 'virtuous cycle', according to CE principles. It can be split in:

- **Procurement**. This stage is analysed both for private companies and public administrations to provide them with the right tools for making a circular transition. Different approaches are proposed based on the type of input materials:
  - Raw materials: principles for analysing the raw materials flow are provided to understand how to reduce input level of materials and increase efficiency (e.g., the course "*Design for Circular Economy*" by the *School of Sustainability Foundation* offers this teaching).
  - Sustainable alternative materials: many courses go deeply into this subject, providing worthwhile alternatives for the resources currently in use. As a case in point, the master degree "*Sustainable chemistry and technologies for circular economy*", by *University of Padua*, offers courses on biopolymers, sustainable mineral geo-resources, recycling and transformation of inorganic materials.
- **Operations**. For what concerns the operations management, there are two recurring aspects explored in detail. These are waste management and energy management, which are analysed considering:
  - the tools and technologies useful for increasing their efficiency;
  - how to implement and integrate new techniques to the traditional systems;
  - specific practices for managing waste of plastic, packaging and other materials (e.g., aluminium);
  - how companies can generate energy from waste (e.g., thermal, biological).

4. **Circular eco-design**. Design for reuse, repair, recycling, remanufacturing and demanufacturing are the most frequently discussed approaches and, in some cases, these are explained with reference to a specific industry (e.g., the course "*Circular Economy for sustainable built environment*" by *Oxford Management Center* is specialized for the built environment).

5. **Policies and EU regulations**. A lot of HE courses have modules specifically dedicated to policies and EU legislations to make companies aware of the environmental laws that must be respected and also consider possible incentives that EU gives to companies which pursue CE practices.

6. **Introduction to advanced technologies enabling CE implementation**. The implementation of the CE in current processes is being made easier by the development of more and more advanced technologies, which enable the transition to Circular I4.0. The following technologies are examples of those explained by some HE courses (e.g., "*Circular Economy for sustainable built environment*" by *Oxford Management Center*, "*Circular Economy: Increasing Resource Efficiency and Designing Out Waste*" by *ADBinstitute*, "*Master in Circular Economy*" by *Politecnico di Bari*, "*Circular Economy Masterclass*" by University of Exeter Business School, etc.). In these courses, the technologies are simply tackled as complementary to ease the circular transition, but they do not represent the core of the course as in the twin transition part:

- Blockchain,
- Digital platforms,
- Additive manufacturing,
- Cyber-physical systems,
- Advanced technologies for recycling and recovering (e.g., chemical recycling, mechanical recycling, and energy recovery),
- Advanced waste sorting and separation technologies (e.g., automated sorting, robotics, and artificial intelligence),
- Data-sharing solutions for material tracking and waste management.

7. **Assessing & Monitoring**. Developing the ability to assess both environmental and economic impacts through KPIs is one of the objectives of the courses analysed. Therefore, for measuring economic impacts, circular and sustainable finance concepts are given, in addition to notions on budgeting, project financing, and how to predict future scenarios. While for measuring environmental impacts, some courses teach how to conduct the LCA and assess the SDGs impacts.

B. Sustainability transition at HE level

The "sustainability transition" category includes HE courses that concentrate on gaining expertise that can help with the shift to ecologically and socially responsible practices (Annex 2). The following are the primary subjects they address.

1. **Introduction to sustainability**. Definition and principles of sustainability; how to integrate a sustainability vision; what are SDGs and Environmental, Social, Governance (ESG) standards; what is circular CE) and how it is linked to sustainability.
2. **Sustainability management.** Most of the courses provide instruction on the fundamentals of business models, elaborating on the meaning of sustainable business models; in addition, the tools necessary to implement a good sustainability strategy are deepened, along with the development of leadership skills and organizational change capabilities related to organizational design and reward systems (e.g., the course "*Leading Sustainable*

Business Transformation" develops these skills). Only one master of science, i.e. "*Sustainability Management and Circular Economy*" (*Università Politecnica delle Marche*), and the course "Diploma in Business Sustainability" have a module dedicated to green marketing.
3. **Assessing & Monitoring.** All the courses belonging to the "sustainability transition" category delve into key metrics necessary to measure both economic, social, and environmental impacts. Indeed, these always refer to the TBL and are intended to respect the ESG standards. The courses also aim to develop skills on evaluating long-term impacts and explain key concepts on sustainable finance (impact investment).

C. Twin transition at HE level

Only one HE course in the sample was identified as part of the "twin transition" category, namely the category that includes those courses that develop skills for enabling both green or circular transition together with the digital one, through the support of advanced technologies (Annex 3). The developed competencies are mainly related to:
1. **Key concepts of sustainability and CE**. Principles and definition of sustainability, CE and their relationship.
2. **Energy management**. Aspects such as renewable energies, socio-economic impacts, energy efficiency of buildings, and energy certifications are explored in depth.
3. **Green technologies**. The project "SkillBill" proposes courses which deepen the knowledge and capabilities of implementing green technologies with the existing infrastructure, thus enabling energy efficiency.

5.2.2.2 VET: Macro-Categories

As it can be understood from Figure 30, the majority of courses in the VET sample was classified into the "CE transition" category, followed by "twin transition" and "sustainability transition".

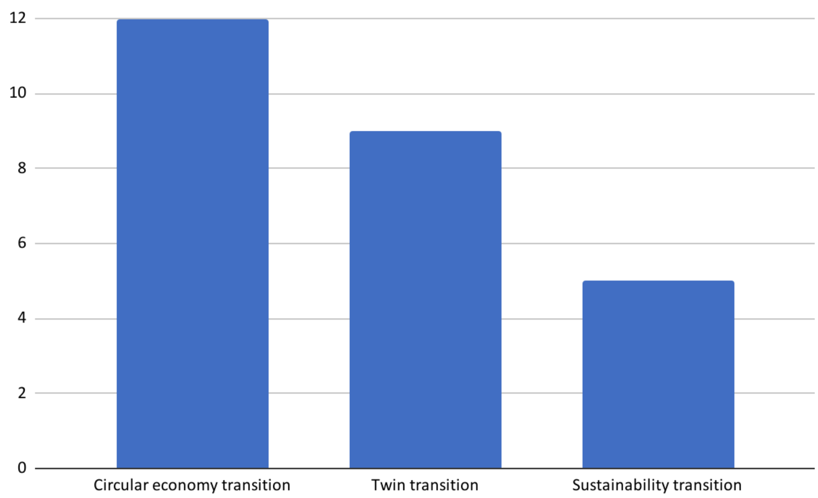


Figure 30: Macro-Categories at VET level

Table 11 summarizes the relevant topics for each macro category identified for VET, reporting the topics and sub-topics in which they are composed and developed. In addition, topics have been translated in skills (following the framework proposed in the SLR), to support the conduction of the gap analysis presented in section 5.5.

Table 11: Relevant topics and sub-topics per macro-category

Macro-Category	Topic	Sub-topics	Skill
Circular economy transition	Introduction to circular economy	- Definitions of CE - CE/sustainability difference - Advantages & Obstacles - Opportunities & Needs in the labour market	· Sustainable development (ESG standards, SDGs) · Design Circular Business Models and CSC
	Circular business models	- Definitions of business model - Circular business models - Innovation strategies	· Design Circular Business Models and CSC · Circular Product Design Skills
	Business Management in the CE	- Decision making - Evaluation of economic & environmental impacts - Entrepreneurial skills	· Decision making and assertiveness · Financial Management skills
	Circular supply chain	- Procurement: · Raw materials · Sustainable alternative materials · Green public procurement - Operations: · Waste Management · Waste Audit · EU legislations - Marketing: · Greenwashing · Communication strategies	· 3d printing · Circular product design · Waste collection and recovery skills · Compliance and policy management skills · Marketing and Sales (Business Management and strategy skills)
	Circular design	- Design for reuse, recycling, remanufacture, repair, upcycling, sharing, testing - Design thinking - EU regulations	· Circular Product Design Skills · Compliance and policy management skills · Circular (re)manufacturing skills · System Thinking
	Advanced technologies to support CE implementation	- Artificial Intelligence - 3D printing & scanning - Additive manufacturing - Digital sharing platforms - Tracking systems	· Industry 4.0 Technologies application · Data management and analytical skills
Sustainability transition	Climate change	- Definition of climate change - Main challenges	· Circularity and environmental assessment skills
	Social circular economy	- Definition of social circular economy - Circular business models - Innovation ESG strategies	· Sustainable development (ESG standards, SDGs) · Design Circular Business Models and CSC
	Entrepreneurship	- Social and sustainable entrepreneurship - Eco-entrepreneurship	Business Management and strategy skills
	Monitoring & Assessing KPIs	- Life Cycle Assessment - Definition and choice of relevant KPIs - Circular tools	Circularity and environmental assessment skills
Twin transition	Sustainability & Circular Economy	- Definitions of CE - CE/sustainability difference - Advantages & Obstacles - SDGs - Circular business models	· Sustainable development (ESG standards, SDGs) · Design Circular Business Models and CSC · Compliance and policy management skills

		- Frameworks to implement sustainable circular practices - EU policies	
	Digital Tools	- Definitions of digital tools - Advantages & obstacles - Automation & AI - IoT - Visualization platforms - Quantum computing & Blockchain - Digital Twin	· Industry 4.0 Technologies application · Data management and analytical skills · Master 3D Printing and VAM reality
	Robotics	- Principles of Robotics - Collaborative Robotics - Lean Robotics	Robotics and Automation
	Design for X	- Design for robotic cells, recycling, reuse, etc. - Design for waste management - Design for energy efficiency - Eco-design - EU legislations	Circular Product Design Skills
	Monitoring & Assessing KPIs	- Life Cycle Assessment - Definition and choice of relevant KPIs - Circular tools	Circularity and environmental assessment skills

A. CE transition at VET level

The 'CE transition' macro category includes those VET projects and courses and related projects (13 in total) that aim to develop knowledge and capabilities enabling the transition from a linear to a circular model (Annex 4).
After an in-depth analysis, seven relevant topics were detected through the SLIP method (Maeda, 2006). These topics are set out and further explained below.

1. **Introduction to CE**. All the courses belonging to the analysed sample offer specific modules dedicated to the introduction to the principles of CE. These principles mainly regard the definition of CE and its frameworks (e.g., 4R – Reduce, Reuse, Repair, Recycle); the difference between CE-sustainability, and how these topics are related; the advantages and main obstacles to CE implementation; the opportunities and needs in the labour market expected to be created by CE by 2030 (*circular jobs*). In one course (i.e., '*Education for Zero Waste and Circular Economy (EduZWaCE)*'), these principles are also explained by referring to a specific industry (i.e., the construction industry).
2. **Circular business models.** Also this topic is addressed by the majority of the courses in the sample. The primary knowledge and capabilities addressed regard the definition of business models, their principles, and the concept of '*circular business models*', which is based on moving from the current linear approach to a circular one, where waste can again become a resource. For many companies, especially if they have a traditional business model, it may be difficult to make this transition. Thus, it is necessary to also provide knowledge on how to implement a circular model, proposing possible strategies of innovation. For instance, the course '*FURN360*' explains these competencies specifically for the furniture industry, supported by business model case studies and circular model strategies in that industry.
3. **Business Management in the CE**. Few courses offer modules dedicated to increasing the capabilities of how to create, organize, manage, and make decisions when applying circular models. Indeed, it is important to teach how to evaluate both the commercial and

environmental impacts, alongside the development of entrepreneurial skills (e.g., this is done in the '*Circular Skills'* project).

4. **Circular supply chain.** From the analysis, it emerged that many courses teach innovative approaches on how to make circular the supply chain's stages.
    a. **Procurement**. How can companies sustainably procure raw materials? Only a few courses propose modules that address this topic, sub-articulated in three main voices:
        - Raw materials: the courses can present the different types of categories and characteristics for specific materials (e.g., the training course '*EduZWaCE*' does it for wood).
        - Sustainable alternative materials: in some cases, courses also propose sustainable alternative materials to the raw materials usually used (e.g., the training course '*EduZWaCE*' teaches how wood materials in the building sector can be reused in new projects).
        - Green public procurement: the project '*Circular Skills*' addresses this topic since the GDP of public procurement represents 12% globally, but public authorities are not yet fully adopting sustainable practices. Therefore, tools to move towards green procurement are needed.

    b. **Operations**. The main addressed topic is waste management, in some cases with regards to the EU recommendations and legislations (e.g., the projects '*FURN360*' and '*EduZWaCE*'). The common knowledge and capabilities taught regard the basic principles of waste management, how to do the waste audit, and the possible procedures to be implemented.
    c. **Marketing**. The project '*Building green skills for circular economy'* offers a module dedicated to addressing a relevant topic for nowadays: *greenwashing*, which is a marketing strategy used by many companies to attract consumers, making them believe that a product/service is eco-friendly but, in reality, it is not. The objective of this module is to incentivize to not use this strategy only for brand image purposes., Instead, it implies the adoption of communication strategies based on key factors, such as familiarity, or tailored to specific industries (as suggested by the course '*FURN360*' for the furniture industry), in order to influence consumers' choices and create value for them.

5. **Circular design**. At least eight projects/courses offer teaching on circular design, which relates to the 'Design for X' (DfX) approaches. Specifically, many courses propose insights on design for reuse, recycling, remanufacture, repair, upcycling, sharing, and testing. These approaches are explained including insights on *design thinking* (an approach to innovation that can help companies in solving complex problems), and EU regulations, which set limits to be respected in the various stages.

6. **Advanced technologies to support CE implementation**. This topic is addressed only by one VET project and two training courses (i.e., '*FURN360*', '*Design for a Circular Economy*', and '*Circular Economy: Increasing Resource Efficiency and Designing Out Waste*'). Their insights mainly relate to the presentation of new technologies that can support CE, such as Augmented Reality (AR), 3DP and scanning, digital collaborative platforms, and tracking systems.

B. Sustainability Transition at VET level

Within the sample, five projects were identified as part of the macro-category called 'Sustainability transition'. This category includes all those projects whose objective is to develop training courses enabling the transition towards sustainable practices, both on the social, economic and environmental sides (Annex 5). Therefore, what mainly characterizes these projects is a strong focus on the ESG standards (which stands for Environmental, Social and Governance), also known to be linked with the TBL.

Through the SLIP method, four topics of relevance were identified:

1. **Climate change**. All these projects begin their teaching path introducing a relevant problem: climate change. Thus, the definition of climate change is provided, followed by the description of environmental, social, and economic issues that this phenomenon has already generated or will cause in the future.
2. **Social CE**. All the projects address this topic, providing an overview of the subject, they define key terms, and describe the main business strategies and innovative ideas; at the same time, they offer an explanation of the potential benefits CE can deliver to people, planet and profit (the so-called 3P), and introduce the concept of resilience.
3. **Entrepreneurship**. There are many courses proposed to develop entrepreneurial skills, supported by examples of real innovative businesses, with the aim of encouraging new entrepreneurial ideas. This topic is taught taking into account two main distinctions:
   - Social and sustainable entrepreneurship: it refers to entrepreneurial thinking which considers the relationship between business development and its social-environmental impacts.
   - Eco-entrepreneurship: it focuses primarily on environmental, green or ecological aspects.
5. **Monitoring & Assessing KPIs**. Only one project (i.e., '*The CATALYST*' Project) offers courses to learn how to measure and assess social CE through several tools and KPIs, including those:
   - to develop materiality assessment for a tailored sustainability strategy;
   - to evaluate the in terms of efficacy of sustainable practices, considering also the circular ones (including notions on Sustainable & Circular Finance);
   - to assess SDGs implementation and their alignment with EU policies;
   - to assess complex environmental concerns from scientific, ethical, and social perspectives;
   - to understand how to discuss and reflect on the results obtained, in relation to the TBL.

C. Twin transition at VET level

The 'Twin transition' macro-category includes those projects and courses that develop training modules to facilitate the adoption of new technologies (such as those belonging to the I4.0 paradigm) and promote the digital transition while also supporting the green or circular transition (Annex 6).

Among the projects/courses analysed, 8 are classified as part of this macro trend. However, it is necessary to point out that many of these educational programs, being mainly training courses that require active participation offline, do not present detailed information about their modules on their websites as it is specified that some providers prefer to communicate the content details directly to the participants on site. Considering this, the analysis of projects/courses' objectives-modules made it possible to identify five topics that characterize this macro-category:

5. **Sustainability and CE**. These are topics introduced by all the projects/courses belonging to the 'twin transition' macro-category. Indeed, the majority explains the key principles of CE, what are circular business models, and other tools that favour the implementation of CE (e.g., Value Hill mapping, which divides the product's lifespan into three phases: 1. Pre-use (which is when the product begins its' ascend up the hill and value is added to the product at every step of the climb); 2. use phase where the product reaches the maximum of its value and is consumed for its utility; 3. post-use phase, where the product begins its' descend downhill and loses its value as it is no longer of use to the consumer) (Upadhayay and Alqassimi, 2020). Nevertheless, some courses link the concepts of CE to sustainability ones, giving general information on SDGs, green certifications, and policies.

5. **Digital tools**. New advanced technologies can help companies to optimize their production flows. Thus, some courses provide an overview of the technologies that can support digital transformation, together with their primary benefits and challenges, and how to integrate them into the traditional systems. The main technologies discussed are:
    - Automation & Artificial Intelligence. For instance, the training course "*Construction Blueprint*" goes deep in explaining this field, showing the principles and benefits of automation in terms of cost and time management; and how drones and robotics can allow digital information to be transferred.
    - Internet of Things (IoT). IoT can help to connect smart devices (such as sensors, smartphones, smartwatches), allowing the sharing of data between them and detecting real-time issues, therefore reducing downtime, and increasing efficiency.
    - Visualization platforms. These can be very useful to monitor and detect issues in the different units of a company while enabling energy savings, time-cost management, and overall efficiency. The training course "*Construction Blueprint*" also explains the BIM (Building Information Modelling) and BEM (Building Energy Modelling) tools, their advantages-challenges, and their integration workflows.
    - Quantum computing and Blockchain. General information on these technologies is taught, focusing on how they can improve the effectiveness of smart contracts, quality control, gather data, and increase supply chain productivity (including notions on Digital Twin).

5. **Robotics**. The project "CROCEM" is highly committed to developing courses that teach notions on robotics, in the specific:
    - Collaborative robotics. Definition and classification of collaborative robotics; the main components and features; field of collaborative robots implementation (e.g., logistics, quality control, assembly).
    - Lean robotics. Definition and principles of Lean supporting CE; how to integrate it for monitoring, reduce waste, and risk assessment.

    Basic knowledge on robotics applied to the construction industry is also provided by the training course "Construction Blueprint".

5. **DfX**. Different approaches of Design for X in manufacturing are proposed; these mainly regard:
    1. Design for robotic cell,
    2. Design for recycling, reuse, upskilling, and remanufacturing,
    3. Eco-design,
    4. Design for energy efficiency,
    5. Design for waste management.

    In general, these approaches are tailored for specific industries (e.g., the building industry), and are supported by the explanation of the main EU legislations that regulate the different stages of the product/service life cycle.

5. **Monitoring & Assessing KPIs**. Some courses teach notions on how to calculate the environmental impacts of a product/service life cycle, understand how to interpret the results, make optimal choices between different product/service options through the LCA; how to define and choose the KPIs; which tools are circular and how to use them to measure environmental impacts (e.g., Greenhouse Gas (GHG) emissions).

5.3 Survey

This section provides the results coming from the analysis of the survey. In this paragraph, answers are described per each question, reporting the percentages of the respondents who answered the specific question. This number may vary from the total participant count (102), which includes not only individuals who answered all of the questions of the survey but also individuals who submitted only their personal data and/or offered significant answers only to some open-ended or multiple-choice questions.

The first section of the survey (from question 1 to 9) dealt with personal details of the respondent. Four fields (name, surname, email address, and organization name) were asked to profile participants. The fifth question was related to the respondents' role inside their own company (to be selected among the five available options: *consultant, academic, industrial, policy-maker, other*). The majority (48% of 96% of total participants) indicated *Other*, meaning that none of the alternatives available as predefined answers was descriptive of their role, but no further specifications were provided for this category. Then, in order, *industrial*, *consultant*, and *academic* range from 20% to 10% of respondents, whereas only 2% were *policymakers*.

Question 6 was an open question aimed at deepening the profiling of attendees by asking for their job title. Among the replies, *manager* was indicated by several participants, followed by *sustainability manager* and *project manager*. Besides that, *engineer, officer, director, professor, audit, business, sales, and IT representative* were other figures reported. It emerges that a broad spectrum of roles is analysed and that the survey has been shared among employees belonging to different areas and seniority levels.

Questions 7 and 8 were the first related to CE, respectively asking respondents if they have been working on CE-related activities, and if yes, how many years. Around 73% answered positively, while the remaining 27% never worked on CE. This fraction is expected to decline in the coming years, considering an increase in initiatives such as CERES, which aid in creating a new labour force sensible to these topics. 73% of respondents stated being enrolled in CE-related activities, of which

15% for less than 1 year, 50% 1-4 years, and around the 35% more than 4 years. This indicates that a minority has only recently started to focus on environmental issues, while a significant percentage has been active for over 4 years. This period is coincident with the increase in awareness in the European Union (EU) related to important environmental issues (as CO_2 emissions) over the last ten years through dedicated regulations and actions linked to CE strategies (such as UN ESG, Net Zero, Green Deal,). Half of the participants began to be interested in these topics 1-4 years ago, following the introduction of such regulations, reflecting a growing interest from both the industry and citizens.

Question 9 was related to unveil the attendees' area of responsibility (Figure 31). In this case, multiple answers were allowed (among 14 possible options), and several participants selected three or more options. The majority (39 respondents) selected *Training & education*, whereas categories such as *Sustainable management,* and *Other* recorded 30 responses, followed by *R&D*/Innovation (27). On the contrary, *After sales services supporting use phase (maintenance, repair, etc.), EoL – remanufacturing, Logistics, Human resources* and *Reverse logistics* had less than 10 respondents.

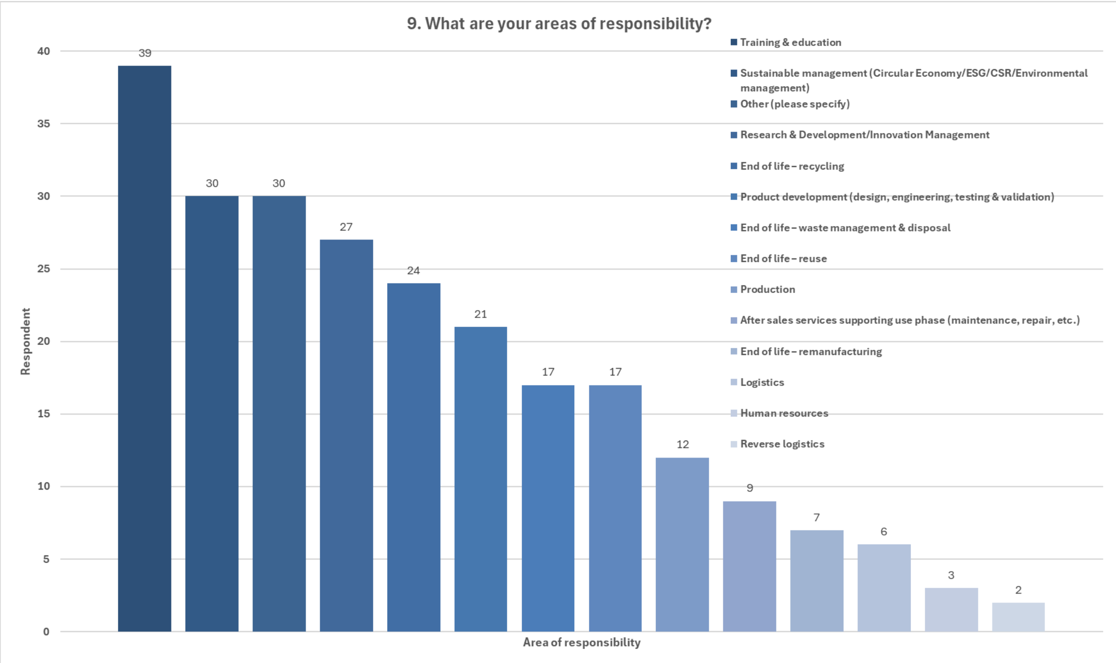


Figure 31. Areas of responsibility of respondents

Questions 10, 11, 12, and 13 were related to the organization description. Regarding question 10 (Figure 32), asking for the industries in which respondents' organisations are involved in, multiple selection was allowed. Most of the respondents selected *Other*, specifying industries such as health care and medical, certification, research and teaching, consulting, construction and civil engineering, tourism, architecture, packaging and plastic, hotel, governmental body, food and beverage, NGO, and public administration. Electrical and Electronic Equipment (*EEE)* scored 22 votes, confirming its relevance in the CE domain (and reflecting the target audience of ECO and REPIC partners to the CERES *consortium*). Indeed, except the group of several industries gathered under *Other*, the remaining options (in order: textile, ITAD&ITAM, trade association, wind turbine, and automotive) were selected less than 10 times.

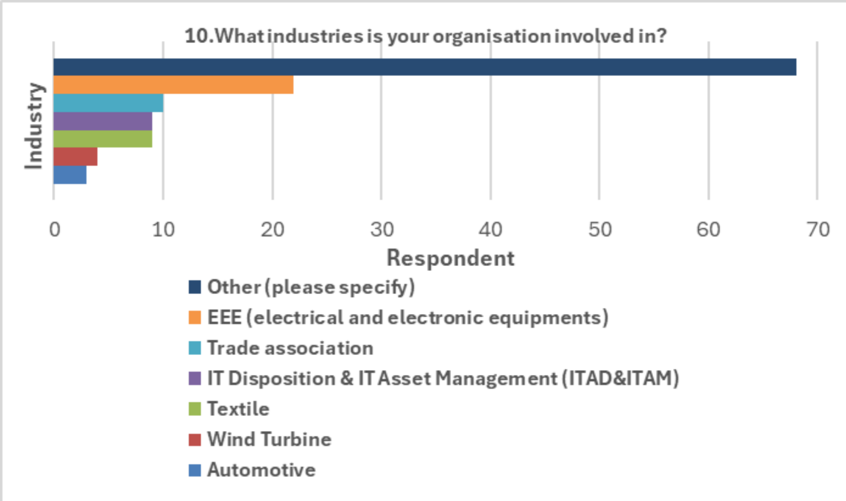


Figure 32: Industries in which organizations are involved

In question 11, asking in which activities respondents' organizations are involved in, options *development* and *manufacturing* were the most selected (Figure 33). Also in this case, the category *Other* was indicated by several respondents, highlighting the heterogeneity of the participants (and including: assessing, certifying, and teaching CE practices; standardization; maintenance of products; retail; audit; education; accounting; development of policies and legislation; and nature conservation).

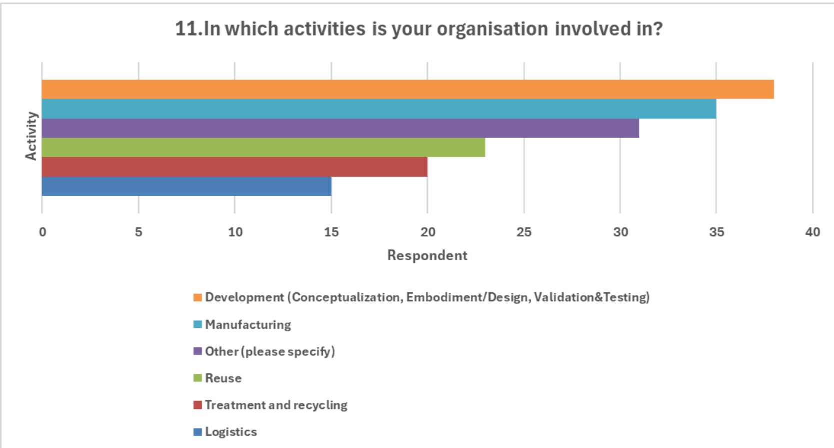


Figure 33: Activities in which organizations are involved

Question 12 aimed at mapping the respondents according to the size of their organization. The survey considered these options: *Large (staff headcount>250; turnover>50m), SME (staff headcount<250; turnover<50m)*, and *Micro (staff headcount<10; turnover<2m)*. Each of the three categories showed percentages around 30%, with *SME* slightly higher (35%). The survey was representative because it encompassed a considerable share of every organization size, even if 5% of 102 participants did not reply to this question. Question 13 investigated the level of granularity of organizations' actions on the territory. *Regional/local, national, and international* were the options, and multi-selection of answers was possible. *International* referred to companies working exclusively with foreign partners, *national* with partners within their own country, and *regional/local* if collaborations were confined to the region in which they are located. *National* and

international categories each received approximately 50 responses, while the regional/local category garnered 24 responses. Despite this, the survey adequately represented all three options.
The following four questions (from 14 to 17) assessed organizations' understanding of the CE, highlighting respectively obstacles (Figure 34), gaps, maturity, and priorities. Specifically, in question 14, the participants were required to identify the barriers they faced in adopting CE principles. The top three challenges mentioned were (i) a scarcity of financial resources, (ii) a shortage of expertise and sector-specific experience, and (iii) a lack of collaboration with other stakeholders. To summarize, businesses encountered financial obstacles to support the deployment of circular strategies, flanked by the absence of benchmarks and prior sector-specific experiences useful to guide the identification and organization of actions. Additionally, there was a notable challenge in effectively communicating the CE concept within companies, which hindered the comprehension of its entrepreneurial impacts.

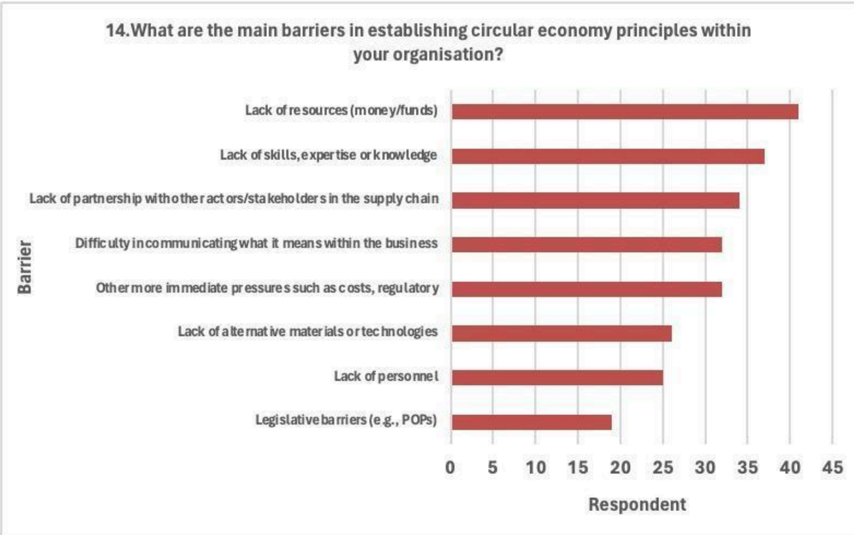


Figure 34: Barriers in adopting CE

In question 15, respondents were asked to select among six options the one which best described their company's level of maturity, from an absence (level 0) up to full adoption (level 6) of CE. Considering that approximately 6% of the participants did not respond, the majority (around 30%) indicated that they have a good understanding of CE and are beginning to adopt related practices. A similar percentage specified that CE is at the core of what they do, whereas 4% only did not know anything about it. These findings are encouraging and significant, underscoring that not only CE is recognized by most of the organizations, but it is also gaining strategic and business relevance.
Approximately 47% of the 102 participants provided answers to question number 16. The 16.67% of them stated that they did not encounter any gap related to their CE expertise, neither initially nor at any point of their transition. On the other hand, the rest of the participants shared the challenges they faced and/or how they addressed them. In particular, it has been highlighted that there was a widespread absence of regulations and standards, which obstructed the adoption of circular practices. Additionally, there was a cultural hurdle, with some potential customers hesitant to commit to long-term circular solutions, and a prevalent lack of expertise in this area. In practical terms, collecting data that would be functional to CE adoption was challenging since it hadn't been a priority in the past. Consequently, obtaining the necessary information for environmental assessments of materials or products took a considerable amount of time. For example, one

company explained its struggle in finding specifications for a suitable equipment to recycle aggregates from buildings and demolition sites. Significant effort was required to develop specialized skills in specific industries (such as construction).

Question 16 was strictly related to question 15, asking, only in case of a good understanding and maturity of CE, further details about gaps in organizations related to CE adoption and the way they have been addressed. Companies from different fields and industries described their strategies to build an expertise in CE. As stated by one participant, it is important to notice that it has been (and, to some extent, it still is) a problem to ensure a wide and equal cross-company knowledge. Technical and legislative competences are centralized on very few people who, as part of the business maturity process, must be available to spread further this knowledge within the organization. Consequently, companies have leveraged on their internal talents, promoting commitment at senior level and employment engagement. Figures such as sustainability managers were at the core of the transition to CE. One respondent explained that prevention and reusing practices have been implemented within the office to educate the personnel and promote a transformation of culture and habits. Overall, internal training and communication have been indicated as common tools to increase the awareness about CE. In case the required profiles were not already present internally in the organization, sustainability experts have been hired to bring their knowledge among people in the company, and consultants have been inquired to receive recommendations. On the other hand, external training has been indicated by the 25% of participants as the most efficient strategy to familiarize and gain knowledge about this topic. Collaborations with partners and clients, networking, synergies, market insights on technologies and best practices, scouting and seeking for fundings were also fundamental to embrace the change. The ISO 14001 standard also contributed to set guidelines, and few companies went through the certification process.

Question 17 inquired about primary goals related to CE adoption, and relevant regulations or guidelines followed by organizations to address it. Figure 35 is provided to illustrate this connection, also reporting few cases as examples. Results highlight that the CE topic might be addressed by many regulations due to the interconnectivity of the different concepts. For example, the *lower footprint* is mentioned in *GHG protocol, Net Zero targets, SBTi, Fit4-55, EMAS, ISO 14064, ISO 14067,* and *EU taxonomy*. Moreover, few respondents cited their experiences as virtuous examples of sustainable and circular behaviors. These include *Company A*, a Danish company known as the first one in its field to feature textiles with up to 10% recycled content, as specified in the related reports, and *Company B*, which played a significant role in developing *Recycling City*, recognized as Europe's most eco-friendly scrapyard. Furthermore, *Organization A*, an employer federation from Cyprus and a technical Bulgarian University (*University A*) mentioned their efforts to contribute to climate neutrality and limit their environmental impacts.

Among the regulations, the *Green Deal* has been mentioned by the 20% of the respondents who linked it mostly to recycling activities. Indeed, several companies were dedicated to achieving the objectives established in this framework (for instance, sectors like WEEE, textiles, and construction). Beyond recycling, a smaller group of participants underscored the significance of reusing as essential priorities in the textile and WEEE realities. Additionally, the *New European Bauhaus* initiative was mentioned as a novel way to merge the *Green Deal* with the development of sustainable living spaces and experiences.

Respondents also mentioned the ISO certification process in 29% of replies, citing standards such as ISO 14001 (for environmental management systems (EMS)), ISO 14064 (for the quantification and reporting of GHG emissions and removals), ISO 14067 (for the quantification and reporting of the carbon footprint of a product (CFP)), ISO 50001 (for establishing, implementing, maintaining and improving an energy management system (EnMS)), and the ISO 59000 series (for guiding on CE approaches and business models). Generally, once addressed these standards, organizations are recognized as capable to guarantee compliance with regulations and to have a sensibility towards sustainability and circularity related topics. The survey highlighted that these aspects are important also for customers, who prefer companies that respect ISO standards. To conclude, the certification process has been appreciated since it aims to foster the development of circular approaches and an efficient management of energy systems while limiting environmental impact, greenhouse gas emissions.

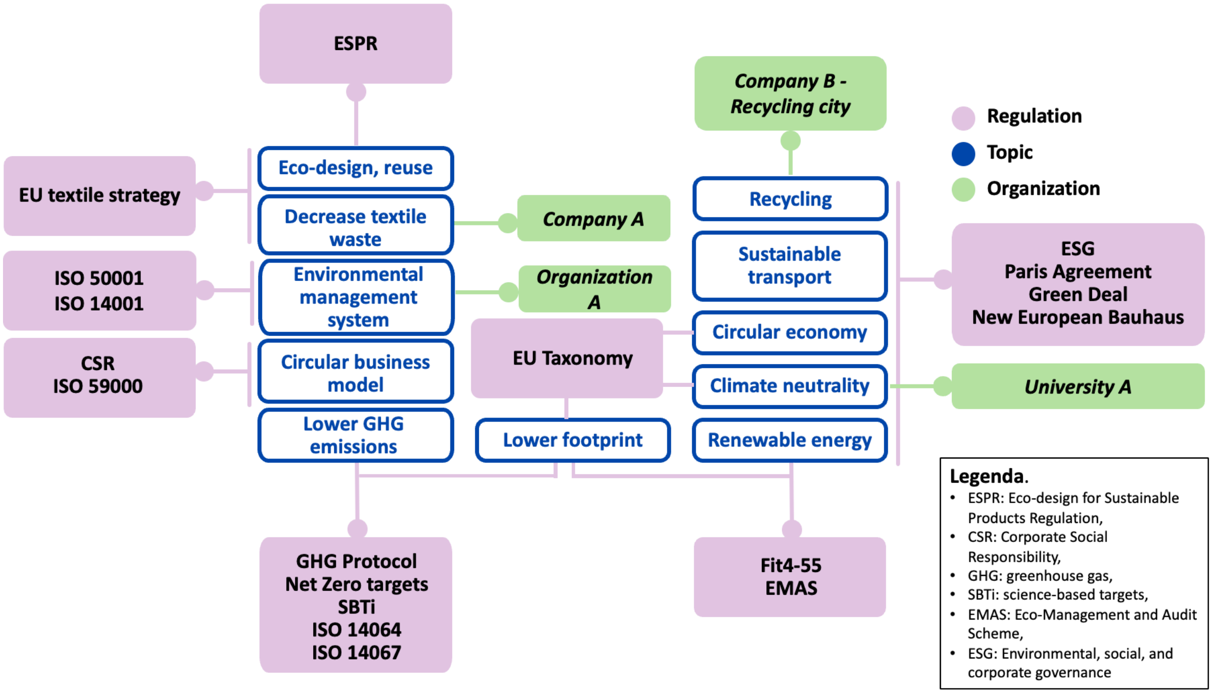


Figure 35: Link among CE topics and regulations

Questions 18 and 19 asked respondents to rank a list of CE-related skills according to their priorities. In question 18, concerning advancing CE in their organization, respondents provided the following priorities for skills development and training:

1. Design of systems, products, and components for durability, reuse, recyclability, and recycled content;
2. Design of circular business models to create added value and incentives including different ways of working with supply chains and customers;
3. Commercial and market awareness to retain profitability and seek funding and investment for change;
4. Procurement and supply chain working to increase closed loop recycling and reuse of components;
5. DTs, information systems and machine learning to manage and use data effectively to manage the performance, use and EoL of products and components;
6. Remanufacturing, refurbishment, and repair of products to extend product life and optimal energy use;

7. Technological advancements to improve design, choice of materials and reuse and recycling of materials;
8. LCA to understand impacts of material choice, production, and EoL management of products and materials/whole life costing/net zero;
9. Communication and consumer engagement: to create a sharing economy for products that are used infrequently, wider acceptance of leased product and second hand or refurbishment, etc.;
10. Legislative barriers and opportunities presented by future legislation (e.g., DPP, ESPR);
11. Retail and logistics for more efficient distribution of products, parts and takeback/reverse logistics.

Results underscore the pivotal role of design in the transition from a linear to CE and explains why companies seek educational opportunities that improve these skills. A transition to CE also needs ad hoc business models and market awareness to create value. Consequently, organizations ranked as second and third these skills, prioritizing education on circular business and marketing.

Related to question 19, respondents ranked the skills needing to be further developed to support CE adoption as follows:

1. Resilience Cross-cutting skills (related to Circular Business Innovation) (e.g., Entrepreneurship, Innovation, Circular Business Modelling, Sustainable Competitiveness, Systems, and Design Thinking);
2. Resilience Soft skills (related to communication and teamwork) (e.g., Leadership, Flexibility, Responsibility, Team building, Problem-defining and solving, Self-awareness);
3. Skills for Technology Innovation in the CE (e.g., development, provision and management of technologies as Blockchain, IoT, Artificial Intelligence, Virtual and Augmented reality, Fourth Industrial revolution);
4. Skills for digital transformation of businesses (e.g., Technology Management and Digital Transformation, Smart PSSs, Digital Economy, Platforms in a digital economy, Data-driven approach (GDPR, IPR);
5. Specialised/technical skills for waste management (e.g., Digital Passports, Packaging, Circular Design, Resource flows (collection, sorting, reuse, recycling, etc), supply chain design, feasibility and sustainability;
6. Specialised/technical skills for Clean Tech and Advanced materials enabling CE (e.g., Composite materials, Zero waste economy, energy efficiency, circular bioeconomy, carbon capture and storage).

From this ranking it is clear that cross-cutting, soft, and digital skills were the most important ones, highlighting the interconnectivity nature of CE. In this context, it is important for companies that every employee involved in CE has a basic knowledge of all the steps of the value chain. This enables an efficient communication with other actors, levering on digital skills to share data and know-how.

Question 20 explored the types of training preferred by respondents (Figure 36). Three options stood out as favourites: *Continuing Professional Development (CPD) provided by an accredited chartered body*, *Academic courses (e.g., Master of Science or master's in business administration modules)*, and *Formal certification*. These options were similar in terms of provision of a certificate or a degree upon completion, which is considered a plus for the attendees. Additionally, *Online tutorials* and *s* came, followed by the option *Other* (*Seminars* and *Business associations* were proposed by respondents). The last choice was *Apprenticeship*. This could be biased by the level of respondent completing the survey or could be due to the fact that apprenticeships could be usually undertaken by parts of the workforce not involved in CE.

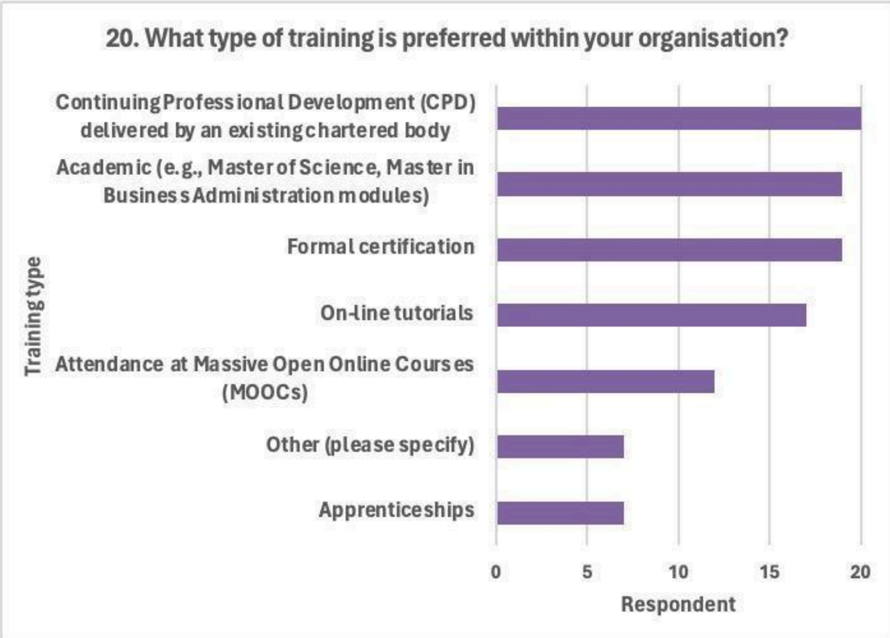


Figure 36: Types of training preferred within organizations.

Questions 21, 22, and 23 dealt with the required new technical skills from a CE perspective. Each question focused on a specific life stage of the whole product lifecycle, respectively beginning, middle and end-of-life (BoL, MoL, and Eol).

For question 21, related to BoL, according to most participants (38%), circular design of products was the most required skill. To achieve this competence, materials choice to minimize resource consumed, and DfX approaches (i.e., disassembly, repair, reuse, and recycling) were the most relevant topics. In this stage, production management systems together with business models should be developed to support the switch to CE. Moreover, LCA has been mentioned as fundamental in circularity assessment and in carbon footprint, environmental, and social impacts evaluation. This method was also important to assess the sustainability of manufacturing processes. Necessary technical skills were related to STEM disciplines (such as engineering), but also interdisciplinary holistic abilities were considered important. Among these, communication, entrepreneurship, and system thinking have been underlined by the attendees. Regarding strategic skills, the following have been specified: good understanding of product life cycle, sensitivity to recognize opportunities for the transition from linear to CE, and stakeholder engagement to share knowledge about it.

For question 22, concerning MoL, understanding of product durability and repairability was fundamental to develop circular strategies. To this aim, planning of regular maintenance and repairing activities allowed to enhance products lifetime. In this regard, the comprehension of the European regulatory framework gave useful guidelines, such as for the implementation of reverse logistic systems. New types of marketing activities and commercial offering were also suggested to improve consumers' and producers' awareness during use. On the other hand, digital skills proved to be at the core of service and products delivering. Indeed, one participant suggested the implementation of a database where manufacturers could upload available components to be sold, and step-by-step manuals for repairing their products.

For question 23, related to EoL, assessing the state of health of goods was the most important skill to implement CE at disposal stage. Specifically, it was fundamental to distinguish between repairable and non-repairable products, and to recognize the actors involved in both circumstances. An efficient separation between these categories made the implementation of reusing strategies easier. To this aim, new competencies in recycling technologies for multi-material and cleaning techniques for post-consumer waste must be developed. It was also mentioned the need of sharing data and labelling materials in a standardized method to facilitate communication among stakeholders. Skills in identifying critical raw materials and valuable chemical substances were also required to value each component of the product. In this context, one participant asked for incentives to build factories for the extensive recovery of materials, and another one suggested the reuse of materials in the same sector from which they come from; for example, aggregates from demolition waste should be utilized in the construction industry. In this context, it was also important to highlight the contribution of consumers that should be facilitated by user-friendly remanufacturing processes. At this purpose, behavioural design was preparatory to understand users and how they can be nudged to dispose products in the correct way.
Question 24 wanted to unveil which are the stakeholders who can play an important role in providing advice about the transition to CE (Figure 37). Most people believed that *customers* (26%), and *consultants* (23%) were the most useful. Indeed, clients could drive the market by purchasing specific products that were more circular, for example by preferring recycled packaging instead of the conventional one. Consultants can provide knowledge and insights about circular strategies that might be implemented.

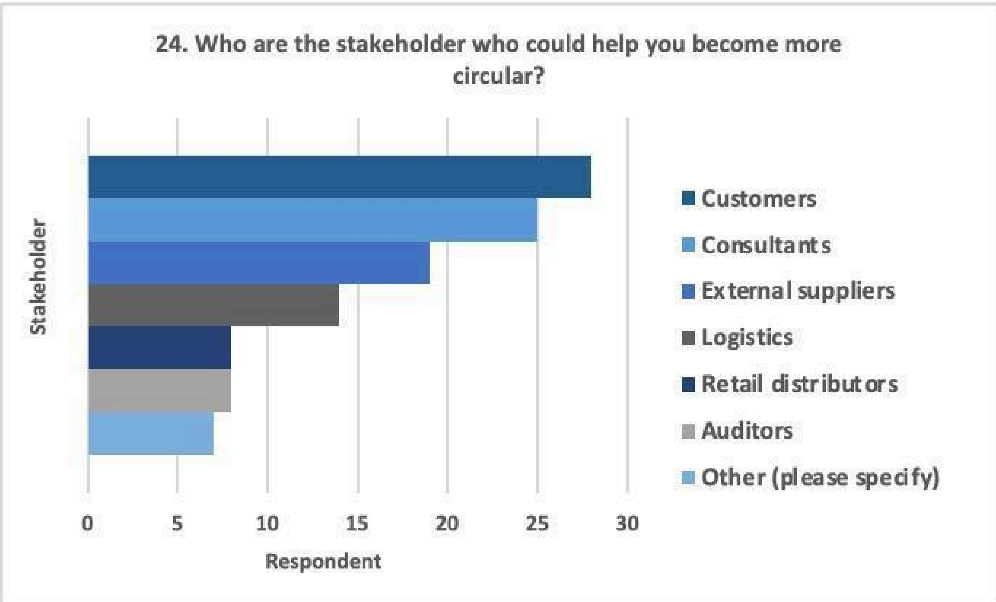


Figure 37: Stakeholders helping to approach CE.

Moving to question 25, the attention moved to the job profiles mostly required to face the economic transition across the value chain (with a 39% of response rate). The majority (90%) believed that there were job profiles required to transit to CE. Personnel knowing how to implement circular business models and to implement sustainable finance have been suggested. Sustainability and circularity managers also were fundamental figures, since they had a holistic view of the supply chain and the chance to interact with several actors. Also technical personnel,

such as engineers and repair workers, were necessary to put into effect circular manufacturing lines by developing refurbishments activities, dealing with second-raw materials, and recycling processes.
Delving into the matter of courses, question 26 asked whether the respondent was aware of training courses available on the market. The majority responded *yes* (61%), and most of them (74%) claimed that these courses were easily available for their companies, as explained in answers to question 27. These outcomes demonstrate that trainings are accessible, but it is difficult to find those addressing specific aspects of the CE, such as for circular design of electronic components or circular business strategies in the textile industry. Question 28 dealt with the available types of courses (Figure 38). *Professional online courses* and *MOOCs* were the most voted categories. This could be due to the fact that they are often recorded, and thus more easily and flexibly accessible. Furthermore, they are readily available online and focus heavily on professional topics, addressing specific and practical subjects. The 68% of respondents confirmed that they took advantage of the training offers on the market (question 29).

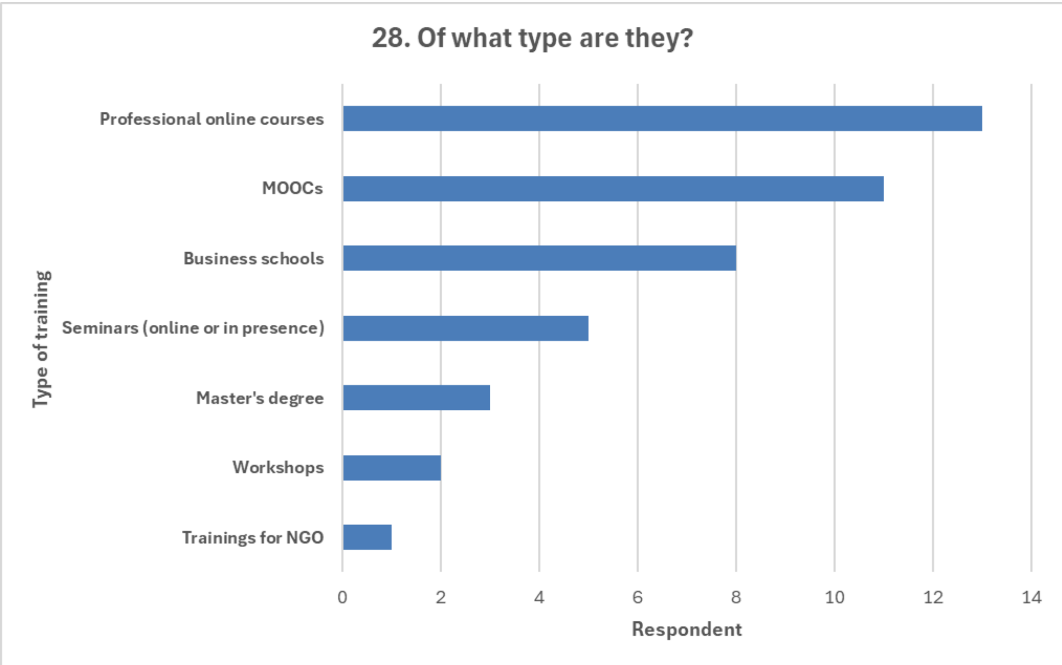


Figure 38: Types of courses.

5.4 Interview

This section reports the results of the interviews by separating the different industries and observing them throughout the 7 areas of the protocol described in sub-section 4.4.

5.4.1 Textile

The first industry analysed is textile, accounting for the creation of 92 million tonnes of textile waste generated every year worldwide (https://earth.org/statistics-about-fast-fashion-waste/). To provide some figures, in Europe, every person uses on average around 26 kg of textiles and the 87% of the discarded textile is incinerated or landfilled (https://www.europarl.europa.eu/topics/en/article/20201208STO93327/the-impact-of-textile-production-and-waste-on-the-environment-infographics) impacting on water, air and land pollution. This misbehaviour needs to be addressed requiring immediate actions especially by companies operating in this sector.

1. Interviewees profiling and company information: The two people interviewed from Companies A and B are responsible for coordinating sustainability and circularity initiatives inside their companies, thus they can be considered experts in this field. Both the related companies related to the interviewees declared to be actively involved in sustainability and circularity activities since many years. To this concern, the expert from Company B considered the commitment towards these topics as embedded in the company's strategy and thus present since its foundation in 2011. Moreover, the interviewee from company B, (i.e., the Sustainability Manager) was recruited in 2017 to boost the circular transition, adding to the social and environmental sustainability area a circular oriented perspective. Company A, has been committed to circularity initiatives, with a focus on recycling opportunities, since its foundation but it entered the industry only 2 years ago. So, the focus on this company is quite recent compared to Company B.

2. Sector peculiarities: both Company A and B expressed their positive opinion concerning the topics selected in the interview protocol in relation to the textile industry when dealing with the circular transition. In particular, they considered as fundamental to start from the re-design of products including the detection of new materials to be used. This redesign should also be thought to facilitate end-of-life treatments, which should meet the needs of consumers by providing them with the right support throughout the product life cycle.
   Starting from the re-design of products and new material opportunities, Company A highlighted that they are currently designing new products by assessing their environmental impacts along their product lifecycle and by introducing an increased amount of secondary materials (such as polyester from post-consumption recycling treatment) to reduce virgin materials exploitation. Nevertheless, the expert ensured that all the materials used are certified and respect the quality standards not to become harmful. Company A declared that it offers support to the consumers through cleaning guidelines to facilitate the product lifecycle extension.
   Company B stated that they developed eco-design criteria towards an internal standard. In addition, in Company B, comparative LCAs to select the best design option and to account the CO_2 emissions generated from every product are carried out. The expert from Company B highlighted that they collaborate in "working groups" to ensure they are aligned with external requests and circular innovation actions. Regarding the material selection, in addition to the adherence with the eco-design criteria, they have developed a strict vendor ratings template to select proper suppliers aligned with their strategy. However, after the supplier selection, they expose materials to strict mechanical and physical quality tests.
   Consumers' support from Company B is under construction. Hence, through social media they try to share as much information as possible. They are still working on the creation of a Digital Product Passport (DPP) to deliver verified and complete information. This is an effort that is propaedeutic to easily embrace the new-coming norms and regulations of DPP that still need to be finalized.

Regarding end-of-life treatments and waste management, two similar approaches were described by the interviewees. Indeed, they both pay attention to the unsold products, however, although none of the two incinerate the clothes, the approaches are different. Company A manages the unsold products through the usage of outlets by selling the clothes at a discounted price, but they ensure not to incinerate or landfill none of the unsold clothes. Company B instead is currently involved in charity initiatives to provide the needed clothes. None of the two companies incentivize the reuse opportunities by creating the right infrastructure. However, Company B in the pre-consumption phase stated that, although the waste is lower than the 20%, the material that cannot be re-inserted as input is given to third entities which enable the reuse. Company A may recycle part of the waste but is still searching for a partner that would reuse the industrial waste almost directly to recover more value.

3. Job profiles needed: Regarding the circular job profiles already presented in the organizations, Company A and B have two different approaches. Company A has a sustainability team which does not consider by now circularity aspects while Company B has a sustainability team dedicated to all the SDGs paying attention on circularity practices.

   Indeed, following its strategy, Company A has stressed the importance of a sustainability analyst to develop a sustainability balance sheet to be aligned to the new legislation etc. Company B has stressed the importance of a culture that pays attention to the whole value chain to be able to acquire and use the right data to create circular systems.

4. Skills and competencies needed: Both soft skills and hard skills were considered fundamental by the two companies. Company B stressed the need to recruit people with EI-related skills (so open-minded people, ready to collaborate with all the different functions inside a company, and able to create the right link among the different departments but also with external entities). Company A highlighted the need to have people able to work in teams and knowledgeable of different languages to streamline potential negotiation with externals. Regarding the hard skills, for Company A digital skills are not so relevant by now while for Company B is essential to have the right skills to elaborate and exploit data by using DTs if required.

5. Training programs developed: To acquire the needed skills both companies rely on training activities although the approach is different. Company A does not propose internal training activities, but they are scouting the market to detect the right courses where to enrol their personnel. According to Company A, in Italy, students do not acquire circularity-related skills during their education programs, and this is even worse if looking at the textile sector so once they are recruited, no matter the age, they need to be trained on these topics. Company B proposes several courses and webinars to the whole personnel using also external support since they perceive as well that people are not yet properly educated and most of the circularity-courses are for marketing issues. Moreover, they try to reinforce not only sustainability-related skills (like GRI standards, GHG computations, LCA, etc.) but also digital skills to make people able to manage data. Indeed, they are training people to have data analysts and not only sustainability experts.

6. External partnerships established and needed: Regarding external partnerships, both Company A and B express their positive opinion, considering them fundamental to creating circular systems. Indeed, Company A has selected a recycler to manage industrial waste, and Company B has established collaborations with Universities, the United Nations, and working groups on microfibers to be always aligned and aware of the recent advancements in the field.

7. Future outlook: Both the involved organizations consider the current commitment of companies and consumers the real driver that today is moving society towards the creation of more sustainable systems. Indeed, according to Company A, governments are not properly supporting this transition since they have not yet created transparent and easy to address and apply rules. Company B also stressed the fact that neither universities nor schools are really helping the next generation to enter the labour market with the required skills. Nevertheless, they both think that technological advancement will be the supporter in the future to ensure this transition in the textile sector. In particular, 3DP, and material treatments are going to be the drivers in the future.

5.4.3 Waste from Electrical and Electronic Equipment (WEEE)

WEEE, also known as e-waste, originates from a variety of products that are increasingly integrated into society's consumption patterns, such as cell phones, computers, TVs, medical equipment, among others (Cucchiella et al., 2015). WEEE is one of the fastest-growing types of waste generated (EC, 2024). In 2019, 53.6 million tons of electronic waste was produced globally, averaging 7.3 kg per capita (Forti et al., 2020). Despite the EU's pioneering initiatives towards a CE in this sector (Bressanelli et al., 2020), specifically in Europe, the average generation of e-waste was significantly higher, exceeding 16 kg per capita (Forti et al., 2020). Improperly managed electronic waste is critical due to the potential for unrecovered value and environmental problems (Cucchiella et al., 2015; European Commission, 2024). This scenario becomes even more complex when considering projections that the global WEEE rate could reach 74.7 million tons by 2030 (Forti et al., 2020). Therefore, this industrial sector needs to adopt a holistic approach to effectively transit towards CE principles (Bressanelli et al., 2020), requiring the presence of trained professionals capable of employing circular strategies to transform the current reality.

1. Interviewee profiling and company information: For Company C, the interviewee was originally brought into the organization to upskill repair and reuse activities, operations for electrical products and professionalize the sector. In recent years, there has been a push by the UK Office for Product Safety & Standards (OPSS) to also ensure that second-hand products are safe and reliable and thus the company is focussed on this requirement. Company H, the other company interviewed, is part of a commercial group which includes waste management, logistics, and cooling and freezing appliances and small WEEE authorised treatment plants. The interviewee from Company H is solely focused on a new business operation within the group for the refurbishment of old and new (warranty returns) appliances. It is specialized in breathing new life into used appliances and

consumer electronics, reducing waste. Its team of skilled technicians refurbishes and repairs these products to the highest quality standards, ensuring that they are as good as new. As a 360-degree solution provider, Company H offers comprehensive services throughout the entire product lifecycle. From collection and assessment to refurbishment and resale. Company C, being established in 1989, has always been involved in CE initiatives, although predating wider use of the name CE, and using other terms to describe their activities. As CE and safety concerns have become more prominent, then additional work has been undertaken to set up professional systems for the sector. Company C is the lead body for reuse charities and social enterprises in the UK. It represents and supports charities and social enterprises (e.g., with input to WEEE legislation and how it impacts on them, and the development of guidance on how to repair and test reused products). They have developed a certification system for reuse for their members and provide information and knowledge to their members on skills, training, and qualifications. As an example, different charities had different approaches to repair and testing historically. Some only had the skills to do Portable Appliance Testing (PAT) which may be suitable for a kettle, but a wider range of tests are needed for more complicated products such as fridges and TVs. Company C has developed the Fit for Reuse Report which aims to drive professionalism in social enterprises.

2. Sector peculiarities: Company C highlighted the importance of reusing components and products in the WEEE sector when dealing with end-of-life products. The interviewee stressed the need to provide warranties for second-hand products to enhance consumer confidence in changing their behaviours. Indeed, their products go through safety and functional tests to ensure they are suitable for reuse and resale. This is strictly related to the need to embrace the waste hierarchy. He also stated that until now there has been too much focus on the end-of-life phase and very little attention to the design phase and in doing that he said that all the stakeholders mut be aligned and work together. Regarding Company H, the interviewee emphasized that the refurbished products are as good as new, but there is a perception that the product won't last as long as new products, but fortunately the consumer mindset is changing due to their experiences with tech. They are getting more used to buying refurbished phones for example. One difference between tech and appliances is that there can be more cosmetic damage to household appliances generally.

3. Job profiles needed: There were some key differences between the two organisations. Company C's response related to a sector dominated by small not for profit organizations with no regional logistics footprint. Whilst Company H has national logistics operations, large scale WEEE recycling but has a new reuse operation with expansion plans. According to Company C, several types of new jobs are needed in the near future like warehousing and logistics, and repair technicians. They need people able to manage the delivery of regional reuse hubs and to respond to large donations and collections from large organizations. This implies that logistics roles are required, and he stated: "*we need to be moving more products around and more quickly*". Indeed, there is the need to have people that easily interface with retailers and producers on returns. Moreover, warehouse space is at a premium for new products, hence, used product taken back needs shifting quickly

(high turnover rate). This will need a professional logistic system which marries up with new products to remove bottlenecks. If retail returns start to outstrip local authority collection as the primary arising of WEEE, then this requires a different logistics system. Moreover, also cleaning and repair services are needed and thus, some new jobs may arise in this field. Last, reuse organizations (charities and social enterprises) need to recruit people able to move to more large-scale operations experience for IT reuse and to start providing new services. For Company H spare parts technicians will be very important in the future; more engineers, and specifically IT specialists who can create efficiencies by managing complex information and data. Company H also underlined that efficiency will be the driver – better ways of handling large amounts of data. There are also a lot of products coming through that will be smart connected, and data security must not be neglected.

4. Skills and competencies needed: More engineering and IT skills are needed in the new future because of the great complexity of the system this sector has to create. Nevertheless, they also need more people with logistics and warehousing skills to help deliver the scale and logistics for Company C. Also, greater skills in sales and promotion of second-hand products are needed to attract more and more consumers. Last, following that, also soft skills are needed, especially promotional skills. Digitalization is crucial for Company H, especially for the waste sector and for the implementation of CE. Also for this company promotion and marketing are essential to build trust of reused and refurbished products in consumers.

5. Training programs developed: Company C has internally promoted different training programs to enhance skills in its membership of reuse organisations, including negotiation, and how to deal with members of the public who are struggling with the cost-of-living crisis. According to the interviewee, there is no need to create a new role with CE-specific skills, but there is a need to enhance each role with adequate CE transversal competencies. To the best of their knowledge, the interviewee was not able to evaluate how the current education system works and how it could be improved to better align the transferred skills with the labour market needs. Company H has internal training programs and specific electrical brand training. The problem Company H faces is that the skills needs are well understood, but finding the right person is not easy. In fact, the recruitment of engineers is a *nightmare* which may be related to a decline in people seeking this profession. Trying to get engagement on training and recruitment with schools and colleges providers is a real struggle, because they don’t want to form a partnership and local authority resources are stretched. To involve young people, Company H focuses on being a technological and data driven company as these types of careers are more attractive to younger professionals.

6. External partnerships established and needed: Collaboration for Company C represents the key element in establishing circular systems. According to the interviewee, partnerships are especially relevant internally to the value chain (both linear and reverse ones) e.g. between retailers, reuse organisations, and producers. For Company H there is a big need for collaboration on training, and knowledge sharing of supply chain information. Another

important collaboration is the one with Housing Associations and charities to make new ways of getting the product out to people who need them.

7. Future outlook: To enhance the circularity of this industry, Company C stressed the need to reinforce the logistics that is still lacking for them. Indeed, the interviewee pointed out recent challenges around legacy Persistent Organic Pollutants (POPs) and Brominated Flame Retardants (BFRs) which mean that some products cannot be recycled or reused. Some products coming back in the waste stream contain substances which have been banned in from use since 2008. Identification of such products can prove challenging and impact on products which can be reused. Therefore, this part of the industry needs support in understanding legislative changes. More generally, more needs to be done to support a change in consumption behaviour. For Company H it will be important in the future to focus on certain issues such as making products easier to repair and pushing takeback/EPR legislation to encourage more product reuse, and also increasing investment in the education of citizens towards reuse.

5.4.3 Automotive

The automotive industry is one of the sectors with low adherence to the CE principles, with recycling being the primary strategy currently implemented (Prochatzki et al., 2023). This sector is gaining increasing prominence due to the expansion of electric cars that contain a wide range of materials that need to be properly recovered to avoid environmental impact (Demartini et al., 2023). However, the scenario for recovering materials from electric cars is still in the development phase with low recycling volumes (Richter, 2022). Therefore, professionals need to develop skills and technologies to establish more circular-oriented production processes and more effective end-of-life solutions for this industry (Demartini et al., 2023).

1. Interviewees profiling and company information: The interviewees of Companies D, E, F, G belong to different departments (i.e., electronic, materials, mechanical, and sustainability) in the four companies, but they are all involved in sustainable-oriented projects from different perspectives.
   Company D has been involved in sustainability-driven projects since many years but concrete efforts have been put especially in the last 2 years. Company E has been following recyclability legislation for more than 20 years regarding mechanical parts. Also, Company F has been involved in sustainability projects for around 20 years with the creation of the Environmental Product Department in 2000. They got certified ISO-14006 in 2017 and they are currently trying to embrace circularity principles in their recent projects (also through EU-funded projects). Company G is currently working to become more sustainable in their product components to be used in the automotive sector.

2. Sector peculiarities: The four companies are addressing sustainability and circularity projects especially driven by legislation and consumers' requests. Company D is working on evaluating the environmental impacts of materials along their lifecycles, performing a lifecycle assessment (LCA), and studying how to make them more durable to extend the car lifecycle from 8 years to 12 or 14 years. Regarding the second objective, they are acting to

provide the proper service to their customers to extend the car lifecycle. In addition to that, they need to address the request of having at least 85% of the vehicle recycled at the end of its lifecycle. To facilitate this process and recover the components and materials in used cars, they have created a CE hub. Company E is following the same approach of Company D. They are committed to perform on their products an LCA. Their product design is no longer based only on the three traditional pillars (cost, quality, and planning) but also the sustainability one has been added recently. Anyhow, they currently don't take care about the customers support being it in the hands of the carmakers. company F revised the product design embedding eco-design practices for all the products focusing not only on reducing the CO_2 emissions but also on reducing the material used. They consider these efforts as part of their DNA. Company G is currently approaching a new product design by embedding circularity principles, anyhow they are still on the testing phase of them and no product has been already sold.

One of the most disruptive changes in this sector is linked to the introduction of electronic vehicles. According to Company D, the most impactful issue is battery production and management. Batteries are made upon several critical raw materials that need to be properly managed and recovered at their end-of-lifecycle but limited commitment has been seen by now. Therefore, they consider circularity principles even more important in this field than in another to find valuable strategies aiming at reducing the dependency to other countries owing the sources of these critical raw materials. The same thoughts about critical raw materials management and reuse were shared by Company F and Company G. In addition to that, Company F also expressed some fears about the increasing disassembling costs due to the manual activities required. Company E doesn't see big issues due to this introduction except for battery management along the product lifecycle and because of this, they have introduced a new department dedicated to study a technology able to manage the batteries at the end of their lifecycle. In addition, to be aligned with the regulations, they are also investing in providing the right solution for the battery removal (mandatory by 2027) to facilitate the recyclability of batteries' components.

3. Job profiles needed: Regarding the new job profiles, Company D highlighted the fact that in their organization are emerging several sustainable related profiles mainly because their suppliers are pushing them to collect and analyse several data about emissions etc. Moreover, they consider crucial to acquire the right profiles to develop a sustainability report entirely internally and this means to have people able to identify which data are needed for that, where to collect data and how to analyse them to positively contribute to the generation of the report. Company E, through the introduction of a new branch fully dedicated to sustainability, considered important to have profiles able to design and apply new business models based on circularity principles. Regarding Company F, new job profiles need to be able to manage the new dismantling plant just developed and to manage critical raw materials. Last, Company G stated that no new profiles are needed in reality but technical profiles with technical skills need to be enlarged by CE ones.

4. Skills and competencies needed: In this context, the four companies were aligned in stating that digital skills are needed together with soft skills. Company E was particularly convinced

about the need to use data and thus to be able to collect, analyse, and use big data. Company D, instead, stressed the need to be able to share values externally to make people aware of the value they are offering. Furthermore, flexibility, open mindset, and interdisciplinarity are needed according to all the companies. Both Companies E and F highlighted the need to enhance digital skills to facilitate the disassembling phase.

5. Training programs developed: Regarding training programs, the four companies rely either on internal experts or external ones to share the needed knowledge with all the managers and operators according to their needs. Indeed, Company D uses internal experts to run training programs tailored on their needs because when they purchase courses externally, they perceive them as too generic. Most of the courses internally deployed are technical and usually based on chemical skills advancements. Also Company F perceives this issue. Indeed, Company F offers internal training programs needed to be adherent to the new regulations and thus, in addition to courses, they are also recruiting materials specialists. Actually, due to the complexity of the industry and the lack of specific courses, they usually develop internal courses rather than exploiting external ones. Company E is starting now to invest in CE courses but they perceived that the first commitment should start from the middle management that has not yet ready. A change in mindset is needed more than specific skills, once this has been achieved, both digital and circular skills can be learnt to insert eco-design practices and monitor sustainability performances to be aligned with customers' requests. Company G rely on both internal and external courses trying to stimulate technical people to open their minds and their projects towards sustainability.

6. External partnerships established and needed: All the companies agreed that collaboration remains the priority in circular systems. Thus, without it, no circular flows can be established. Collaboration, according to Company D, enables to anticipate customers future needs. Associations, research centres, universities, suppliers, and customers could be the first to be involved according to Company D, F and G. Company F also states that start-up engagement could be extremely valuable as well.

7. Future outlook: In the future, all the interviewees expect that more valuable support could be given by governments by providing new norms and regulations, but aligned with producers' needs to enable the accomplishment of these rules. Also, Company F and G expect to be driven by adequate rules proposed by governments to properly drive investments. In accordance with this, Company E states that at least an internal alignment in Europe based on standards is needed and these cannot be changed too fast to give the time to update internal processes to all the companies. In this context, the introduction of Digital Product Passport starts to become essential to make aligned all the actors along the value chain.

5.5 Gap analysis

The development of the twofold gap analysis framework for HE and VET levels, involves all the results coming from the previous researches. If skills are present or not in the list of those

addressed by course analysed in the market analysis, they have been kept on the framework respectively in green (needed skill) or red (already covered skill).
The frameworks are presented in sub-section 5.5 of this deliverable and represents a visual starting point able to provide useful recommendations about which skills the CE education should focus on.
Looking at the framework related to HE level presented in Figure 39, it is visually evident that extant courses on the market focus on *resilience cross-cutting skills* and *specialized/technical skills*. In these dimensions, from an empirical perspective, few more specific skills are required to be added (i.e., *Environmental and social awareness* and *Reverse logistics and operational management skills*). This is confirmed also from a theoretical point of view, where, among the 5 most cited skills in the literature, the two Resilience cross-cutting skills *Business management and Strategy skill* and *Customer and user-focused understanding* flank the *Maintenance and equipment selection skills* from the Specialized/technical ones.
It is also interesting to evaluate the gaps of the market compared to the theoretical less cited skills. For the Resilience cross-cutting skills, *Management*, *Coordination* skills are lacking, resulting in lack in *Environmental and social awareness, Design and implementation of Training Programs* but *also Writing and research capability.* Concerning the specialized/technical skills, *Resource utilization skills*, and *Master quality and safety* are lacking, also flanked by the *Reverse utilization skills* (also raised by practitioners.
Looking at the left side of Figure 39, digital technologies skills and resilience soft skills are less addressed by the courses already proposed on the market. This open rooms towards the detection of more skills to be empowered through the CERES curricula to support the adoption of CE. It turns out that from an empirical perspective are needed, among Resilience soft skills, *Collaboration and network connection*, *Negotiation*, *Effective communication,* and *Flexibility*, while among Digital technological skills, Data management and analytical skills, *Master virtual, augmented and mixed (VAM) realities*, and also *Robotics and automation*. From a theoretical perspective, several are the Resilience soft skills needed: *Effective communication, Problem defining and solving, Teamwork, Lifelong learning commitment, Critical thinking.* Instead, the Digital technologies skills suggested by academics are: *Data management and analytical skills, Programming skills, Design digital services and product-service systems (PSS).*
Finally, concerning the skills less cited in academic papers, there are also resilience soft skill to be further explored: *Commitment and interest, Negotiation, Decision making and assertiveness, Creativity, Flexibility, Decision making and assertiveness*.

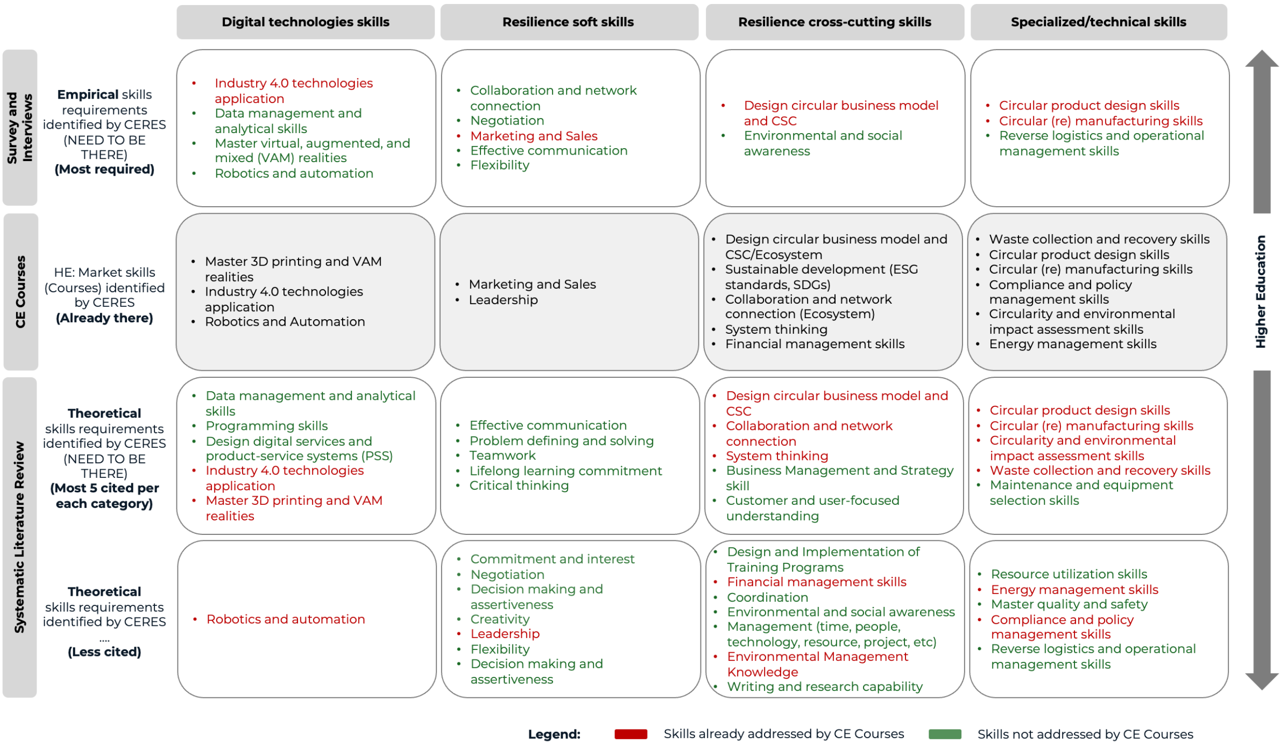


Figure 39. Gap analysis for HE level

Looking at the framework related to VET level presented in Figure 40, also in this case it is visually evident that extant courses on the market focus more on *resilience cross-cutting skills* and *specialized/technical skills*. In these dimensions, from an empirical perspective, the same specific skills required at HE level are required to be added (i.e., *Reverse logistics and operational management skills* and *Environmental and social awareness*). This is confirmed also from a theoretical point of view, where, the main differences with the HE level stand in Resilience cross-cutting skills, in the not need of the *Business Management and Strategy skills* and in the need of *Collaboration and Network connection*. Instead, at level of Specialized/Technical skills, the skills needed are the same of the HE level: only a small change is detected among the less cited skills in literature, where *Energy management skills* are to be added to those to be explored in new curricula.

Concerning Digital technology skills, *Data management and analytical skills* are not needed at VET level compared to HE, but raising the need to develop courses for Master 3D printing and VAM realities (among the 5 most cited in literature) and *Robotics and automation* (among the less cited).

Finally, among Resilience soft skills, several are also in this case the skills needed to be coped with new curricula. In this case, empirical results suggest also *Marketing and sales* but also Decision making and assertiveness (among the less cited in theory).

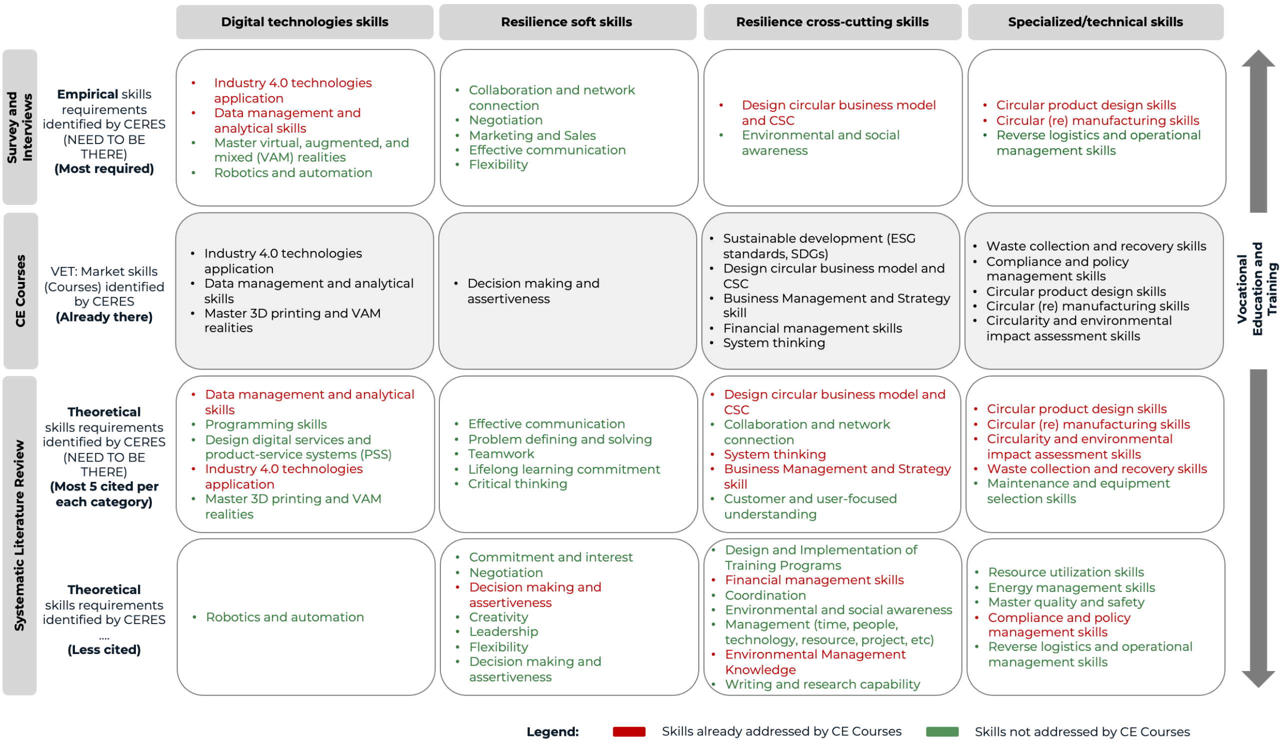


Figure 40. Gap analysis for VET level

6 Discussion

This section is aimed at discussing the results coming from the activities performed in CERES WP1 (i.e., the SLR in the CE skills and competence research domain, the market analysis of the available courses on the market for HE and VET levels, the online survey and the interviews to investigate the actual needs of companies in terms of skills and job profiles to effectively implement CE practices in their processes). In this way, existing gaps between market needs and the available educational offer are discussed. In addition, the most useful training courses are proposed and their potential impacts on the job market are evaluated. These courses should provide accessible insights to feed HE/VET/Market actors' competence development and promote the field of CE education, providing key facts and insights as well as recommendations for the development of CE education in organizations.
Finally, a comparison with the results coming from D2.1 is provided in sub-section 6.7.

6.1 Literature review

The systematic analysis performed was aimed to identify the main skills and market needs in terms of professional qualifications for the transition towards CE. Its results revealed that future professionals need to develop skills that are not only technical but also multi-systemic, encompassing interpersonal skills and those associated with digital transformation. In other words, CE encompasses a multifaceted labour market with individuals requiring continuous educational development. The findings also demonstrate that a highly qualified workforce is crucial to meeting the current challenges posed by the green and digital transition (i.e., the twin transition). Lack of skills may evolve into barriers hindering a successful transition (Dwivedi et al., 2022; Justy et al., 2023; Trevisan et al., 2023). Given this context, it will be necessary to establish active teaching and learning approaches that promote multi-disciplinarity and encourage the development of critical and systemic thinking.
In terms of theoretical implications, building on previous research (e.g., Burger et al., 2019; Akyazi et al., 2022; Pinzone and Taisch, 2023), this study offers several contributions to current scholarship. Indeed, it detected and systematized 40 skills required in the twin transition era, divided in three main dimensions.

First, a resilience skillset is provided. It concerns all skills to restructure current socio-technical regimes towards more resilient production systems, such as designing new circular business models and creating collaboration networks. Coherent with Giannoccaro et al. (2021) and Walker et al. (2023), this study demonstrates a massive demand for labour that knows about establishing CSCs and developing new businesses with environmental and social value propositions. Moreover, the literature review shows that there is a great emphasis on maximizing effective communication skills using not only verbal but also visual resources (Akyazi et al., 2023; Watkins et al., 2021). Indeed, quality communication reduces the rigidity of organizational structures and increases the integration of company departments (Trevisan et al., 2023), influencing the innovation activities of circular solutions (Watkins et al., 2021). Therefore, the resilience skills discussed in this study provide theoretical foundations for adapting industrial systems to constant technological, economic, and environmental changes.

This research also contributes to the ongoing debate on essential skills for implementing circular strategies in the I4.0 (Akyazi et al., 2022; Luo and Qiao, 2023). The study systematized a series of skills associated with business digitalization processes aimed at circularity. Among the skills presented, the application of DTs such as the Internet of Things, Cloud, Artificial Intelligence and Big Data are frequently highlighted by scholars. According to previous literature (e.g., Akyazi et al., 2023; Ghobakhloo et al., 2023), it is necessary to train professionals who can include these new technologies in different organizational activities and processes. On the other hand, the literature has not yet explored in depth the skills for automation and robotic development. For example, although Straub et al. (2023) identified four different digital skills (application design, data analytics, IT excellence, graphic design, and multimedia), the study focused on business models and consequently did not explore essential skills in the manufacturing sector. In this context, the automation and robotic development includes not only creating and operationalizing robots (Luo and Qiao, 2023), but also establishing mechanisms for effective human-machine collaboration (Akyazi et al., 2022). Therefore, this research goes beyond the previous literature showing that skills in DTs category are intrinsically linked to resilience skills, as they enable the exploration of the benefits of digital transformation to create new value-delivery approaches and to support automation, collaboration, and decision-making processes. By expanding theoretical knowledge about the demands for I4.0, it is possible to establish more effective practical guidelines to fill the gap in the labour market and increase the resilience of production systems.

The findings also contribute to enriching the theoretical baseline on the most critical specialized/technical skills for a circular economic model in the manufacturing industry. As evidenced by the literature (Leal et al., 2020; Reichmanis and Sabahi, 2017; Sassanelli et al., 2020), scholars emphasize that circular product design ability is fundamental to including CE principles at all life cycle stages. In particular, this study reinforces the need to integrate eco-design strategies with engineering knowledge. Such strategies encompass a variety of expertise, such as circular design for longevity, design using recyclable and waste materials, design for remanufacturing and multiple-use cycles (Avadanei et al., 2021; De los Rios and Charnley, 2017; Rizzo et al., 2017). This work advances the body of knowledge, showing that in addition to knowing how to idealize and design more circular products, it is also essential to pay fair attention to techniques for assessing environmental impacts and monitoring circular indicators. In accordance with prior research (Giannoccaro et al., 2021; Walker et al., 2023), professionals should have the skills to understand which tools and methods are best applicable according to the nuances of each business solution. In this context, the research emphasizes the importance of integrating specialized/technical skills with technological innovation and digital transformation. Previous studies (Kristoffersen et al., 2020; Liu et al., 2022; Sassanelli et al., 2021) have already highlighted the potential of DTs in various phases of the product life cycle, as well as in optimizing multiple processes. Therefore, specialized/technical skills should be cultivated to meet the demands of the digital era.

In terms of practical contributions, this study, assessing skills for CE, provides valuable insights for practitioners (both industrial managers/designers and educational instructors).

From an industrial point of view, managers and designers can better understand the skills and training needed to upskill professionals in the manufacturing sector. Considering that competent employees are more likely to develop innovative solutions (Behl et al., 2024), the set of skills mapped in this work can direct the search for new ways of training human intellectual capital. Also,

knowing the critical skills allows managers to have greater clarity about which aspects need to be fostered within the organizational team, developing strategies to recruit and train new talent. The study shows that organizational structures require training program implementation skills. Therefore, this work also contributes to the development of internal technical training plans and the development of interpersonal skills.
For CE educational instructors, this study provides crucial guidance for establishing educational courses and programs perfectly aligned with market demands. This allows students to be more prepared to deal with the challenges of I4.0 and circular transition. Given that the twin transition reflects a constant evolution of production systems, educators can adjust their teaching approaches and adapt to changes to provide high-quality education, bridging theoretical knowledge and practical applications.

Finally, this study also has policy implications. First, standardization of skills needed for CE and digital transition can be triggered by this work. Governments can create mechanisms to promote different skills, such as complementary professional training programs and establishing collaboration networks among the public, industry sector and society. Policymakers can act positively through initiatives that encourage teaching skills from basic educational formation. According to Torreggiani et al. (2021) skills such as communication and creativity are not necessarily inherent to the individual. Therefore, strategies, even in primary education, can support developing soft skills that reduce the gap between technical and interpersonal skills required by the job market. Additionally, through the skill set provided in this study, governments can create opportunities through programs, projects, and technical courses for the digital inclusion of individuals while fostering programming, automation, and robotics development skills. Such initiatives can support the inclusion of future workers rather than their replacement as technological innovations progress.

This study also contributes to previous work that has continually called for more research on skills and educational approaches for CE (e.g., Isaksson et al., 2018; Sumter et al., 2021; Akyazi et al., 2023). The findings reveal that different methodological and teaching approaches can be used to offer sustainability-oriented professional training. The choice of these methods should be guided by the type of skill intended to be developed, as certain approaches may be more suitable for learning specific domains. For example, methods such as prototyping and experimentation are more adapted to support the development of skills in DTs such as 3DP (Despeisse et al., 2017). On the other hand, data indicates that methods such as lectures/tutorials/guest lectures are not recommended for promoting DT skills. According to Martin et al. (2014), the learning resulting from this method is passive and disconnected from actual experiences. In expository classes, students generally obtain broader and simpler knowledge of a given topic, going opposite to what is expected of skills for DTs that require practical application and specific contextualization of a real scenario. Furthermore, the literature on CE has not yet highlighted the method of e-learning and self-learning for acquiring DT skills for sustainable purposes. This finding may indicate the lack of scientific studies that shed light on this topic and may also represent a scarcity of currently available materials on DT-CE that make students seek self-learning and training through digital platforms. In general, the results of this study show that methods such as project-based learning and problem-based learning are adopted by all skill categories, supporting resilience, DTs, and specialized/technical skills. Such methods allow knowledge to be acquired based on contexts that reflect reality (Martin et al., 2014; Mills and Treagust, 2003), focusing on solving real problems and developing projects.

Finally, the developed research agenda reflects the need for more in-depth studies that consider the recent transformations through which productive systems are undergoing. Several research questions were proposed that can be used to guide new studies (see Table 9). The rapid evolution, both in terms of introducing new DTs and implementing greener and more sustainable strategies, leads to a profound modification in the demands for new professionals. Despite scholars acknowledging that new skills are necessary in the context of digital and circular transformation (Beducci et al., 2024; Ghobakhloo et al., 2023), research avenue 1 emphasizes that more studies still need to be conducted in terms of skills, particularly in seeking to understand the best teaching and learning approaches to reskill and upskill workers.

Furthermore, this study, assessing teaching skills and methods for CE, constitutes a valuable contribution for practitioners (both industrial managers/designers and educational instructors). From an industrial point of view, managers and designers can better understand the skills and training needed to upskill professionals in the manufacturing sector. The set of skills mapped in this work can direct the search for new ways of training human intellectual capital. Also, knowing the critical skills allows managers to have greater clarity about which aspects need to be fostered within the organizational team, developing strategies to recruit and train new talent. The study shows that organizational structures require training program implementation skills. Therefore, this work also contributes to the development of internal technical training plans and the development of interpersonal skills. For CE educational instructors, this study provides crucial guidance for establishing educational courses and programs perfectly aligned with market demands. This allows students to be more prepared to deal with the challenges of I4.0 and circular transition. Given that the twin transition reflects a constant evolution of production systems, educators can adjust their teaching approaches and adapt to changes to provide high-quality education, bridging theoretical knowledge and practical applications.
Studies considering the Eurocentric teaching perspective (Giannoccaro et al., 2021; Watkins et al., 2021) were proposed and contributed significantly to advancing the literature. However, as noted in research avenue 2, understanding how education programs can be adapted across countries with different economies, based on the nuances of each region, remains a promising area of investigation. Regarding research avenue 3, scholars indicate that technologies such as simulation can significantly support operator training to foster the CE and I4.0 (Sassanelli et al., 2021), but further research considers the impact of other DTs (e.g. AI, IoT, Blockchain) and the human-machine relationship should be conducted. While prior studies indicate that CE demands a holistic, multidisciplinary approach (Giannoccaro et al., 2021; Mayer, 2020), research avenues 4 and 5 highlight that new efforts to develop tools, train people, and integrate hard and soft skills across disciplines should be elaborated.

To date, the extending literature proposed models and tools to assess maturity levels and circular practices (Acerbi et al., 2024; Sacco et al., 2021). Nevertheless, these endeavours direct the focus to the organizational level, and as pointed out in Research Avenue 6, new studies understanding proficiency levels from a human perspective need to be developed. Therefore, academic studies should be aligned with these contemporary issues not to fail to provide theoretical and practical guidance.

6.2 Market Analysis

The market analysis provides valuable insights into the current opportunities for individuals and organizations at both HE and VET levels. Below, some considerations in terms of courses available on the market to enhance circular-oriented skills, are highlighted and discussed.
The first consideration regards the difference among the courses at VET and HE level in terms of type of topics and degree of depth (or level of granularity).
For what concerns the projects and courses at VET level, in general the teaching approach is much more based on theoretical aspects rather than practical ones. This is not consistent with the type of audience addressed. Indeed, the majority of these courses have been developed through projects funded by the EC with the aim of creating training courses for the CE transition, many of which are still ongoing. This insight unveils that some teaching providers are starting to implement a transition towards an educational offer that integrates CE and sustainability themes, but still at a mostly experimental level.
Moreover, by analysing the topics addressed by the courses belonging to the VET sample, specific related gaps have been identified. Specifically, in the "*CE transition*" macro-category, the courses are mainly focused on providing knowledge about basic principles of CE, circular business models, and circular design, but only few of them offer teachings that provide students with the basics of financial aspects, fundamental metrics useful in measuring environmental/economic/social impacts, LCA, and identification and monitoring KPIs necessary to achieve the optimization of process flows. These elements are essential in implementing circular models. On the contrary, the courses in the "*sustainability transition*" and "*twin transition*" macro-categories deepen these topics and provide practical examples of their implementation to improve the learning process.

Except for the "*twin transition*" macro-category, another gap is the lack of teaching modules that delve into those advanced technologies and tools which are already present on the market and could be potentially implemented by manufacturing companies to facilitate the circular and sustainable transition. This could be linked also to the type of macro-categories considered that have a limited attention over digital technicalities.
Only a few courses in the "*CE transition*" macro-category deal with relevant practices and aspects useful for making the shift towards CSCs, and these topics are not addressed in the educational programs in the other macro-categories.
Moreover, entrepreneurial skills are developed mainly by those courses belonging to the "*sustainability transition*" macro-category and very few in the "*CE transition*" one.

Looking at those courses addressed at HE level, the majority of them have been clustered inside the "*CE transition*" macro-category. This result, in fact, was expected considering the initial queries used (i.e., "course circular economy" and "master degree course Circular Economy'') and the objective of this market research, which focused on deepening the educational offering linked to the CE.
At HE level, many topics - such as circular business models - are considered as prerequisites that students should learn during the introduction of teaching modules, while other arguments, like

policies and EU regulations, are considered as an important section that needs to be explored in depth in dedicated modules. However, after a careful analysis of the courses' learning objectives and teaching modules, it was possible to understand that the majority of them deal with many aspects relating to the topic of the CE but in a fairly generic way, and only a few courses address the topics at an advanced level. Another consideration that emerged from the analysis concerns the fact that some courses classified into the "*CE transition*" also involve the introduction to advanced technologies enabling the CE (such as blockchains and digital platforms). Such technologies can facilitate the implementation of circular production processes, therefore it will be necessary to combine both themes (i.e., CE and DTs) to develop new teaching courses that can prepare students for the new future market needs, which will see advanced technologies as key pillars.

Comparing the educational programs among HE and VET levels, it emerged that HE courses tend to address the topics linked to CE without focusing on a specific industry, unlike VET courses which, in general, explain the main concepts and then go into detail by industry (e.g., agri-food, construction, fashion).

Furthermore, more frequently than VET courses, HE educational programs provide many theoretical concepts and, in many cases, they deepen the themes of monitoring and assessing relevant KPIs, also offering a broad overview of the main technologies that can support the circular transition. However, they lack practical teaching, thus making it difficult to put the theoretical concepts learned into practice.

A gap of concern, common to both HE and VET levels, regards how to handle the problem of greenwashing. Indeed, there are many EU policies and regulations which oblige companies to achieve objectives in line with CE and sustainability. Nevertheless, having to comply with these rules can often lead companies to adopt opportunistic behavior, as many of them tend to embrace practices that apparently respect the environment or social values, but in reality it is only for facade. Therefore, there is the need to create awareness of this issue in order to make companies aware of the significance of their actions' effects, and impel them to actually take the CE and sustainability transitions.

Another aspect that can be understood thanks to the descriptive analysis concerns the accessibility of these courses: the majority of HE are paid and the required cost is on average greater than €1,800, thus representing a limit of accessibility (not all people can afford them); on the other hand, VET courses are almost all available for free. Moreover, many courses (both at HE and VET levels) are only provided in English, which could still be a barrier for some groups of individuals (depending on their age) even if it is the most spoken language in the world and primarily known by the younger generations (such as Gen Z).

This market analysis contributes to both theory and practice, also providing a set of managerial and policy implications.

From a theoretical perspective, it provides a systematization of a broad sample of courses at HE and VET levels, clustering them into 3 main macro-categories (i.e., "CE transition", "sustainability transition", "twin transition"), and also detailed into relevant topics and sub-topics addressed by their teaching modules. This systematization can be useful to all the researchers engaged in the field of CE and sustainability, helping them to understand what the current market offer is, and which are the main trends and gaps.

At the same time, this research contributes to practice, impacting both course providers and practitioners (e.g., companies' employees). Indeed, providers (such as universities) can consider the results of this research for understanding how to position their educational offer in the market and how to improve it according to the market needs. On the other hand, practitioners (such as companies) can refer to the main topics and detect which are the most interesting areas useful to improve their transition towards CE, for instance.
The market analysis also has managerial implications, since companies' managers can take as a reference the systematization into macro-categories of the courses detected and analyzed to improve the decisions about which topics (and related courses) should be chosen for reskilling/upskilling companies' employees, in line with the circular transition.
Finally, the results provided by this analysis can also have policy implications. Indeed, even if concern towards educational programs in the CE field is increasing, this market research raises a relevant gap (i.e., the quite general and theoretical approach used to explain the CE topic, neglecting specific and detailed applications). Therefore, policy makers can use these results as a starting point for developing and formulating new educational funding programs able to fill this gap and help practitioners to acquire more practical-oriented skills and to put into practice what has been learned theoretically.

6.3 Survey

The purpose of conducting the survey was to identify the industrial and practical needs associated with the required professional roles, necessary to address the transition towards a CE model as well as training needs and preferred training forms. Even though only about 35% stated that they come from industrial and consultancy sector, and 49% come from *Other* sectors (presumably including services), about 73% have worked with CE, out of which 50% between 1-4 years, and 35% more than 4 years. This indicates that the respondents are knowledgeable about the CE transformation in their own context. Also the years of engagement with CE are in line with general evaluations (The Ellen MacArthur Foundation, 2020) that the pandemic has made the CE more relevant than ever and that it can create greater resilience to shocks in industry and society (ibid).

Looking at the barriers to CE implementation stated by the respondents, lack of resources (money/funds) is the most frequently stated one. Even though this is not the most frequent barrier identified in the literature (Govindan and Hasanagic, 2018), the economic barriers have been well identified and recognized as critical ones, embracing high-up front investment costs, long pay-back periods, cheap virgin material, etc. (Kirchherr et al., 2017a; Taddei et al., 2024). The second most frequently stated barrier was lack of skills, expertise or knowledge which can also be connected to the fourth barrier related to the difficulty in communicating what CE means to the business. Shortage of wider education in the organizations might prevent internal communication in the companies as there is lack of shared understanding of the concepts, possibilities for solutions and implementation, and of definition of performance metrics and their monitoring. This is in line with the literature that identifies lack of skills and know-how in CE product design (leveraging of Design for X approaches (Sassanelli et al., 2020)), lack of technical skills, both internally in the focus organization, but also on the supplier and customer side (Govindan and Hasanagic, 2018). This might explain the third barrier identified in this survey which relates to lack of partnership with other actors in the supply chain (Taddei et al., 2024).

This analysis contributes to both knowledge and practice, also providing managerial and policy implications. From a theoretical perspective, the survey contributed to unveil which are the skills, job profiles, and types of education more needed to foster education in the CE research domain. Practical gaps and barriers hampering an easy transition have been also collected, together with priorities and regulations adopted by organization to climb their CE maturity levels, unveiling key areas of improvement and of further research in the domain of CE education. From a practical point of view, the results obtained through the survey enabled to clarify the state of practice about the current needs of companies in pursuing a transition towards circularity especially in the field of new skills needed. This can be supportive both for educational institutions in helping them to develop more effective courses and training sessions and *curricula* and for companies willing to approach CE in understanding what could be the key topics to be addressed to upskill and reskill their managers and operators.
Also, policy makers could take advantage from the results of this research. Leveraging on the needs detected they could propose new education- and training-related actions (on the same stream of the CERES project) able to ease the twin transition of manufacturing and of society.

6.4 Interviews

The results obtained throughout the interviews are below discussed highlighting the peculiarities that emerged from each industry and comparing the various needs across the three industries (i.e., WEEEs, automotive, textile). In support of the following discussion, the results obtained have been summarized in Table 12.

Table 12. Summary of the results obtained from the interviews.

	Textile	WEEE	Automotive
Sector peculiarities:	• Product redesign with secondary materials or based on the results of preliminary analyses (e.g., LCA) or internal criteria. • Consumer support through social media or guidelines. Creation of the DPP. • Vendor ratings template. • Recovery of the unsold through secondary markets or charity initiatives. • No incentives for reuse. Management through external companies of pre-consumer waste.	• Need to give warranties to encourage customers to buy second-hand devices. • Need to focus on the design phase, after having paid great attention to the end-of-life management.	• Product redesign also according to sustainability principles and assessment of environmental impacts through LCA. • Support to customers through services. • Need to develop strategies and procedures for battery management. • Need to develop circular strategies for managing the valuable materials recoverable from batteries, so as not to depend on external markets. • Concerns about disassembly costs. • Need to formulate procedures for battery removal.
Job profiles needed	• Sustainability teams partially involved in the circular transition. • Need for managers to comply with regulations. • Need for a culture that can manage the right data.	• Need for technicians to manage the devices quickly and effectively. • Need for experts in the logistics sector to manage the flows of information and materials of a complex system that is being created. • Need for personnel for reuse organizations.	• Sustainability-related figures able to collect and interpretate the right data. • People able to compile an entire sustainability report. • People able to design and implement circular business models. • People able to manage dismantling plants. • People already employed within the firm, but with enhanced circular skills.
Skills and competencies needed	• Both hard and soft skills (e.g., be open-minded, able to work in a team) are relevant. • Discordant opinions on the relevance of digital skills.	• Engineering and IT skills. • Logistics skills. • Sales and promotion hard and soft skills.	• Digital skills (e.g., big data analytics). • Soft skills (e.g., be open-minded and able to work in a team). • Skills related to value communication.
Training programs developed	• Training program on circular and digital skills mainly from external sources. • Gap between the skills required for the circular transition and those provided in common educational pathways (e.g., degree).	• Internal training program. • No need for a dedicated figure for CE but need to train all figures with cross-functional skills on CE.	• Internal courses due to the sector's very specific requirements. • External courses on more general aspects.

External partnerships established and needed	● Active collaborations with industrial, academic and institutional partners.	● Crucial role of collaborations, especially within the value chain.	● Crucial role of collaborations with both public and private partners, as well as start-up.
Future outlook	● Need for policymakers, to provide clear rules and regulations. ● Need, for universities and educational institutions, to train the new generation with the required skills. ● Technologies such as 3DP and material treatments will be crucial to ensure the circular transition.	● Development of a logistics network suitable for managing a complex system. ● Development of rules and regulations to support the sector.	● Need for policy and regulations which support the circular transition within the sector by giving to the firms the time to adapt their internal processes to the new prescription. ● Need for DPP. ● Need for EU standards.

Starting with the textile industry, it emerged that aspects of the circular transition have been known for a long time and that companies in this sector are implementing a range of actions in a systemic way. In both companies interviewed, a product design process is being implemented with supporting environmental analyses. This action is fully in line with the paradigm of transition to a CE (Ceschin and Gaziulusoy, 2016). Furthermore, the relevance that both companies give to the network of partners for the management of waste and unsold products shows how, within this sector, there is an awareness of its environmental criticality and a reactive approach. Both characteristics are crucial for a successful circular transition process of an industrial sector (Zucchella et al., 2022). As for the professional profiles required to manage the current transition, no specific evidence emerged in the textile sector (except than managers to comply with the rules and manage the right data), but only the need for skills (both hard and soft) that are not currently taught during traditional school and university training courses. Therefore, the companies interviewed offer training courses to fill this gap. An interesting result concerns the discordant opinion that the two companies gave on the relevance of digital skills. For one respondent, the acquisition of these skills is not a priority, while, for the other, it is essential to be able to comply with current demands. Differently, both interviewed companies were active in terms of ongoing collaborations, which are another key element for the successful implementation of circular strategies (Brown et al., 2021). In addition to confirming the need to train new workers with the skills they identify as lacking in current training courses, the textile companies emphasized the need for a clear framework of regulations to adhere to.

As for the WEEE industry, a need for very specific skills and job profiles emerged. In accordance with the interviewee's opinion, there is a need for people who are, on the one hand, able to physically manage the flows of used devices, thus experts in logistics, and, on the other hand, able to manage the data generated within this complex system (i.e., digital skills). This need was also confirmed by (Rizos and Bryhn, 2022). The need for people who can promote and sell used products and who are able to convey a new way of purchasing electronic devices was also highlighted in this sector. Indeed, social non-acceptance is one of the main barriers found for the correct implementation of circular business models in this sector (Rizos and Bryhn, 2022). In addition, no misalignment between the supply of educational pathways and the demands of the work market was found in this sector. However, it emerged how, in the respondent's opinion, there is no need for specialized personnel on issues related to the circular transition, but training on soft skills for employees already within the company is more effective. Finally, also in the case of the WEEE sector, a particular relevance of collaborations emerged, especially within the same value chain.

From the automotive experts’ responses, it emerged that this sector is beginning to gain awareness with respect to its environmental criticality, especially in terms of the enactment of different limits to be met (e.g., 85% of the vehicle should be recycled at the end of its life) and regulations, as well as demands from customers. To this concern, product redesign is put in place in accordance with the results of environmental analysis such LCAs. The trend that, however, appears to be most significant in the automotive sector is the shift to electric mobility. Regarding this issue, interviewees pointed out that there is a need to develop specific practices for the management of batteries, which are the most critical components and, above all, that the recovery of materials contained in batteries could also be strategically advantageous from the point of view of the European market. Indeed, most of the materials that constitute electric car batteries are to be considered as critical raw materials (Simon et al., 2015). Also, in the case of this sector, it emerged that digital skills are essential to cope with the current circular transition and that upskilling people already employed in enterprises is helpful. Respondents from the automotive sector also commonly pointed out that, due to the highly specific characteristics of this sector, mainly internal training courses are provided. Finally, because of the increasing focus on the critical environmental nature of this sector, experts from the automotive sector pointed out that there is a need to clearly delineate a framework of regulations to adhere to.

a. *According to the interviewee's perspectives, it seems that although each sector is characterized by its peculiarities, common aspects and actions are shared. Among all, digital skills are considered important to monitor performances and track products across the value chain. This is pushed especially by the creation of DPPs that are entering all the sectors (starting from the batteries). Soft skills are considered essential especially to drive collaboration which is considered the key pillar under the creation of circular systems. Furthermore, collaboration is not needed simply internally among function but also along the value chain and across different value chains involving also external actors like universities, research centres, etc.*

No specific job profiles are perceived to be needed to be introduced but they expect that technical profiles will also embed circularity skills to adequate their innovative projects. This could be done by creating a stronger bridge between universities and labour market.

6.5 Overall results discussion

To recall, the objective of the WP1 of the CERES project is to investigate market and resilience needs for competences and skills to better address the challenges of CE transition. Market needs were explored through literature review, survey, and interviews with actors (academics and practitioners) involved or interested in CE, while current offerings and developments of training and education were explored through review of existing VET and HE courses and education-related projects. The following paragraphs discuss the identified gaps between needs and existing offerings.

Sector-specific knowledge. Looking at the barriers for CE transition, an interesting finding from the survey is that practitioners ask for sector-specific experience and expertise that can guide them and help in prioritizing actions. This is also confirmed through the interviews where it was found that the different sectors prioritized the skills differently. The EEE sector required more logistics, warehouse and engineering knowledge, the textile sector required more interpersonal and collaborative skills, while the automotive sector highlighted the materials-related and digital skills besides the soft skills. This should be considered in the future development of the educations, since as found in the systematic literature review (Figure 9), most of the papers (33) address manufacturing sector in general or several industries in parallel, while there were identified between 1 to 7 papers per specific industry (e.g., EEE, automotive industry, textile). Similarly, most of the identified HE and VET courses are general for all industries, while there are few sector-specific courses or parts of courses dedicated to specific sector (plastic, renewable energy, textile, agri-food, etc.) primarily in the VET context. This shows the *need and potential for developing more sector-specific modules or elements within the modules*.

Skills (individual level). Practitioners ranked *designing systems and components* for CE compliance and *circular business models and CSCs* as the most important skills. This aligns with the literature review, which identified these two skills as the most addressed. However, in terms of difference with the literature review, practitioners identify *commercial and market understanding* as the third top priority skill which is to be expected as it is key for ensuring profitability and investments to support the change. Closely related to this are the skills related to *increasing customer and consumer awareness and knowledge on different aspects of CE* (remanufacturing, disposal, etc.). Understanding customers' expectations, perceptions of value and market needs (Walker et al., 2023) and acting appropriately, is key enabler for increasing market share and ensuring profitability. Therefore, practitioners see the customers as key stakeholders that have important role in the transition towards CE (Chiappetta Jabbour et al., 2023a, 2023b) by providing the market for the circular products, besides the consultants that can provide the knowledge on circular strategies. In line with practitioners' requirements, current HE and VET course offerings on the market are placing a strong emphasis on circular design, circular business models, and circular supply chain management. While HE courses are addressing also financial aspects of the CE transition, this is lacking in the VET courses. One major gap in both categories of offered courses is knowledge related to market understanding and increasing customer awareness. Even though this is partly addressed in the HE courses through marketing strategies, *understanding the market and customers' expectations, needs, and perceptions of values is lacking*.

Skills (macro categories level). Looking at overall categories of skills, the survey showed that the practitioners ranked resilience cross-cutting and soft skills highest. This was partly confirmed by the interviews, especially in the textile sector highlighting the need for collaboration across functions and with external entities and working in teams, and in the automotive sector highlighting the need for shared values, flexibility, interdisciplinarity and open mindset. Digital transformation and technology innovation skills were next in priority. The interviews specified these even further by pointing the need for data analysis and using big data skills, as well as developing and utilizing technologies to improve efficiency and effectiveness in different phases of the reverse value chain (for example in disassembly phase). This ranking partly overlaps with the findings from the SLR where resilience skills were dominating, while DT skills were the least addressed, and specialized/technical skills in between these two. The current offerings on the market mainly address the cross-cutting resilience skills but lack addressing the soft skills. Digital and advanced technologies are also addressed in the offered VET courses for CE transition, however they are more dominating and extensive in the twin transition courses. On the other hand, the HE courses have more limited focus on digital and advanced technologies. The specialized/technical skills were ranked lowest by the practitioners and are partly addressed by the offered courses as part of circular supply chain topics. This identifies *the gap in addressing the soft skills which are identified as crucial by the survey and the interviews*. In addition, *more extensive training of specialized/technical skills should be considered especially if the course is devoted to specific sector.*

<u>*Course arrangements*</u>. Comparing at the training modes preferred by the practitioners with the trainings that are most accessible there seems to be some mismatch. An obvious one is related to the formal academic courses (e.g., Master of science) which are in the top preferred trainings in the surveyed organizations, while they appear fifth in their current availability (as responded in the survey). In addition, the interviews pointed out that the graduates do not possess knowledge on CE aspects and they needed to be trained additionally. Even though there seems to be wide offering of courses and projects on the CE skills, the surveys and interviews might indicate that there is a *need for developing more CE specific academic courses*, especially with sector-specific focus. Another top prioritized training was CPD by an accredited body. As CE knowledge is evolving continuously it seems *that companies are looking for reliable sources of knowledge and more formalized courses*. Looking at the course delivery forms, in both HE and VET offerings online form was dominating, followed by hybrid and offline form. However, when asked, the practitioners ranked the online tutorials and MOOCs lower. This might be due to the previously stated need for formalized education, while they might perceive the online tutorials and MOOCs as non-formal types.

A summarizing table is provided to allow an easier comparison of the results obtained through the four analyses (SLR, market analysis, survey, and interviews) according to the 6 drivers (Prioritization on a macro-skills level, (Top prioritized) individual-level skills, Duration of education, Teaching method prioritization, Teaching delivery method prioritization, Learning assessment prioritization) discussed above.

Table 13. Overall comparison of results

	SLR	Market analysis	Survey	Interviews
Prioritization on a macro-skills level	-Resilience skills (RS) -Specialized/Technical skills (SS) -DTs skills (DS)	-CE transition (1st at HE and VET) -Sustainability transition (2nd at HE, 3rd at VET) -Twin transition (3rd at HE, 2nd at VET)	-Resilience cross-cutting skills -Resilience soft skills - Skills for technology innovation in CE Skills for digital transformation -Specialized technical skills for waste management -Specialized technical skills for Clean Tech and advanced materials	-Soft skills (textile sector, WEEE, automotive sector) -Hard skills (textile sector, WEEE sector, automotive sector)
(Top prioritized) individual-level skills	-Circular product design (SS) -Design of circular business model and circular supply chain (RS) -Effective communication (RS) -Circular (re)manufacturing skills (SS) -Circularity and environmental impact assessment skills (SS)	-Introduction to CE/sustainability (HE, VET) -Circular business models (VET) -Strategy & Marketing (HE) or Business management in the CE (VET) -Circular supply chain (HE, VET) -Circular eco-design (HE, VET) or Deign for X (VET) -Policies and EU regulations (HE) -Advanced technologies supporting CE implementation (HE, VET) -Assessing & Monitoring (HE, VET) -Energy management (HE) -Green technologies (HE) -Digital tools/Robotics (VET)	-Design for reuse, recyclability, and durability -Design of circular business models including supply chains -Commercial and market awareness -Procurement and closed loop supply chain -DTs, machine learning for performance management	-Collaboration skills, work in teams, negotiation skills (textile sector) -Data analysis skills (textile sector, automotive sector) -Engineering skills (WEEE) -IT skills (WEEE) -Logistics and warehousing skills (WEEE) -Sales and promotion (WEEE) -Communication, sharing values (automotive sector) -Flexibility, interdisciplinarity (automotive sector) -Open mindset (textile, automotive) -digital skills for disassembly (automotive sector)
Duration of education	-2-4 months (whole course) -number of lectures in an existing course	- average nr. of modules: 5.9 for HE, 5.5 for VET - duration of lecture load: 1 – 30 hours (VET), 1 day (HE)	-CPD -Academic courses -Formal certification -Online tutorial -MOOCs	-courses and webinars (textile sector) - training by internal and external experts, or internally developed courses (automotive sector)

				-course on advanced chemical skills -course on new regulations
Teaching method prioritization	-Case analysis/problem-based learning -Project-based learning -Lecture/guest lecture -Group work/cross-disciplinary teams -Experimentation -Self-learning (e-learning)	-Theory-based, case study (1st at HE) -Theory-based, application-based, case-study, simulation (2nd at HE) -Theory-based (3rd at HE, 1st at VET) -Case study (2nd at VET) -Gamification (3rd at VET)		
Teaching delivery method prioritization		-Online (HE, VET) -Hybrid (HE, VET) -Offline (HE, VET)		
Learning assessment prioritization	-Multiple-choice test -Pre- and post-workshop questionnaire -Individually graded final exam -Evaluation of report of a project or assignment	-Multiple-choice exam (HE, VET) -Project work (HE, VET) -Final individual written exam (HE, VET) -Continuous assessment (VET)		

6.6 Comparison with D2.1 results

A comparison of the results between D2.1 (Table 1 and Figure 1) and D1.1 (summed up in Table 13) reveals significant insights to develop the CERES curricula further.

The specialized/technical skills identified provide significant insights for the courses to address crucial aspects of circular lifecycle management, clean tech, advanced materials, and waste management. Integrating these specialized skills into the curricula will allow learners to navigate various industries' complex sustainability and environmental challenges. Therefore, the specialized courses will concentrate on findings related to circular lifecycle management, including circular re-manufacturing, circular product design, and circularity and environmental impact assessment, equipping learners with skills in monitoring and assessing CE initiatives and ensuring effectiveness and impact measurement. In addition, the curricula will cover clean tech and advanced materials, focusing on compliance and policy management, maintenance and equipment selection, energy management, and quality and safety considerations. Furthermore, the courses will explore waste management strategies, encompassing reverse logistics and operational management, waste collection and recovery processes, and efficient resource utilization techniques.

Additionally, the interviews and surveys showed the need to include commercial, market awareness, sales, promotion, procurement, closed-loop supply chains, engineering skills, logistics and warehousing skills, design for reuse, recyclability, durability, and digital skills for disassembly.
The cross-cutting skills identified in D1.1 align closely with the Entrepreneurship skills outlined in D2.1. For the Entrepreneurship module, CERES curricula will incorporate additional cross-cutting skills such as Business Management and Strategy, emphasizing customer and user-focused understanding. Participants will also develop expertise in crafting circular business models and Closed-Loop Supply Chains (CLSC), ensuring a comprehensive grasp of sustainable business practices. Furthermore, the module will enhance writing and research capabilities, vital for effective communication and evidence-based decision-making in entrepreneurial contexts. The program can also cover the design and implementation of training programs to foster CE practices. Integrating these cross-cutting skills into the curricula will provide the multifaceted competencies necessary for successful entrepreneurship in a rapidly evolving sustainable business landscape.
Regarding the Resilience & Soft Skills module, the curricula will include additional essential competencies such as decision-making, assertiveness, leadership, and negotiation. These skills are fundamental for individuals to thrive in dynamic and challenging environments, enabling them to navigate complexities confidently and resiliently. By integrating these competencies into the CERES curricula, the aim is to cultivate well-rounded professionals capable of adapting and excelling in diverse professional settings while promoting resilience, collaboration, and effective leadership.
The digital skills identified will enhance and build upon the insights obtained so far in the project (in D1.1 and D2.1) by concentrating on specific technologies and applications. To enrich the digital skills module, it is proposed to incorporate data management and analytical skills essential for harnessing the power of data in decision-making and problem-solving. The CERES curricula will also cover designing digital services and product service systems to meet evolving consumer demands and market trends. Emphasis will also be placed on applying I4.0 technologies and smart manufacturing processes. Furthermore, learners could need to gain proficiency in 3DP and scanning methodologies, enabling innovative product development and rapid prototyping. The module could also delve into VAM realities, providing insights into immersive technologies for various industries. Lastly, robotics and automation training could be needed to prepare participants for roles in optimizing processes and enhancing operational efficiency using robotic systems.

Finally, the CE and sustainability skills identified to support the twin transition will be crucial in developing a comprehensive green transition module. To enrich this module, CERES proposes incorporating key topics such as introducing the CE and providing a foundational understanding of its principles and importance in sustainable development. The curricula will also explore circular business models and innovative approaches to value creation that minimize resource use and waste generation. Business management in the CE context will be emphasized, focusing on strategies for integrating circular practices into organizational operations. Additionally, the module can cover CSCs, circular design principles, monitoring and assessing CE initiatives, and their applications in fostering sustainability. Furthermore, the social aspects of the CE, including inclusive practices and community engagement, could be explored. This comprehensive approach will empower participants to drive meaningful change toward a more sustainable and circular future.

7 Conclusions

The results presented in this deliverable (grounded on a literature analysis from a theoretical perspective, complemented by a market investigation, a survey, and interviews with practitioners) will be exploited to develop dedicated courses in the CERES project. These courses, dedicated to HE and VET levels, will be made available in the new CE-DIH to be developed in CERES (Sassanelli et al., 2023b). In particular, the objective of this deliverable has been multi-faceted. It wanted to:

- investigate market's and resilience needs for competences and skills to better address the challenges of CE transition and the European Green Deal,
- review existing VET and HE training in CE,
- provide accessible insights to feed HE/VET/Market actors' competence development and promote the field of CE education.

Indeed, grounding on a SLR (sub-section 5.1), this deliverable investigated the required professional skills for a successful transition to the CE in the manufacturing sector. The primary contribution of this study is to provide a comprehensive synthesis of skills, acknowledging the current changes resulting from the circular and digital transformations experienced by firms. A set of 40 skills categorized into three dimensions was identified: Resilience skills, DTs skills, and Specialized/technical skills. The literature review confirmed the critical value of resilience skills for a CE, especially related to adapting and designing circular business models and restructuring supply chains to the recent transformations that socio-technical systems are undergoing. However, among all the skills identified, the one that stood out most is in the specialized/technical dimension that corresponds to the design of circular products, including a variety of strategies to allow products to reduce their impacts throughout the whole lifecycle and to return them to production systems. This study also sheds light on skills for implementing DTs for circularity, ranging from skills to digitally transform businesses to innovation based on robotic automation.

However, inherently to any scientific study, this research has some limitations that can be converted in future studies directions. First, the findings obtained are exclusively based on a literature review of journal and conference papers. Due to publication selection bias, business reports were not analysed. In addition, case studies in specific manufacturing sectors could be conducted, refining the skill set mapped in this study. Furthermore, this work did not examine the differences and similarities in terms of skills required according to each nation's geographic and economic specificities. Professionals from emerging countries may require different skills from developed countries, which are already more advanced in transitioning to the CE.

In addition, the SLR provided a research agenda to guide future work in the field of skills and competencies for a CE. Six promising directions for new studies have been identified: (1) Skill, reskilling, and upskilling for circular manufacturing; (2) Geographical and cultural understanding of skills, education, and training programs; (3) Impacts of digitalization and required skills; (4) Methods and tools in CE educational programs; (5) Soft and hard skills integration in multidisciplinary CE courses; and (6) CE skills and professional competency levels. From a theoretical perspective, the main contribution of this analysis is the provision of a strategic research agenda that offers study direction so that young and even senior researchers can better focus their future scientific endeavours. From a practical perspective, the six identified research avenues can be used by educators and managers in the development of intellectual capital training programs that meet practical market demand. The results offer insights concerning the development of both digital and circularity-oriented methods and teaching approaches.

Despite the SLR-based research agenda offered valuable contributions, the research avenues have been outlined solely based on the data collected from the SLR. It is possible that practitioners, educators, and higher education professors may have research demands or suggestions for new works that were not considered in this study. Therefore, collecting input from industry professionals and educators about their needs regarding new developments could enrich the findings and expand the scope of our results.

The market analysis (sub-section 5.2) was conducted to map the formative and training opportunities already available on the market in the educational scenario related to the CE domain. To do that, the analysis started with the search of learning and training courses offered on the market, leading to collecting 113 educational programs. These were then examined based on 25 drivers of analysis to gather descriptive information of the courses, explore the content of their modules, and then classify and systematize them into 3 main macro-categories (i.e., "CE transition", "sustainability transition", "twin transition"). Each macro-category was gauged in detail, allowing also to define the relevant topics and sub-topics characterizing each of them. In the end, the research enabled to detect the gaps present in the current market.

It is necessary to specify that the results obtained are also in this case subject to limits of the research. For instance, the entire sample of teaching and training courses analysed focuses on providing education exclusively for VET (i.e., courses carried out at upper secondary level and post-secondary level) and HE (i.e., courses provided by universities, business schools, and other teaching institutions for post-secondary education), neglecting other levels of education (e.g., primary schools, middle schools - EQF levels 1,2,3). This is due to the queries used for the initial courses search, which was specific for HE and VET levels.

Another limit of the analysis regards the availability of courses' information. Many courses don't disclose complete information about their organization, learning objectives, teaching modules. Thus, conclusions were reached based on the personal interpretation of the data available at the time the analysis was carried out, but it's possible that some courses could have added/changed information in the meanwhile, or they are no longer available on the market.

Based on the results and limits of this market research, next steps can be suggested to further improve the analysis. First of all, search queries can be extended to cover a wider spectrum of teaching levels (including for example primary schools), in such a way as to gather relevant data that potentially can support the creation of a new set of educational paths which include CE and sustainability themes, raising public awareness and making them become the new standard both for the society and companies. Lastly, another recommendation concerns the potential cooperation among teaching providers of courses in the CE domain to fill and improve the current market gaps.

In addition, the results obtained through the survey (sub-section 5.3) enabled to clarify the state of practice about current practices undertaken by companies, the challenges faced, and the training programmes needed to align the workforce to the twin transition. The research objective has been addressed gathering 103 respondents. The information obtained will be exploited to better define the structure of the teaching and training courses to be delivered at both HE and VET levels to foster a more effective transition of manufacturing and society towards CE.

Some limitations can be unveiled also in this case, such as the restricted number of respondents to really have a complete and generalizable overview of the state of practice. A second iteration could be done to engage more people.

Finally, the interviews (sub-section 5.4) focused on critical skills towards circular manufacturing to clarify the market needs perceived by three distinct industries (Textile, WEEE, and automotive). Through a series of interviews, the paper has identified commonalities and peculiarities in relation to professional profiles, critical skills, and training programs already implemented.

Regarding the commonalities, digital skills are considered essential in all industries, while logistics are perceived as more relevant for the WEEE and legislative skills for the textile industry. Based on the interviewees' responses, new job profiles are not expected to emerge, but upskilled job profiles are needed in the near future. To address these evolving needs, the industries commonly rely on internal and/or external training initiatives. In general, the skills addressed in this analysis can be acquired through collaboration but also by fostering a better alignment with the education system that should support students in being prepared to address the needs of an updated labour market.

From a theoretical perspective, this study enriches existing results in the literature by introducing empirical evidence obtained through interviews with industry professionals. These interviews not only corroborate with previous theoretical findings, for example, reinforcing the importance of digital skills, but also expand the list of essential skills for a circular transition. Indeed, by providing a more comprehensive and well-founded overview, this evidence deepens the understanding of this research area directly connected to market needs.

Regarding practical contributions, managers and designers can use the insights from this study to drive the textile, automotive and WEEE industries towards circularity. Finally, it is essential to highlight that the findings provided in this analysis also have implications for public policymakers. By being aware of the concrete needs expressed by the interviewees, policymakers can formulate regulations and standards that are more aligned with current demands, considering the point of view of practitioners directly linked with the implementation of circular strategies.

Also this study has some limitations that may open up new opportunities for further developments. First, a larger number of respondents per industry segment may support the refinement of the findings. Second, the study's results cannot be generalized in the broad context of circular manufacturing since only three types of industries were considered in the analysis. Finally, future studies can adopt a more quantitative approach and analyse skills according to each professional role.

Finally, from the specific CERES project’s perspective, this analysis identifies the gap existing between current formative offers and market needs and. The results of this deliverable will be presented and validated with selected experts in the first webtalk of the CERES project. As a result, it constitutes the starting point to develop and provide (respectively in WP2 and WP3) new curricula appropriate to the demand of the CE market and to be deployed in the CE-DIH of CERES (WP4).

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Annexes

Annex 1. Circular economy transition courses

Provider/Teaching institution	Country of provider	Title	Main topics
École des Ponts Business School	France	1) Circular Economy Professionals 2) Circular Economy Manager	- Principles and definition of CE - Deeper aspects of CE: strategic design, value cycles, partnerships, ecosystems, advanced used of CE principles - Circular business models
Luiss Business School	Italy	Circular Economy Management	- Principles and definitions of CE - Circular business models - Private and public partnerships - Environmental assessment, certification systems, EU legislations - Influence Strategies for the CE - Circular finance
Ellen MacArthur Foundation	UK	Circular Economy: The Big Idea	- Principles and definition of CE - Strategic design technique, value cycles, partnerships and ecosystems - Advanced use of CE principles - Circular business models - Policies decision and design - Assessing & Monitoring KPIs
Luiss Business School	Italy	Management Of Circular Economy	- Principles and definition of CE - Strategic design technique, value cycles, partnerships and ecosystems - Advanced used of CE principles - Circular business models - Business strategy - Policies decision and design - Assessing & Monitoring KPIs - Advanced technologies to support CE implementation: Blockchain, Smart Cities, Digitalization,
edX: Wageningen	The Netherlands	Capstone Economics and Policies for a Circular Economy	- Introduction to the CE principles - Project management - Policies
Università di Bologna	Italy	Circular Economy and Sustainable Business Models	- Introduction to CE principles and definitions - Circular business models - Monitoring & Assessment KPIs - Entrepreneurship - Policies and regulations
CIVIS	Spain	Circular economy in cities and territories	- Introduction to CE principles and definitions - Design for recycling, reuse - Urban agriculture
Sant'Anna - Scuola Universitaria Superiore Pisa	Italy	Circular Economy Online Course	- CE principles and definitions - CE measurement - Circular business models (product-as-a-service,sharing platforms) - Open innovation - Sustainability and Industry 4.0
Università degli studi di Padova	Italy	Sustainable chemistry and technologies for circular economy	- CE principles and definition - Chemistry and technologies for CE - Circular waste management - Business management

			- Policies and regulations - Design for X (recycling, materials design) Alternative sustainable materials - Renewable energies
Circulab academy	France	Four courses: 1) Develop Circular packaging solutions 2) Teach the Circular Economy 3) Business resilience game 4) Activate Circular Economy	- Principles and definitions of CE (advantages and challenges) - Circular business models - How to evaluate the current business (PESTLE, BCG matrix, Ansoff matrix, Business Model canvas, Porter's 5 forces) Business resilience Design for packaging
International Training Centre	Italy	PROMOTING GREEN JOBS IN A CIRCULAR ECONOMY	- Principles and definitions of CE - Circular business models - Developing & implementing policies and strategies in the CE context - Green entrepreneurship - CE ecosystems and partnership - Assess & Monitoring (circular finance, social impacts)
University of Exeter Business School	UK	Circular Economy Masterclass	- Principles and definition of CE - Strategic design technique, value cycles, partnerships and ecosystems - Circular business models - Business strategy - Policies decision and design - Assessing & Monitoring KPIs - Advanced technologies (Blockchain, Smart Cities, Digitalization)
Circular Berlin	Germany	1) Business and Operations for a Circular Bio-Economy 2) DelftX: Waste Management and Critical Raw Materials	- Principles of CE - Circular business models - Design for X (remanufacturing, recycling, product design, reuse, refurbishment) - Alternatives materials - Circular procurement for governments and companies - Circular supply chain - Business strategy and resilience Circular finance
class central - Delft University of Technology	The Netherlands	Circular Economy: An Introduction	- Introduction to CE principles - Circular business models - Design for X (remanufacturing, waste management, reuse, repair, recycling) - Circular ecosystems
The University of Chicago	USA	Circular Economy and Sustainable Business	• Introductions to the principles of CE (and its connection with sustainability) • Digitalization and circular economy (energy & materials efficiency) • Assessing & Monitoring KPIs • Circular ecosystems and partnerships (different stakeholders)
Udemy platform	USA	Master Course in Circular Economy 3.0	• Introduction to the principles of CE (definitions, benefits, challenges) • Circular business models (considering also the resilience concept) • Policies and EU legislations
Circular Economy Alliance, in collaboration with the Circular Economy Research Center (hereinafter	France	Circular Economy Specialist	• Introduction to the principles of CE • Circular design, design for x (waste management) • Circular business models • Energy policy & legislation

referred to as 'CERC') and École des Ponts Business School			• Circular Industry 4.0 (process efficiency, cost reduction, and productivity improvement and to rethink circular products and new services.) • Circular ecosystems & partnerships • Training for circularity (upskilling, reskilling)
Campus AENOR	Spain	MÁSTER AENOR EN GESTIÓN DE EMPRESAS DEL SECTOR AGROALIMENTARIO	• Policies and regulations (standards and protocols) • CE in the agri-food industry • Tools for business management • Internal audit of management systems
United Nations Industrial Development Organization, Università degli studi Roma Tre, Università degli studi di Ferrara	Italy	INDUSTRIAL POLICIES FOR A CIRCULAR ECONOMY	• Policies and CE • Design for X (product design, reuse, repair, remanufacturing and recycling) • Alternative circular processes (e.g., Anaerobic digestion/composting)
Politecnico di Bari	Italy	MASTER DI II LIVELLO IN ECONOMIA CIRCOLARE	• Introduction to the principles of CE • Circular business models • Design for X (remanufacturing, demanufacturing, recycling, eco-design, waste management) • Assessing & Monitoring (LCA) • Circular leadership • Circular supply chain • Advanced technologies to support CE implementation (Cyber-Physical Systems, digital platforms)
Udemy platform	USA	The Circular Economy	• Introduction to the principles of CE • Circular business models • Assessing & Monitoring, circular finance
Wageningen University & Research	The Netherlands	Circular Economy: An Interdisciplinary Approach	• Introduction to the principles of CE • Circular business models • Assessing & Monitoring, circular finance • Policies • Business strategy and operations
United Nations Institute for Training & Research	Swiss	Waste Management and Circular Economy	Introduction to the principles of CE Policies Waste management
Circularity	Italy	PLASTICS: CIRCULAR ECONOMY AND END OF LIFE	• Introduction to plastic • Waste management • Materials classification and alternatives • Advanced Technologies
Munster Technological University	Ireland	Circular Economy	• Introduction to the principles of CE • Circular Business Models • Resource management, plastics and packaging • Supply chains and logistics • Circular design strategies • Policies • Communicating Circular Economy Ideas
Delft University of Technology	Netherlands	Circular Economy: An Introduction	• Introduction to the principles of CE • Circular Business Models • Design for x (remanufacturing) • Waste management
Delft University of Technology	Netherlands	Circular Economy for a Sustainable Built Environment	• Principles and definition of CE (in the built environment) • Circular business models • Circular design • Assessing & Monitoring impacts (LCA)
Delft University of Technology	Netherlands	Sustainable Packaging in a Circular Economy	• Principles and definition of CE • Circular business models • Circular design for packaging • Designing with renewables and bio-based materials

Delft University of Technology	Netherlands	Engineering Design for a Circular Economy	• Principles and definition of CE • Design for X (reuse, repair, remanufacture, recycle), eco-design
Delft University of Technology	Netherlands	Waste Management and Critical Raw Materials	• Principles of CE • Circular business models • Circular Design (remanufacturing, refurbishment-reverse logistics, disassembly, repair), circular product design • Advanced technologies to support the implementation of CE • Circular procurement for governments & companies • Advanced technologies for recycling (pre-processing, metallurgy, challenges)
Politecnico di Milano, ReteAmbiente, Remtech Expo	Italy	Economia Circolare - Da rifiuti a risorse: un'economia in transizione	• Principles of CE • Circular business models • EU policies and legislations in CE • Design for X (recycle, reuse, remanufacturing) • LCA • Circular finance, with notions also on ESG & sustainable finance
Università di Trento	Italy	Circular Economy	• Principles of CE • Circular business models • Waste management • Plastic challenge: trends, drivers, environmental impacts • How waste can generate energy through thermal, biological and chemical routes
Asian Development Bank Institute	Japan	Circular Economy: Increasing Resource Efficiency and Designing Out Waste	• Introduction to CE principles and definitions • Circular business models • Circular design • Strategies to fight plastic pollution
Venice International University	Italy	Circular Economy: Policies and Practices	• Introduction to CE principles and definitions • Circular business models • Circular design (waste) • Resource management (efficiency) • EU policies and regulations
Norwegian university of science and technology	Norway	Circular Economy and sustainability	• Introduction to CE principles and definitions • Circular business models • CE ecosystems and partnerships • Product design
The Circular Economy Institute	London	Circular Economy (Specialist)	• Principles and definitions of CE (advantages and obstacles) • Circular business models • Design for X • Monitoring & Assessing (company evaluation based on CE standards) • Code of ethics
The Circular Economy Institute	London	Circular Economy (Instructor)	• Principles and definitions of CE (advantages and obstacles) • Circular business models • Design for X • Monitoring & Assessing (company evaluation based on CE standards, Circular Indicators) • ACIT as training methodology: Adapting to your audience, Clarifying circularity, Implementation focus, Telling circular stories • How to implement CE (tools: Circular Canvas, Mapping circular initiatives)

Oxford Management Center	UK	Circular Economy for sustainable built environment	For the built environment: ● Introduction to CE definitions and principles ● Circular business models and economic value ● Advanced technologies to support CE implementation ● Waste management and Resource efficiency ● Circular Procurement and Supply Chain Management
School of sustainability foundation	Italy	Design for Circular Economy	● Principles and definitions of CE ● Circular business models ● Green circular procurement (supply chain) ● Advanced technologies (additive manufacturing)
Cranfield university	UK	The power of applied innovation	● Principles and definitions of CE ● Circular business models ● Customers' needs and markets discovery ● Customer's journey ● Innovation tools
Cranfield university	UK	Putting the Circular Economy into Action	● Corporate sustainability and sustainable innovation ● Principles and definitions of CE ● Circular business models ● Design for CE ● Resources efficiency ● Advanced technologies (Industry 4.0, 5.0) ● CE in the textile industry
Università Telematica Internazionale Uninettuno and CRIS Cittadella Universitaria Poggiardo	Italy	Circular Economy 4.0: Energy, Technology and Environment	● Principles and definitions of CE ● Marketing ● Waste management and legal aspects ● Energy management (efficiency, smart grids, renewables) ● Sustainable development (technical physics, buildings' energy performance, energy certification of a building) ● Monitoring & Assessing environmental sustainability
The University of Edinburgh	UK	Circular Economy	● Principles and definitions of CE ● Circular design ● Circular business models
University of Surrey	UK	Life Cycle Thinking and the Circular Economy	● Life cycle thinking: introduction and CE ● Circular business models ● Policies and regulations in CE ● LCA methodology ● Circular design
International Council of Circular Economy	UK	CIRCULAR ECONOMY: PRINCIPLES & PRACTICE	- Principles and definition of CE - Circular business models - Circular supply chain - Redesigning systems - Assessing & Monitoring (LCA, Environmental impacts) - Introduction to advanced technologies in CE
International Council of Circular Economy	India	LINEAR TO CIRCULAR ECONOMY	- Principles and definition of CE - Circular business models - Circular design
International Council of Circular Economy	India	Circular Business Management	- Principles and definition of CE - Circular business models - Business management - Circular ecosystems and partnerships (stakeholders) - Circular design
International Council of Circular Economy	India	ZERO WASTE LIVING	- Introduction to Zero Waste (ZW) lifestyle - How to integrate ZW lifestyle (reducing waste, sustainable habits, C-footprint)

University of Ferrara	Italy	International School in Circular Economy Project Management	- Principles and definitions of CE - Energy management and efficiency - Plastics: composites, recycling - Waste management -Assessing & Monitoring (LCA) - Alternative sustainable materials
Trinity College Dublin, The University of Dublin	Ireland	Circular Economy and recycling technology	- Principles and definitions of CE - Energy management and efficiency - Plastics: composites, recycling - Waste management - Assessing & Monitoring (LCA) - Alternative sustainable materials
Leiden University	US	A Circular Economy of Metals: Towards a Sustainable Societal Metabolism	- Introductions to metals: definitions, main challenges (with reference to the environment impacts, and SDGs) - The solution to the challenges: Circular Economy -Monitoring & Assessing: how to predict future scenarios, assess environmental impacts, SDGs impacts
McMaster University	Canada	Circular Economy & Climate Change Certificate of Completion Program	- Principles and definition of CE - Circular business models - Business management - Policies and EU regulations - Assessing & Monitoring impacts
University of Bradford	UK	Innovation, Enterprise and Circular Economy MBA	- Principles and definition of CE - Circular business models - Business management - Marketing - Assessing & Monitoring impacts
Cranfield University	UK	Putting the Circular Economy into Action	- Principles and definition of CE - Circular business models - Business management - Advanced technologies (Industry 4.0) - Assessing & Monitoring impacts - Ecosystems & Partnerships
Lund University	Sweden	Circular Economy: Sustainable Materials Management	- Principles and definition of CE - Circular business models - Circular design - Policies - Partnerships & circular ecosystems
Delft University	The Netherlands	Open Course in Engineering Design for a Circular Economy	- Principles and definition of CE - Circular design for X - Circular business models
European Institute of Innovation and Technology	Hungary	Circular Business Models for Sustainable Urban Food Systems	- Principles and definition of CE - Circular business models - Policies and regulations - Assessing & Monitoring
United Nations Development Programme (UNDP)	USA	Green Entrepreneurship	- Green entrepreneurship - Business models and business plan - Value creation - Assessing & Monitoring
Lund University International Institute For Industrial Environmental Economics (IIIEE), Eit Rawmaterials, Vito Geological Survey Of Denmark And Greenland, National Technical University Of Athens,	Sweden	Circular Economy - Sustainable Materials Management	- Principles and definition of CE - Circular business models - Policies and regulations - Circular design - Partnerships & circular ecosystem

Ghent University, Delft University Of Technology			
Edinburgh University	UK	Circular Economy	- Principles and definition of CE - Circular business models - Policies and regulations - Circular design - Partnerships & circular ecosystem
ReLondon	UK	Discover the CE in action	- Principles and definition of CE - Policies and regulations - Partnerships & circular ecosystem
ReLondon	UK	Develop a CE Action Plan	- Principles and definition of CE - Circular business models - Partnerships & circular ecosystem - Developing Action Plan
ReLondon	UK	Training: embed circular procurement	- Principles and definition of CE - Circular business models - Partnerships & circular ecosystem - Circular procurement
CIWM	UK	Circular Economy and Waste Management	- Principles and definition of CE - Circular business models - Circular ecosystem - Waste management - Circular procurement - Policies
CIWM	UK	Introduction to CE	- Principles and definition of CE - Net Zero - Circular ecosystem - Waste management - Circular procurement - Policies
CEIC	UK	Circular Communities Innovation Communities Programme	- Principles and definition of CE - Circular business models - Circular ecosystem - Circular design
Institute of Mechanical Engineering	UK	Re-engineering for a circular economy	- Principles and definition of CE - Circular business models - Assessing & Monitoring - Circular design - Net Zero
Aalborg University	Denmark	Circular Economy and Technology Assessment	• Analysis of social practices and LCAs • Design strategies • Circular business models
Aalborg University	Denmark	Potentials and challenges of circular economy as sustainability strategy in businesses and cities	• Re-design processes • Re-design products • Re-design value chain • Internal organization redesign
Aalborg University	Denmark	Summer School in Applied Circular Economy	• Introduction to CE principles and definitions • Circular business models • LCA • Circular Business strategies

Annex 2. Sustainability transition" courses at HE level

Provider/Teaching institution	Country of provider	Title	Main topics
University of Cambridge	UK	Circular Economy and Sustainability Strategies	- Introduction to sustainability and CE: principles, relationship, business models - Monitoring & Assessing - Sustainable finance
IMD - International Institute for Management Development	Switzerland	Winning Sustainability Strategies	- Sustainability vision - Implementing sustainability strategy - Organizational change - Purpose-driven organizations - Monitoring & Assessing
IMD	Switzerland	Driving Sustainability from the Boardroom	- Sustainability vision - Implementing sustainability strategy - Organizational change - Purpose-driven organizations - Monitoring & Assessing
Università politecnica delle Marche	Italy	Leading Sustainable Business Transformation	- Sustainability and ESG - Implement sustainability strategy - Sustainable business models - Build leadership capabilities - Drive organizational change - Ecosystems and partnerships
University of Cambridge together with Emeritus	UK	Sustainability Management and Circular Economy	- Sustainability management (ESG) - Assessing & Monitoring Sustainability - Green marketing - Policies and regulations - Designing sustainable products, eco-design - Bio-based supply chain - Introduction to circular economy
University of London	UK	Circular Economy and Sustainability Strategies	- Principles & definitions of sustainability - Introduction to CE - Sustainable Business Models - Driving innovations - Sustainable finance
Institute of Sustainability Studies, Glasgow Caledonian University	UK	Diploma in Business Sustainability	- Introduction to sustainability - Sustainable finance - Assessing & Monitoring - Green Marketing - Introduction to CE
Institute of Materials, Minerals and Mining	UK	Design for Sustainability & Circular Economy	- Introduction to sustainability - Assessing & Monitoring impacts - Tools for implementing sustainability - Introduction to CE
Aalborg University	Denmark	Sustainable design	- Design for Sustainability - Sustainable transition - Production Systems, and Sustainability
Aalborg University	Denmark	Sustainable Products and Services	- Eco-Design - Life Cycle Assessment - Assessing & Monitoring environmental impacts

Annex 3. “Twin transition” courses at HE level.

Provider/Teaching institution	Country of provider	Title	Main topics
University of Tuscia, University of Sevilla, University of Utrecht, Metropolia	Italy, Spain, Finland and Netherlands	SkillBill - European specialization program	- Energy transition - Sustainable & renewables - Sustainable mobility - Energy transition - Energy management storage, and efficiency - Green technologies

Annex 4. Circular economy transition" courses at VET level

Provider/Teaching institution	Country of providers	Title	Main topics
Erasmus+ project	Belgium, Germany, Spain, Finland	FURN360	• Principles of circular economy • Circular business model innovation • Business Management in the circular economy • Marketing in the circular economy • Advanced technologies
Erasmus+ project	Sweden, Finland, Germany, Italy, Poland, Slovakia	CIRCULAR SKILLS	• Principles of circular economy • Circular business models • Green public procurement • Design prototype to a CE challenge
Erasmus+ project	Greece, Poland, Czech Republic, Portugal, Romania, Spain, Slovenia	Education for Zero Waste and Circular Economy (EduZWaCE)	• Principles of circular economy • Best practices in CE • Circular design • Business Management
Erasmus+ project	European network	SKILLNET– Sector Skills Network of VET centres in Advanced Manufacturing	• Principles of CE • Opportunities and needs in the labor market
Erasmus+ project	The Netherlands, Lithuania	Building green skills for circular economy	• Principles of CE • Circular business models • Marketing in the CE • Materials management • Best practices in CE and circular design • Sharing economy
Erasmus+ project	Poland, Greece, Bulgaria, Sweden, Portugal	Design4Climate project	• Principles of CE • Circular business models and innovation • Circular design • Materials management
Erasmus+ project	Italy, Ireland, Greece, Germany, France, Finland	Training Innovation for Circularity and Holistic economies	• Principles of CE • Circular business models • Circular design
Erasmus+ project	Italy, Spain, Greece and Romania	Circular Bricks: Circular Bioeconomy for improving agrifood VET institutes' teachers' skills and competencies	• Principles of CE • Circular business model • Circular design
Circulab Academy	France	Activate the Circular Economy	• Principles of CE • Circular business models • Circular design
Alison	Ireland	Environmental Education: Circular Economy	• Principles of CE • Circular business models • Alternative materials
The Circular Economy Institute	UK	Circular Economy (trained)	• Principles of CE • Circular business models • Circular Design
ADB institute	Japan	Circular Economy: Increasing Resource Efficiency and Designing Out Waste	• Introduction to circular economy • Circular Business Models • Business Management in the CE • Advanced technologies to support CE
openSAP	Germany	Design for a Circular Economy	• Principles of CE • Circular business models • Circular Design • Advanced technologies

Annex 5. Sustainability transition" courses at VET level

Provider/Teaching institution	Country of provider	Title	Main topics
Erasmus + project	Spain, Belgium, Italy, Poland, Greece, Romania, Netherlands, Finland	Anchoring Social Circular Economy Attitudes in VET	• Climate change • Social circular economy • Social entrepreneurship
Erasmus+ project	16 partners from North Macedonia, Germany, Austria, Greece and Portugal	The CATALYST Project	• Climate change • Social circular economy • Measuring & Assessing KPIs
Erasmus+ project	North Macedonia – Serbia – Kosovo -Montenegro – Bosnia and Herzegovina – Cyprus	Eco-Entrepreneurship & Circular Economy	• Ecological and environmental issues • Sustainable entrepreneurship • Eco-entrepreneurship
Erasmus+ project	Lithuania Bulgaria, the Netherlands Estonia	Micro and Project-based learning for Teaching ciRcular Economy and Ecological awareness in VET schools (TREE)	• Climate change: definition, environmental, social and economic impacts • Sustainability and circular economy
Erasmus+ project	Italy Spain Belgium	Training for sustainable food systems development	• Sustainability • Assessing & Measuring impacts • Introduction to Circular economy

Annex 6. Twin transition” courses at VET level

Provider/Teaching institution	Country of provider	Title	Main topics
Erasmus + project	Poland, Spain, Germany, Austria	CROCEMS	• Robotics: collaborative robotics, lean robotics • sustainability and circular economy • Operations: waste management-->strategy mapping & value networks • Design for X • Circular Economy
Erasmus + project	Belgium, France, finland, Italy, Ireland, Germany, Greece, Portugal, Spain, Slovenia, Lithuania	Construction Blueprint project	• Sustainability & Circular economy • Digital tools • Operations
Erasmus+ project	Spain, Portugal, Italy, France, Germany and Lithuania	CIRCVET	• Sustainability & Circular economy • Eco-design & LCA • Digital tools • Monitoring & Assessing performance KPIs (LCA)
Erasmus+ project	Italy, Greece, Belgium, Slovakia, Spain, Finland and Netherlands	SkillBill	• Energy efficiency • Innovations in the field of renewables
Erasmus + project	Bulgaria, Romania, Netherlands, Greece, Denmark, Belgium, Germany, Czechia,	BioComp	• Sustainability & Circular economy • Eco-design Digital tools • Monitoring & Assessing performance KPIs
EIT RawMaterials Academy and IFTS Circular Society project	Italy	Junior Expert in Circular Economy	• Sustainability & Circular economyOperations: Energy efficiency • Design for X (LCA) • Monitoring & Assessing performance KPIs
Lahti University of Applied Sciences (Lahti UAS), University of Gävle, University of Latvia, Itmo University	Finland, Russia, Sweden, Latvia	Crea-RE: RESOURCE EFFICIENCY AND CIRCULAR ECONOMY	• Sustainability & Circular economy • Design for X • Monitoring & Assessing performance KPIs • Digital tools
UNESCO-UNEVOC, in collaboration with Circle Economy	Germany Ghana, Kenya, Nigeria, South Africa, Tanzania and Uganda	Training of Trainers (ToT) programme on ‘Circular Economy in Entrepreneurial Learning in TVET’	• Sustainability & Circular economy • Design for X • Monitoring & Assessing performance KPIs • Digital tools

Annex 7. Survey questionnaire

The CERES-Circular innovation Ecosystem REdesigning Skills project identifies that the transition of the circular economy can be accelerated by seeking solutions in the area of digital innovation and by increasing industry expertise. From this recognition emerges the ambition to intersect key technological disciplines with the circular economy model with the aim of providing tools and educational paths to implement technical competences and skills.
The objective of this survey is to identify the industrial and practical needs associated with the required professional roles, necessary to address the transition towards a circular economy model.
The survey requires around 15 minutes for its completion and will be available online up to 10th of December.
This will allow us to develop courses and curricula dedicated and targeted to the circular economy to train new professionals, based on the needs identified by both theory and practice. In the next pages, we will ask you information related to you, your organization, your organization's understanding of circular economy and of the needs related to circular economy skills. Please, share your experience and perception in each of these sections trying to be as detailed as possible, in particular in the last one.
To demonstrate our gratitude to your commitment, we will be back to you with the final report of our analyses (which includes the results of the literature review on skills and competences enabling CE in manufacturing; a map of the formative and training opportunities already available on the market concerning CE; and the results coming from this survey with the practical needs of required professional figures, skills, and competences in the CE domain).
We count on you!
Personal data are treated strictly confidentially. The information transmitted is intended exclusively for CERES project. Any transmission, forwarding, dissemination or other use of this information to different persons or companies is prohibited.

1) **Name**
2) **Surname**
3) **E-mail**
4) **Organisation name**
5) **Who are you?**
   - Consultant
   - Industrial
   - Academic
   - Policymaker
   - Other
6) **What is your job title?**
7) **Have you been working on circular economy – related activities?**
   - Yes - No
8) **If yes, how long have you been working on them? (years)**
   - <1
   - 1-4
   - >4
9) **What are your areas of responsibility?**

- Research & Development/Innovation Management
- Product development (design, engineering, testing & validation)
- Production
- Logistics
- Reverse logistics
- After sales services supporting use phase (maintenance, repair, etc.)
- End of life – reuse
- End of life – recycling
- End of life – remanufacturing
- End of life – waste management & disposal
- Sustainable management (Circular Economy/ESG/CSR/Environmental Management)
- Human resources
- Other (please specify)

About you organization

10) What industries is your organisation involved in?
- EEE (electrical and electronic products)
- Automotive
- IT Disposition (ITAD) & IT Asset Management (ITAM)
- Textile
- Wind turbine
- Trade association
- Other (please specify)

11) In which activities is your organisation involved in?
- Development (Conceptualization, Embodiment/Design, Validation&Testing)
- Manufacturing
- Reuse
- Treatment and recycling
- Other (please specify)

12) What size is your organization?
- Micro (staff headcount<10; turnover<2m)
- SME (staff headcount<250; turnover<50m)
- Large (staff headcount>250; turnover>50m)

13) At what regional level do you operate?
- Regional/local
- National
- International

About your company's/organisation's understanding of Circular Economy

14) What are the main barriers in establishing circular economy principles within your organisation?
- Lack of partnership with other actors/stakeholders in the supply chain
- Lack of skills, expertise or knowledge

- Lack of resources (money/funds)
- Lack of personnel
- Other more immediate pressures such as costs, regulatory
- Lack of alternative materials or technologies
- Legislative barriers (e.g., POPs)
- Difficulty in communicating what it means within the business.

15) How much mature would you define your organization in relation to Circular Economy?

- We don't know anything about it.
- We know about it but don't have the resources or expertise to implement it.
- We understand the concept but don't understand how it is applicable to our business.
- We have a general understanding of it but it is not translated or implemented into company plans or activities.
- We have a good understanding and are starting to adopt some related practices into our business.
- It's at the core of what we do, and we are working across our supply chain to deliver.

16) Where you answered E or F in question N° 15, did you initially encounter gaps in expertise, and how did you address these?

17) Please describe the circular economy priorities for your business, organisation or sector including links to published strategies or plans where available (e.g., Green Deal, ESG, CSR, ISO standard)

Circular Economy Skills Needs

18) Thinking about advancing circular economy within your organisation, where do you see the priorities for skills development and training? (put in order of priority)*

- Design of systems, products, and components for durability, reuse, recyclability, and recycled content.
- Design of circular business models to create added value and incentives including different ways of working with supply chains and customers.
- Commercial and market awareness to retain profitability and seek funding and investment for change.
- Procurement and supply chain working to increase closed loop recycling and reuse of components.
- Digital technologies, information systems and machine learning to manage and use data effectively to manage the performance, use and end of life of products and components.
- Remanufacturing, refurbishment and repair of products to extend product life and optimal energy use.
- Technological advancements to improve design, choice of materials and reuse and recycling of materials.

- Life cycle assessment to understand impacts of material choice, production and end of life management of products and materials/whole life costing/net zero.
- Communication and consumer engagement: to create a sharing economy for products that are used infrequently, wider acceptance of leased product and second hand or refurbishment, etc.
- Legislative barriers and opportunities presented by future legislation (e.g., DPP, ESPR).
- Retail and logistics for more efficient distribution of products, parts and takeback/reverse logistics.

19) Which kind of skills need to be enhanced more to support circular economy adoption? (put in order of priority)*

- Resilience Cross-cutting skills (related to Circular Business Innovation) (e.g., Entrepreneurship, Innovation, Circular Business Modeling, Sustainable Competitiveness, Systems, and Design Thinking).
- Resilience Soft skills (related to communication and teamwork) (e.g., Leadership, Flexibility, Responsibility, Team building, Problem-defining and solving, Self-awareness).
- Skills for Technology Innovation in the CE (e.g., development, provision and management of technologies as Blockchain, IoT, Artificial Intelligence, Virtual and Augmented reality, Fourth Industrial revolution).
- Skills for digital transformation of businesses (e.g., Technology Management and Digital Transformation, Smart PSSs, Digital Economy, Platforms in a digital economy, Data-driven approach (GDPR, IPR).
- Specialised/technical skills for waste management (e.g., Digital Passports, Packaging, Circular Design, Resource flows (collection, sorting, reuse, recycling, etc), Supply chain design, feasibility and sustainability.
- Specialised/technical skills for Clean Tech and Advanced materials enabling CE (e.g., Composite materials, zero waste economy, energy efficiency, circular bioeconomy, carbon capture and storage).

20) What type of training is preferred within your organisation?

- Formal certification
- Continuing Professional Development (CPD) delivered by an existing chartered body
- Attendance at Massive Open Online Courses (MOOCs)
- On-line tutorials
- Apprenticeships
- Academic (e.g., Master of Science, Master in Business Administration modules)
- Other (please specify)

21) According to your experience, which are the required new technical skills related to the beginning of life stage (e.g., design, production, internal logistics) from a circular economy perspective?

22) According to your experience, which are the required new technical skills related to the middle of life stage (e.g., use, maintenance, repair) from a circular economy perspective?

23) According to your experience, which are the required new technical skills related to the end-of-life stage (e.g., remanufacturing, recycling, disposal) from a circular economy perspective?

24) Who are the stakeholders who could help you become more circular?

- Consultants
- Auditors
- External suppliers
- Customers
- Logistics
- Retail distributors
- Other (please specify)

25) In your opinion, are there new job profiles required to face the economic transition across the value chain?

26) According to your experience, are there already any training courses on the market?

- Yes - No

27) If yes, are they easily available for your company?

- Yes - No

28) Of what type are they (e.g., Massive Open Online Course/courses offered by business schools etc.)

29) If you answered YES to question N° 26, have you taken advantage of the training offers on the market?

- Yes - No

30) Are you available to be personally contacted to be interviewed by the CERES staff to deepen more about the needs in your specific industry related to circular economy adoption based on your experience in the field?

- Yes - No

Thank you for completing this survey.

CERES project - Co-Funded by the European Union. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or the European Education and Culture Executive Agency (EACEA). Neither the European Union nor EACEA can be held responsible for them.

Annex 8. Interviews protocol

- Qualitative Interview Guide: Needs and Competencies in the Circular Economy for Sector-Specific Contexts

This interview protocol aims to serve as a semi structured guide for conducting CERES interviews tailored to understand the professional needs, skills, and competencies required in the context of the circular economy for four distinct sectors: Waste Electrical and Electronic Equipment (WEEE), windmills (wind energy), textile, and automotive. Its main purpose is to ensure consistency and thoroughness in the data collection process across different interviewees.
Each section is designed to extract insights specific to the sector in question, recognizing the unique challenges and opportunities each presents in the context of the circular economy.

- Introduction:

1. Introduce yourself and the study's purpose (WP1 activities and aim, methodology, we made a survey to understand market's needs) and the outcomes of the project.
2. Assure confidentiality.
3. Obtain informed consent.

- Demographic and Company Information:

4. Please describe your current role and your responsibilities within your organization.
5. How long has your organization been involved in circular economy or sustainable practices?
6. Briefly describe your company's primary operations and position within [the specific sector].

- Sector-Specific Questions:

For WEEE:

✔ Did you start re-designing your products to address the circular economy principles (i.e. narrowing, closing and extending resources lifecycle)? if yes, which practices did you implement?

✔ How do you support your consumers during the product usage phase to facilitate the product lifecycle extension?

✔ How do you manage the products' end-of-life?

✔ Which challenges do you see in this sector about CE?

✔ How do you see the role of reuse, repair, recycling and refurbishing in managing electronic waste in the coming years?

✔ What challenges do you face in terms of responsible e-waste disposal and recycling?

For Windmills:

- ✔ Did you start re-designing your products to address the circular economy principles (i.e. narrowing, closing and extending resources lifecycle)? if yes, which practices did you implement?
- ✔ How do you support your consumers during the product usage phase to facilitate the product lifecycle extension?
- ✔ How do you manage the products end of life?
- ✔ How do you manage the lifecycle of wind turbine components, especially the blades?
- ✔ Are there emerging technologies or practices in prolonging the lifespan or recycling of wind turbine parts?

For Textile:

- ✔ Did you start re-designing your products to address the circular economy principles (i.e. narrowing, closing and extending resources lifecycle)? if yes, which practices did you implement?
- ✔ How do you support your consumers during the product usage phase to facilitate the product lifecycle extension?
- ✔ How do you manage the products end of life?
- ✔ What initiatives or practices have you adopted for sustainable sourcing of materials?
- ✔ How do you address the challenges of textile waste, both pre-consumer (production) and post-consumer (used garments)?

For Automotive:

- ✔ Did you start re-designing your products to address the circular economy principles (i.e. narrowing, closing and extending resources lifecycle)? if yes, which practices did you implement?
- ✔ How do you support your consumers during the product usage phase to facilitate the product lifecycle extension?
- ✔ How do you manage the products end of life?
- ✔ How is the shift towards electric vehicles impacting the need for circular practices in the automotive sector?
- ✔ Are there new challenges in recycling and repurposing components from electric vs. conventional vehicles?

- Professional Figures and Roles:

7. Are there emerging roles or responsibilities within your organization tied specifically to circular economy practices in [the specific sector]?
8. What roles or jobs do you foresee becoming pivotal in the near future?

- Skills and Competencies:

9. What technical skills are becoming indispensable in your sector due to the shift towards a circular economy? And what about digital skills? In your opinion circular economy could be supported by digital new skills in your sector?
10. Are there any "soft" skills that are gaining prominence given the interdisciplinary nature of circular economy practices?

- Training and Development:

11. What kind of training or skill development opportunities do you offer or seek for employees in light of circular economy trends? And what about digital skills?
12. What qualifications, certifications, training or prize do you request in new job applications?
13. Is there a gap in current educational or training programs related to circular practices in [the specific sector]?

- Collaboration and External Partnerships:

14. How important is collaboration with external partners, suppliers, or even competitors in driving circular initiatives?
15. Can you name any sector-specific networks or partnerships that have been particularly valuable?

- Future Outlook:

16. Looking ahead, what major changes, innovations or digital technologies do you anticipate in [the specific sector] related to the circular economy?
17. How do you see the interplay of technology, policy, digitalization and consumer behavior shaping these changes?

- Conclusion:

18. Do you believe that regulatory bodies and educational institutions are adequately addressing the sector-specific needs of the circular economy?

Thank you for your time. Is there anything else you'd like to add or emphasize?

he CERES innovation ecosystem, the Circular Economy Digital Innovation Hub (CE-DIH), aims to promote stakeholder connectedness and generate a systematized set of services, skills, competences, and knowledge to support the multi-faceted CE domain. The CE-DIH can strategically raise awareness and provide the most suitable and complete services to support the circular enrichment and transition of both companies on the market and individuals in society.

Circular Economy Innovation
Ecosystems REdesigning Skills

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