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UPSKILLING THE FUTURE WORKFORCE: HIGHER EDUCATION'S RESPONSE TO DIGITALIZATION AND INDUSTRY 4.0

Joanna Rosak-Szyrocka
Czestochowa University of Technology

Abstract:
The speeding pace of digital and ecological transitions is redefining the mission of higher education institutions (HEIs) to promote lifelong learning and the resilience of the workforce. The purpose of this study is to create a theoretical model to explore key dimensions of the successful upskilling in the era of industry 4.0 and rapidly changing labour market requirements. The research is designed qualitatively, integratively, and is grounded on the following three sources: (1) analysis of international strategic and policy documents (OECD, European Commission, UNESCO), (2) observation of case studies of HEI that introduced innovative educational models, (3) exploratory bibliometric analysis conducted with the help of VOSviewer, on the basis of 202 publications from the Scopus dish for the period 1989-2025. The latter facilitated the exploration of key research themes and conceptual areas in university-led upskilling. The core output is a six-point framework for developing institutional upskilling strategies, consisting of: flexible learning formats, labour market co-creation, integrate green and ethical competencies (ESG), pedagogical transformation with digital, digital infrastructure, and impact monitoring systems. The article also develop a quality evaluation matrix and offer policy recommendations to institutional and governmental stakeholders. This manuscript addresses a significant gap in the literature by proposing a holistic and theoretically-grounded model for HEI upskilling strategies – a topic that is under-researched in empirical studies and policy debates. The implications, in terms of policy and practice, for an educational reformation, ecosystem sustainability of skills and a future university-readiness are discussed.

"Education does not change the world.
Education changes people.
People change the world"

Paulo Freire

Key words: upskilling, reskilling, ESG, industry 4.0, digitalization, VOSviewer, microcredentials, Pareto-Lorenz analysis

INTRODUCTION

In the highly digitalized and nature-alienating society of the Fourth Industrial Revolution (I4.0), the nature of work is finding itself in deep transition [1, 2, 3, 4]. Automation and digitalization, the advent of artificial intelligence (AI), and the growing impetus to incorporate into business the requirements of sustainable development all mean that workers are required to be constantly updating their skills [5, 6, 7]. In this fast-changing environment, upskilling development of skills and further deepening of existing skills has become a matter of professional resilience, which allows people to face up to new challenges within the labour market without requiring them to be fully retrained (reskilling) [8, 9, 10, 11]. Figure 1 displays an overview the most-sought-after skills of the future, as identified by international employers in the Future of Jobs Report 2023 [12]. The prominence of the customer orientation, creativity, digital literacy and AI gen depicts the increasing need for adaptive and analytical capabilities.

Results from Fig. 1. shows that universities should now move from static to modular and labour-market-reponsive learning. Such dominations of human-centred and cognitive competences also reveal the importance of embedding microcredentials and flexible upskilling pathways within university-led learning strategies [13, 14]. Recent statistics make the clear case of the need to address skills gaps and embed strategic upskilling paths at the level of higher education.

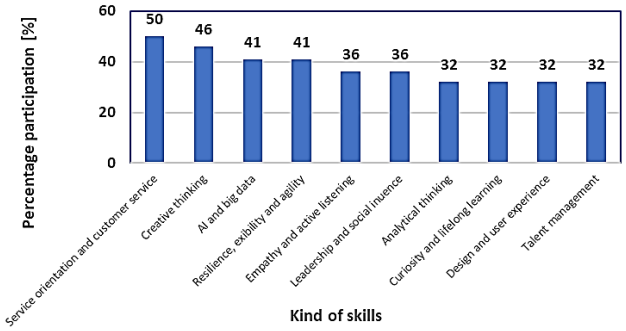

Fig. 1 Top 10 future skills by percentage of employer responses.
Source: own study based on [12].

Almost half of talent development professionals think their employees don't have what it takes to implement the organization's strategy, according to the LinkedIn Workplace Learning Report 2025 [15]. Despite this, just 36% of companies are promoting advanced career development programs that I call career development champions. This group are not only winners in terms of the talent mobility within their businesses, but also their ability to respond to changes in technology. They are 42% likelier to be implementing or using AI tools, 32% more likely to provide AI training and 88% more likely to have project-based learning, like gig assignments. And this phenomenon is also driven by the individual perspective: 84% of employees believe learning brings meaning to their work and 91% of learning and development specialists see soft skills as skills that are increasingly essential in the changing working world. These findings serve to underscore the significance of integrating lifelong learning, flexible learning modes, and micro-credential recognition mechanisms in the mission of higher education institutions seeking to produce talent for the future [16]. The DeVry University research reveals that a staggering 83% of workers and employers agree upskilling is mandate in order to keep up with the rapid pace of technology, such as AI. Yet only 55% of employees actually take advantage of the skills training available to them, and most employers acknowledge that they don't offer it to all of their employees [17].

The aim of this manuscript is to explore how higher education institutions as considerate organizations of expanding social responsibility are adjusting their educational strategies to safeguard upskilling in the age of digital and green transition. An extensive academic literature already exists with respect to higher education and lifelong learning as well as the development of general competencies [18, 19, 20, 21], however the focus has so far been less on the specific instruments, means and forms of delivery that universities are introducing in a response to the challenges of Industry 4.0 and the sustainability agenda. There is also limited comparative understanding of these evolving educational forms in terms of accessibility, flexibility, and practical application, particularly across different geographical and institutional settings. This manuscript fills in these gaps by:

– Mapping and classifying novel educational formats deployed in upskilling interventions (microcredentials, bootcamps, blended courses, open learning models);
– Connecting these formats to critical competence fields in the workplace of the future (AI, ESG, cybersecurity, data literacy);
– Providing representative examples from universities worldwide, that may be emulated for policy and strategy in education.

This manuscript is structured as follows: In section 2, we review the literature on upskilling and reskilling, and the role of higher education in the context of Industry 4.0 and sustainable development. In Section 3, we present theoretical framework which specifies six strategic pillars for university-led upskilling strategies. In section 4, we analyse the results of the bibliometric analysis and systematize evidence from international case studies and calculate Pareto-Lorenz analysis for each network [22]. Section 5 expands on reflection over the strategic implications of the model, connecting it with labor market trends, pedagogical mutation, and institutional preparedness. In Section 6, we summarize findings and provide policy and institutional guidance. Figure 2 presents step-by-step the method of conducting research.

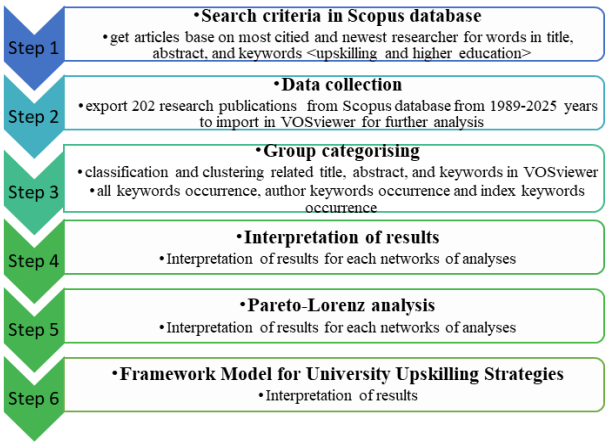

Fig. 2 Step-by-step method of conducting research

LITERATURE REVIEW

Upskilling is the process of developing new skills or improving current ones in order to satisfy shifting industry needs [23]. Reskilling is learning new skills and obtaining new qualifications that allow people to start a new occupation or in a new economic sector as a product of new technologies and new patterns of world trade in which they can't find adequate employment [24]. Unlike upskilling, which concerns upgrading skills, reskilling describes a complete twist in one's occupational identity and it is commonly associated with technological transition, automation, or structural shifts in the economy.

There is an increasing focus in the literature on examining the strategies of HEIs with regard to upskilling in the context of digital and green transitions. Published as of late stress the fact that successful upskilling will not be limited to technical training, but will rather cover social and environmental aspects of learning e.g. ESG competences, data ethics or transversal or soft skills. Many authors [11, 25, 26] refer to the necessity of a systemic, strategic approach to talent development for the era of AI, being additionally

-oriented on new pedagogical models based on personalisation and adaptivity and the immersive technologies (VR/AR). Research by OECD [27] and the EU Commission [28] show that microcredentials are increasingly seen as a key instrument in providing flexible, inclusive upskilling, are increasingly have employers' recognition and are in line with lifelong learning [29]. Empirical evidence [30] shows that there is a rising recognition of the value that shorter credentials are accorded within the wider efforts for graduate employability and mobility. Further, the literature highlights the crucial importance of capturing the world trends in technological mega-transformations in upskilling. HEIs have to respond to labor market needs, and they also must co-create educational innovation in collaboration with industry through co-creation models and appropriate curriculum redesign of the Industry 4.0 era [31]. Likewise author Cheung [32] focus on the need to reimagine the educator-learner relationship by integrating AI-enabled tools and learning analytics in order to personalize the learning pathways. Universities everywhere do upskilling in a range of forms – including standalone microcredentials, stackable certificates and programmes embedded in formal qualification [27, 33]. These are particularly effective when developed in partnership with employers, in response to labour market demand [27]. Table 1 presents differences between upskilling and reskilling in the context of higher education (HE), industry 4.0 and digitalization.

Table 1

Differences between upskilling and reskilling in the context of higher education, industry 4.0 and digitalization

Criteria	Upskilling	Reskilling
Educational Objective	The ultimate objective of upskilling is to improve, fine-tune, or change the type of skills a worker already has in their current field. In this way, people can continue to operate at their best and stay competitive as technologies, practices and roles change. Reskilling tends to cover technological progression (AI, automation, digital platforms) and industry innovation, providing the knowledge and skills for professionals to continue working with new tools or methods without stepping outside their domain. They do so by providing modular, short-cycle and profession-focussed access points to higher education (e.g., micro-credentials, continuing education offerings and industry partnerships). The upskilling model is consistent with lifelong learning and is about being agile and continuously learning to sustain career.	Reskilling would be providing people with all new skills and knowledge to enter a whole new occupation or industry. Instead, the goal of learning is not to expand on a current repertoire of skills but to construct a new vocational or technical infrastructure, literally from the ground up, this comes as a response to job obsolescence as a result of automation, economic restructuring, or environmental transition. The second source will be reskilling courses that generally tend to be longer in length and more multidisciplinary, incorporating hard skills, such as technical skills, as well as soft skills, like communication, problem solving and digital literacy. In this context the role of higher education is to "develop a seamless portfolio of integrated pathways that allow displaced workers to earn both formal qualifications as well as work-based learning experience that is linked to the emerging requirements of the labor market
Scope of Change	Progressive evolution – growth along the same career pathway, i.e., mastering new digital tools, languages, and automation.	Pivoting – shift to a new role profile; for example, administrative assistant to AI specialist or data analyst.
Link to Industry 4.0	A reaction to changing workplace technology, automation, artificial intelligence, cloud technology, and big data systems.	A response to the loss of jobs to digitalization and automation. Reskilling provides access to job roles taking shape or transforming in the future world of work.
Role of Higher Education	The role of universities as skill refreshers, providing flexible education in the form of postgraduate courses, professional certificates, microcredentials and specialised online modules that are responsive to labour market requirements.	Higher education will have to develop holistic, interdisciplinary learning paths that enable people who are not studying a specific topic to build a new profile in collaboration with industry and labor organizations.
Target Group	Professionals wanting to increase the productivity, efficiency and the mobility in their existing career.	People at risk of or dislodged from the labor market who need new skills relevant to dynamic sectors
Type of Education Offered	Short, practical educational formats (often online), that focus on helping people to learn particular technical, digital or analytical skills.	Longer, often hybrid programs that teach some of the basics in a new area as well as soft skills and practical experiences (e.g., internships, group projects).
Relation to Lifelong Learning	A part of lifelong relatively stable professional development that can be looked upon as a career path that enables one to formalize education and work experience, and provides more detailed information to change careers. Upskilling relates to the spiral process of lifelong learning taking place under diverse life periods and in different forms (formal, non-formal, informal). With the support of higher education by module, certification and digitally available.	Fosters flexible career paths and mitigates the impact of outdated skills. Lifelong learning in this sense is also a way of rebuilding human capital and promoting social inclusion, particularly for potential members of a population at risk of exclusion from the labour market. Reskilling supports system resilience and societal agility in the face of megatrends, such as automation, the green transition or demographic ageing.
Green Jobs and Environmental Skills	An increasing range of skills which covers sustainability, renewable energy, ESG (Environmental, Social, Governance), and circular economy. For instance, an environmental engineer is trained in using digital emission monitoring instruments and carbon footprint reportage equipment.	Professional retraining for green-economy jobs, including photovoltaic technician, energy efficiency adviser or city ecological planner. This specialization deals with further competences in renewable energy technology, sustainable construction, environmental economics or circular systems design.

Source: own study based on: [5, 29, 31, 34, 35].

Upskilling refers to extending or adding to existing professional skills today's workers will need to stay competitive as technology evolves. The reality of today's data-driven, AI-aided, and automated workplaces is that professional development is now cyclical and lifelong, not just linear. Upskilling is a process that entails transmitting more than hard skills; it involves developing hard skills as they relate to softer, transversal skills such as systems thinking, cross-sector cooperation, and ethical decisionmaking. HEIs are expected to have flexible and modular as well as personalised learning routes, through for example postgraduate programmes, microcredentials and blended modes of delivery, to accommodate the future-proof and professional development needs [26].

A key element in this respect is upskilling for sustainability (i.e. what we call greening the curriculum). Reconfiguring skills systems is becoming central as economies transition to climate neutrality. The OECD states clearly: "Transition to greener economies and clean energy is imperative for meeting climate targets. "But there's a skills deficit that may hinder that shift." [29] From this viewpoint, green upskilling will increase the quality of current jobs by adding specialisations in sustainable development, renewable energy systems, ESG reporting, circular economy principles, and environmental technologies. An environmental engineer might, for example, acquire expertise in digital emission monitoring systems [5, 30, 36]. Integrating green transitions in upskilling frameworks requires higher education to rethink its focus – from STEM-dominated teaching to multi-disciplinary, ESD-related learning practices. This model contributes to graduates' employment opportunities and matches educational outcomes with wider social and environmental needs (including, specifically, the Sustainable Development Goals -SDG 4 and SDG 13) [5, 35].

Upskilling Pathways in Higher Education

Some 70% of workers in OECD countries will be exposed to impacts of automation, digitalization or green transition, while only 40% of adults participate in any form of education or training every year accordance with the OECD Skills Outlook 2023 report [29]. Furthermore, more than half of adults have no or low digital skills and those who left education with few qualifications are 60% less likely to participate in education and training than their highly-qualified peers [29]. These results decisively emphasize the necessity of system-wide proliferation of contemporary, flexible education models that promote inclusive and successful social group upskilling.

Faced with these challenges, higher education institutions are reinventing themselves, evolving beyond the traditional academic model to provide varied, flexible and practically-oriented learning forms that are adapted to the realities of today's labor market [11, 37]. The most prevalent forms of these alternative forms of education include the following:

- Microcredentials – small, often digital certificates indicating mastery of particular skills (say, basics of artificial intelligence or Agile project management). They are flexible and modular, and usually accessible online [38, 39].
- Bootcamps – short, hands-on training programs (ranging from a few days to a few weeks long) that usually teach in-demand digital or technical skills (like data analysis, cybersecurity, or UX design) [40, 41].
- Postgraduate instruction – classical, but renovated system of professional education according to the contemporary requirements of the labour market (sustainable development, digital education, cybersafety) [39].
- Blended learning programs – comprising elements of both online and face-to-face learning, often used to foster intercultural communication and soft skills in international and hybrid working environments [42].
- Open educational efforts (e.g., Study Hall) – leveraging access to academic content through YouTube for the opportunity to then earn micro-credentials or transfer ECTS credits into a program [43, 44].

Recent data from the OECD and the European Commission provides evidence of the increasing popularity and real-life benefits of microcredentials. In many OECD countries in which national microcredential frameworks are established, 6-10% of higher education students have already taken a microcredential. Additionally, 72% of learners reported that they have progressed in their careers and 60% have a job as a result of these qualifications. These results highlight the strategic importance of short-cycle modular learning as an instrument for tackling labour market imbalances and for promoting employability in the digital economy [27, 29, 45, 46].

Recent evidence highlights the increasing importance of flexible forms of education, such as microcredentials, in addressing skills mismatches in economies. Table 2 presents examples of upskilling initiatives in global Higher Educations.

By creating such agile learning formats, universities can meet society's need for change, with more accessible, scalable and labor market-aligned educational solutions, allowing society to transform careers while ensuring students are sufficiently trained for the new job market [25, 47, 48, 49].

Table 2

Examples of upskilling initiatives in global higher educations

Competence area	Educational form	Description	University
AI	Microcredential	Introduction to basic concepts of AI, machine learning, and the ethics of technology.	University of Helsinki (Finland)
Data Analysis/ Data Science	Bootcamp	Practical experience using data analytics tools, Python, SQL, and data visualization to help prepare learners for a career as an IT professional or Data Scientist.	Le Wagon in collaboration with INSEAD (France)
Sustainability/ ESG	Postgraduate studies	Knowledge of business models for sustainability, the implications of ESG strategy and climate policy structures.	University of Cambridge (UK)
Hybrid Microcredentials + Open Access	YouTube + E-learning with credit transfer	Facilitating learner access to content on YouTube, earn badges and, if desired, attain official college credit.	Arizona State University + YouTube (USA)
Design Thinking/ Innovation	Practical Course/ Innovation Labs	Acquiring skills of empathetic design, iterative prototyping and collaborative working in innovation-themed workshops.	Hasso Plattner Institute/University of Potsdam (Germany)

In addition, many of today's upskilling initiatives are the result of collaborations between universities and tech giants like Google, Microsoft and Amazon Web Services (AWS). These partnerships allow for the development of programs that are continuously informed by the current market requirements and content. Examples include:

- Google Career Certificates: Industry credentials, which were created with universities, that can be earned in areas including IT support, UX design, and data analytics [50];
- Study Hall, a collaboration between ASU and YouTube through CrashCourse, a mechanism that connects open content to formal learning [44];
- Learn for Educators by Microsoft that is bringing the technology-enhanced content to university curriculum through faculty development and free online learning resources [51].

BIBLIOMETRIC LANDSCAPE OF HIGHER EDUCATION'S ROLE IN UPSKILLING AND ITS RESULT

This study uses VOSviewer for network visualization and bibliometric analysis to examine 202 research publications from 1989 to 2025 that are included in the Scopus database. Software capabilities and recognized bibliometric practices served as the foundation for the criteria used in this study [52]. Because of its special capacity to map bibliometric linkages, VOSviewer was chosen for network visualization, which allows for a more organic understanding of complex data sets. VOSviewer was chosen primarily because of its capacity to manage co-authorship and keyword co-occurrence data from the Scopus database [34, 53]. Using Scopus as the primary database ensures that the research is based on credible, peer-reviewed literature and provides reliable insights into the field's development. Fig. 3 presents co-occurrence all key words.

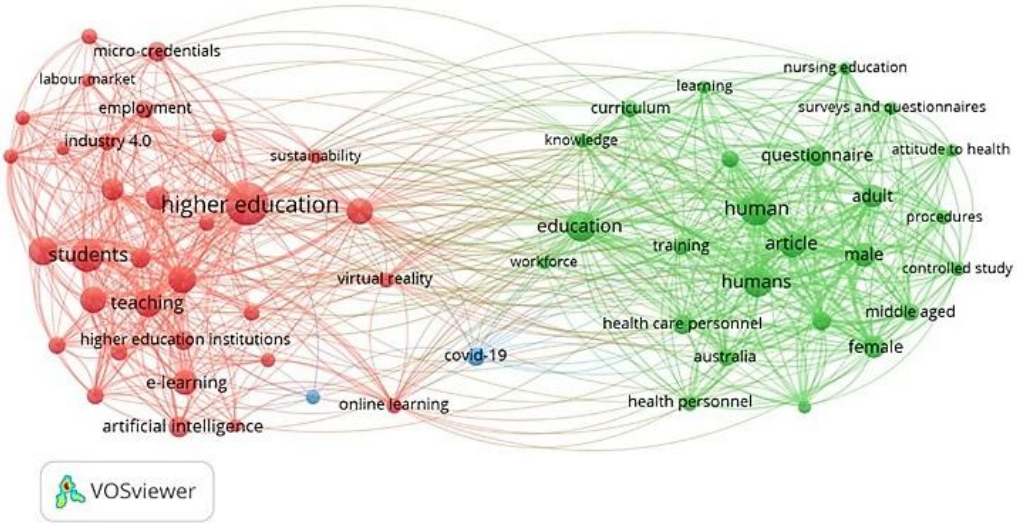

Fig. 3 Co-occurrence all key words (number of occurrence of a keyword 5)

The visualization is a keyword co-occurrence map completed using VOSviewer, which provides a reflection upon the thematic structure and interrelatedness of academic discussion resulting from the use of the key terms of

education, digitalization, labor market, and health. The map is is mainly clustered into red, green and blue end, each corresponding to a different focus of research. These inter-relationships between clusters help highlight what HEIs should be doing in relation to up-skilling society and addressing the challenges of Industry 4.0.

Red cluster comprises higher education, students, teaching, artificial intelligence, e-learning, employment, industry 4.0, micro-credentials and higher education institutions. That's because higher ed is a key element in preparing the workforce of the future for the digital economy. High correlation between industry 4.0, job and students indicates that education system has to adapt curriculum offered to the needs of the market. That includes incorporating cutting-edge technologies – like AI, virtual reality and digital platforms – into how we educate and learn.

Micro-credentialing, or modular, flexibly formatted education that enables learners to gain specific, job-related skills in rapid fashion, often through short, stackable courses, is another development that incorporates the power of digital learning and is penetrating the marketplace quickly.

The green cluster encompasses the terms education, training, human, questionnaire, health care personnel, curriculum, adult, female, and male. It represents a research emphasis on observational studies, especially in the field of health education and population research. This suggests that in addition to the teaching role which education plays as part of a knowledge transfer system, it is also a place of social intervention and examination of the effectivity of pedagogical approaches. For institutions of higher learning, that means intentionally addressing diversity, inclusivity and utilizing data-driven practices. Terms such as questionnaire and controlled study emphasize the need to systematically design and evaluate educational interventions – something that is taken for granted and thus requires faculty with research competency and for a university have infrastructure for research.

Online learning and virtual reality are among the blue cluster keywords, suggesting the focus is on pandemic-related changes to education. COVID-19 was the catalyst for digital transformation, expediting the use of remote teaching tech and immersive tools. An important lesson to be learned for Universities from this period, is that we need to have a better resilience, by learning to adapt and developing hybrid models of education, so as to continue in times of crisis, and to guarantee that students and faculty are more competent in digital terms in the future.

At the other side of the cluster borders stands the word sustainability not only in relation to the practices of universities, which should not only be directed toward immediate labor market needs but should also form part of long-term thinking embedded in social, environmental, and economic sustainable development. Upskilling, therefore, ought to take into account not just technical skills, but soft skills, critical thinking and societal responsibility.

Fig. 3 presents that HEIs have to become dynamic centers for the development of skills in the foreseeable future condition; in other words, they not only have to incorporate groundbreaking digital technologies, provide flexible and micro- based credit opportunities to learn and develop competences, but also to adjust content and syllabi to the changing demands of the labour field, strengthen pedagogic capacity of the teachers/lectures as well as commit to promoting and ensuring inclusive, sustainable educational environment. The Figure 3 both underpins the importance of upskilling as a subject of investigation in higher education and indicates specific strategic imperatives that higher education institutions might follow to adequately address the digital and socio-economic revolution taking place. Figure 4 shows the Pareto-Lorenz analysis for the most frequently occurring all keywords.

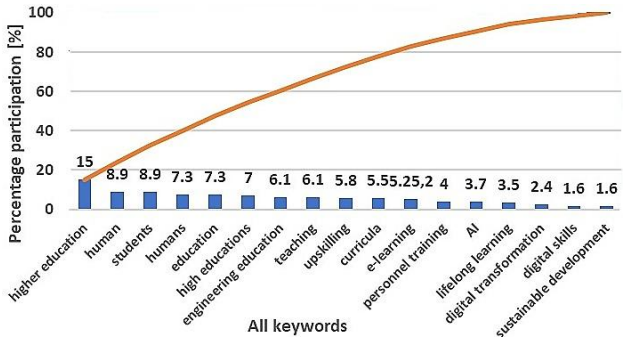

Fig. 4 The Pareto-Lorenz diagram for the most frequently occurring all keywords

Through a Pareto-Lorenz analysis of the all keywords, one can see that the entry of the first 17.64% of words such as "higher education," "human" and "students" – corresponds to 32.8% of the cumulative frequency of words. According to the analysis, change of competencies cannot reduce simply to technology transfer but is requested deep integration inside the educational system and clear identification of human role in the digital factory. Fig. 5 presents co-occurrence author key words.

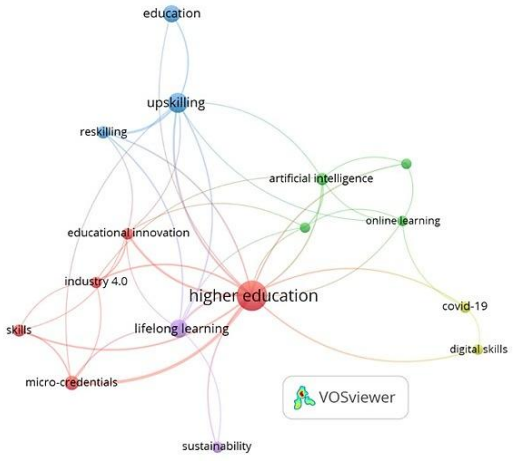

Fig. 5 Co-occurrence author key words (number of occurrence of a keyword 5)

Fig. 5 shows that the map has, at its core, the higher education node, the hub of a constellation of related ideas illustrating different aspects of the current academic field of education and digitalisation. Its close associations with concepts like upskilling, educational innovation, industry 4.0, skills, micro-credentials, lifelong learning, and sustainability suggest higher education is indeed widely recognized as a key player in providing future workers with the knowledge to face the challenges in the digital economy. The upskilling concept, located in the higher part of the map, is closely related to education, reskilling, educational innovation and higher education, stressing the involvement of universities in designing and implementing training projects aimed at fostering not only technical, but also transversal competences. The term reskilling very closely implies that workforce development is not only about increasing one's existing set of skills but also the complete change of a qualification level – possibly an emerging necessity in the fast-pace labor market of Industry 4.0. There are also clear links to industry 4.0, artificial intelligence, digital skills and online learning. These connections suggest that higher education's response to digital transformation cannot be limited to the adaptation of contents to new technologies, but that it must also include new teaching approaches, encouraging different ways of learning (remote, hybrid, etc.). Here, there is a role for educational innovation and online education as instruments in providing scalable, flexible learning opportunities. So too must micro-credentials, skills and lifelong learning – all education terms strongly associated with higher education. Their existence stresses the importance of providing ad-hoc and flexible short-term certifications of acquired competences, which fill in the increasing requirement of rapid adaptation to work in different new environments. This is an example of a structural shift in the educational system from learning once to learning always.

Sustainability and COVID-19, among other elements, are also key themes of the map structure. The sustainability factor indicates that the enhancement of upskilling led by university should comply with the sustainable development, regarding the interpersonal and the economy. In contrast, COVID-19 and its links to digital skills and online learning reframe the pandemic as an accelerant of transformative education – ramping up virtual response and uncovering the depp need for digital capability in society. Figure 6 shows the Pareto-Lorenz analysis for the most frequently occurring author keywords.

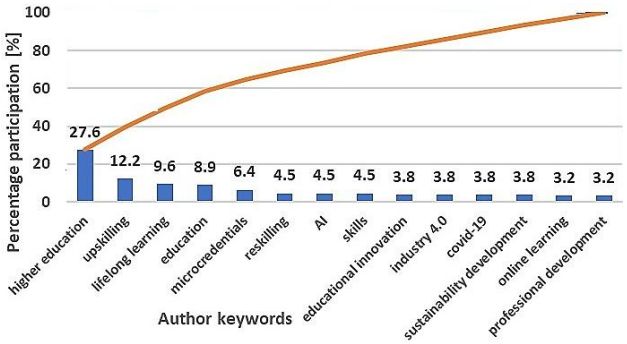

Fig. 6 The Pareto-Lorenz diagram for the most frequently occurring author keywords

The Pareto-Lorenz analysis (Fig. 6) reveals that 21.42% of the highest-frequency author keywords (e.g., "higher education," "upskilling," & "lifelong learning") constitute 49.4% of the author keyword frequency. The results support the importance of universities as upskilling agents. Fig. 7 presents co-occurrence index key words.

The green cluster comprises terms such as higher education, students, engineering education, curricula, educational innovations, learning systems and commerce. The links between these concepts suggest an evident concern in literature to orientate educative content to the necessities of post-industrial and technological society. Of particular importance is the nodes engineering education and educational innovations as these are related to the fourth industrial revolution and indicates a direction of curriculum development towards digital, technical, and practical competencies.

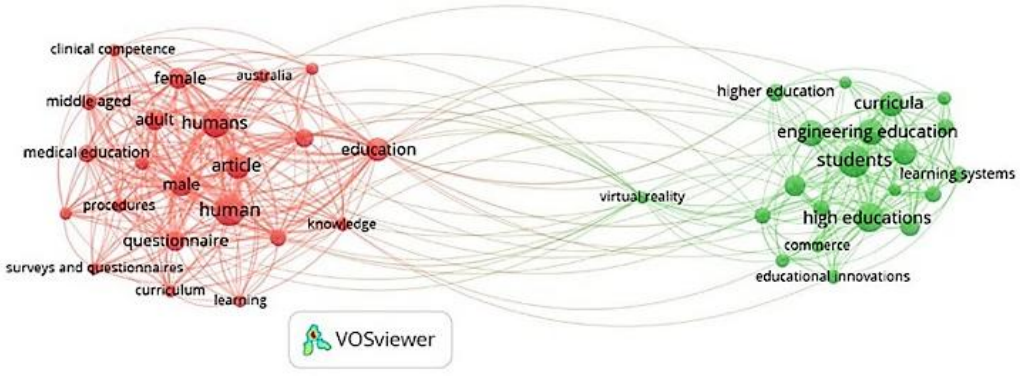

Fig. 7 Co-occurrence index key words (number of occurrence of a keyword 5)

The term virtual reality connects cluster green and red and lies at the center of the map. Its links with technology education and health education research point to the fact that immersive solutions such as VR are inherently transdisciplinary and can serve as means for upgrading ability of working with technology and for professionals working in other domains. This bolsters that digital innovations in

teaching have become one of the givens of contemporary higher education. Figure 8 shows the Pareto-Lorenz analysis for the most frequently occurring index keywords.

The Pareto-Lorenz analysis (Fig. 8) reveals that 21.42% of the highest-frequency author keywords (e.g., "students," "human," & "high education") constitute 38.3% of the index keyword frequency. The results justify the belief that students are crucial actors in upskilling programs, and show that academic and policy discourses meet around human-centered digital transformation.

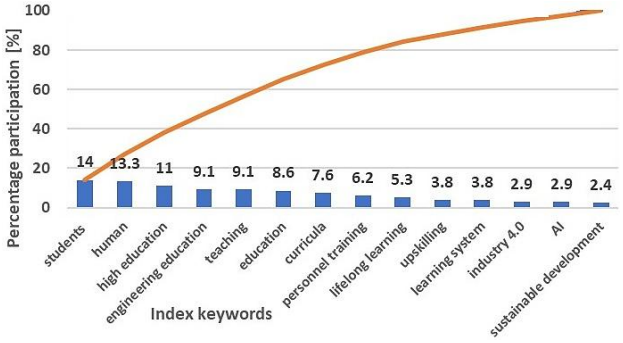

Fig. 8 The Pareto-Lorenz diagram for the most frequently occurring index keywords

FRAMEWORK MODEL FOR UNIVERSITY UPSKILLING STRATEGIES

HEIs are increasingly being projected as strategic actors in national and international upskilling ecosystems in response to ramping-up expectations of digital transformation, green transition and labour market turbulence [54, 55, 56]. Despite a variety of one-off interventions by universities – namely, from microcredentials to lifelong learning centres – the lack of a coherent conceptual framework tends to thwart scale, consistency and policy coherence and harmonization. The author aims to fill this research gap by providing a structured approach to analyze and assess university-led upskilling measures in the Industry 4.0 and digitalization era. Table 3 presents a six-dimensional strategy that singles out their institutional components vital to fostering a proper upskilling response. These are: curriculum flexibility, the labour market relationship, ethical and sustainable issues integration, digital infrastructure, pedagogical transformation and monitoring system(s).

Unlike standard industrial engineering programmes, the upskilling model envisaged here includes glocal learning paths, modular micro-credentials, and human-centered digital ethics, in support of developing not only technically proficient, but also socially aware and systemically adaptive professionals.

The matrix is based on a review of best practices in Europe, North America and Asia-Pacific and international recommendations (OECD, UNESCO, EU Skills Agenda) [29, 58, 59] (Fig. 9).

Table 3

A six-dimensional strategy fostering a proper upskilling response

Component	Description
Flexible Educational Formats	Higher education is adopting shorter, modular formats like microcredentials, blended learning, asynchronous, and hybrid courses. Flexibility also refers to the temporal and spatial reach of learning and participation in the form of work integrated learning (WIL) and distance education for working professionals and disadvantaged communities. These script formats should be associated with standard qualification frameworks (e.g. ECTS) and be interoperable between higher education institutions.
Strong Labour Market Linkage	Contemporary approaches need to work closely with industry and stakeholders. Together with employers, co-create educational programmes to identify key skills in demand (e.g. AI, DevOps, ESG reporting). Joint certification programs, internships, mentoring, and professional-led teaching are critical for matching output to market demand.
Integration of Green and Ethical Competencies (ESG)	Universities need to incorporate in their curriculua themes related to sustainability, such as life cycle assessment, renewable energy, ESG reporting, data ethics, algorithmic justice, and AI ethics. These capacities must be embedded across the spectrum of education, not only within the discrete courses, in the service of addressing, together, systemic sustainability challenges. The idea of fusion skills – the combination of technical skills, cognitive and social emotional skills – has recently taken center stage in global education policy discussions. As emphasized by the UNESCO-EIU report The Future of Work and Education (2033)[57], the successful upskilling should not focus only on isolated skills but on nurturing systemic intelligence through interdisciplinary learning. This means blending AI, data literacy and digital ethics with creativity, empathy and critical thinking; an approach that enables graduates to thrive in hybrid, fast-shaping job roles in digitalized economies.
Pedagogical and Technological Transformation	This is the transformation away from traditional didactic instruction toward active, constructivist learning models leveraged immersive and intelligent tools like VR, AI-based tutors, adaptive learning systems, and gamified learning. Bespoke learning journeys drive greater engagement and enhanced retention.
Digital Infrastructure and Data Governance	It's a comprehensive digital environment with learning management systems (LMS), credentialing platforms (i.e. digital badges), blockchain-based skills portfolios, and learning analytics dashboards. These structures enable real-time tracking of student performance, learning style recognition and instant curriculum optimization.
Monitoring and Evaluation Mechanisms	Any holistic approach must include ongoing impact assessment, based on data. This encompasses the evaluation of employment outcomes, career progress, the validation of certificates, and the acquisition of transversal competences. Feedback from students and industry should be included in formative (process focused) and summative (end product focused) assessment.

Fig. 9 Strategic Model for Higher Education Upskilling

The multi-criteria impact assessment model, defined in Table 4, provides the means by which HEIs and policy makers can assess the performance of upskilling initiatives.

It incorporates quantitative and qualitative indicators including graduate employability, recognition of credentials, teaching and research quality, staff-student ratios, doctoral degrees, international faculty, research papers and international collaborations among others.

Table 4

Higher Education Upskilling Impact Assessment Proposal

Indicator	Description
Graduate Employability and Career Mobility	Graduate tracer studies analyze survey responses regarding the post-program employment status at 6 months, 12 months, job sector changes, promotion rates, salaries increased. Furthermore, evaluations are made on the comparison between current jobs and attained skill profiles, also referred to as job-skill match. The data comes from alumni surveys, LinkedIn and public employment records.
Credential Recognition by Industry	Assessment concentrates on the volume of professional body-accredited microcredentials, the scale of university-industry co-development of courses, and the use of these credentials in recruitment. In addition, integration with systems such as Credly, OpenBadges or Europass is a related benchmark to be scrutinized.
Learner Feedback and Soft Skills Development	Comes with pre/post ability self evaluations, skill specific tests and comments. Universities can also employ peer-review systems, e-portfolios, gamified feedback tools and student retention metrics to track learner's development across these transferable skills, with a focus on teamwork, communication and problem solving.
Alignment with Megatrends and Labour Market Needs	Curriculum mapping against international skills frameworks (WEF, OECD, CEDEFOP), labor market insights from platforms such as LinkedIn or Burning Glass, and interviews with sectoral skills councils. That keeps us in line with the new challenges related to AI, ESG, digital health and data-driven services.

The model facilitates the evidence-based decision-making and continuous programme improvement (Fig. 10).

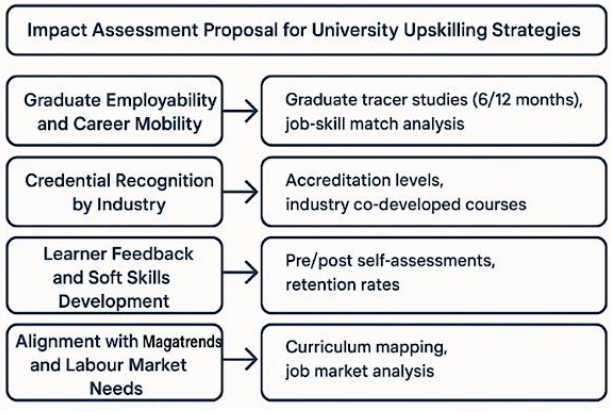

Fig. 10 Impact Assessment Proposal for University Upskilling

Strategies

DISCUSSION

The technology skills courses for the digitalization and electromobility, however, represents the contemporary upskilling strategies in higher education that may not only focus on providing technical skills on digitalization of business systems. The analysis indicate that a successful institutional response to the challenges of industrial and ecological transformation demands radical transformations of pedagogical models, institutional structures, and academic-student relationships [39].

The first, is the traditional academic task of being a transmitter to exper of knowledge, with the task of facilitating learning processes [60, 61]. This transformation implies assisting students in the conception of their own personal learning journey, taking into account both formal and

informal learning resources, as well as promoting reflection and metacognitive awareness. In this role, the educator is a curator and guide of digital material in a complex educational landscape where learning is based on micro-credentials and modular learning experiences [62, 63].

Second, the discussion calls attention to the increasing relevance of cross-cutting competencies, that is, those skills that transcend specific fields of knowledge and prepare people to respond to an changing labor market. That includes digital ethics, intercultural communication, teamwork, and problem solving in automated or AI-driven settings. Consequently, upskilling programs should combine soft skills and digital literacies; they must educate for the demands of the economy and of society [25, 64].

The third dimension of change is a move to learner-centered personalisation – where flexible, modular and stackable learning pathways are personalized to individual needs [65, 66]. The analysis highlights the importance of personal competency portfolios facilitated by technologies such as blockchain and e-portfolios that allow learners to record, aggregate, and transfer micro-credentials across sectors and institutions [8, 30, 51].

The lack of systematic and ongoing mechanisms to assess the quality and sustainability of upskilling programmes in HEIs was observed. While short courses and digital certifications have proliferated rapidly around us, very few organisations are assessing their impact on employability, career advancement and longterm competency development. This requires evidence-based assessment mechanisms which brings together learner feedback, labour market foresight and the recognition of learning outcomes at national and international qualifications levels.

The most recent labor market data only serves to further underline the need for upskilling as a structural response to a transformed world of work. A Forbes/RGP Pulse Survey [67] reports 45% of Financial Decision Makers plan to invest further in reskilling and upskilling of their current workforce, realizing that it is a strategic response to talent shortages, as well as a reaction to technology changing pace. And a World Economic Forum report referenced in the article says 58% of employees believe their skill sets will be completely different in five years, largely thanks to the growth of AI and big data. This increasing skills gap is met with unprecedented investment: Google announced a $75M fund for AI training grants, and Amazon's $1.2B upskilling initiative resulted in up to a 40% wage lift for its graduates. On a larger scale, the AI-Enabled ICT Workforce Consortium (which includes the likes of Cisco, IBM, SAP, and Microsoft) has established the goal of reaching 95 million learners worldwide with upskilling programs in the next 10 years. Most importantly, the importance of permanent learning is now universally recognised. The Human Progress Report [68] found that 85% of 17,000 individuals responding to the survey from around the world consider upskilling and reskilling to be a routine component of their career moving forward. Younger generations – especially Gen Z – prize such learning opportunities even more, associating them with purpose, engagement and career progression. They confirm that tertiary institutions need to reimagine themselves, not only as deliverers of foundational qualifications, but also as agile enablers of continuous, employment-relevant learning within the changing shape of the workforce landscape.

New perspectives such as those provided by the ETS Human Progress Report [69] only serve to underscore the increasing urgency for higher education institutions to reimagine their role in the context of a skills-based economy. Eighty-nine percent of HR decision-makers say skill-based credentials are crucial to closing the gap between education and career preparedness, the report said. Further, 81% of workers believe that over the next 15 years, skills and experience verification will be as important as, if not more important than, attending college. These are figures that suggest a fundamental change in how employers and workers see qualifications – they're calling for a more flexible, modular approach to credentialing.

The report also points out that 91% of HR leaders and 83% of employees see upskilling as being a must-have, not a nice-to-have, which implies that lifelong learning has become a structural must in the new world of work. But access to opportunity is also unequal: 86% of workers say skill certification has a direct impact on their employment opportunities, but informal skill assessments still reign in many industries, perpetuating inequity in the form of recognition. This emphasises the urgent importance for universities to put into place proper mechanisms for accrediting non-formal and informal learning. At the end of the day, 92% of HR professionals say that investing in upskilling pays off for organizations in the long run. Tertiary insitutions are therefore uniquely placed to co-design inclusive learning pathways and recognition mechanisms that empower and reskill individuals and enhance institutional relevance in a fast-changing world of work.

Creating further upskilling opportunities would cannot solely happen through expanding academic offers, but also require a shift in educational design. The evolution of higher education into a more dynamic ecosystem that cultivates personalized, evidence-informed skill development is a crucial step towards arming societies to manoeuvre the imperatives of the Fourth Industrial Revolution.

Upskilling is an evolving mode of strategic competency transformation – one which now incorporates more than just digital change (with an extended focus on digital adaptation) and cross-cutting understandings of ecological responsibility. As the main producer and intermediary of knowledge, universities have to operate as engines of this twofold transition – into digital excellence and into environmental custodianship.

In a period of swift technological change and environmental flux, universities will need to take a strategic approach to upskilling and reskilling that moves beyond traditional degrees. 21st century lifelong learning systems demand bite-sized, flexible and responsive formats with a utility that is in keeping with changing labour market requirements, most notably among adult and mid-career learners. Table 6 suggests a strategic framework which

identifies the critical areas for intervention to facilitate the integration of upskilling into higher education systems.

Table 6
Higher Education Upskilling Impact Assessment Proposal

Strategic area	Recommendation	Outcome
Qualification Frameworks & Recognition	Develop interoperable microcredential systems in line with ECTS and national qualification frameworks	Enhanced the visibility, transferability, and incorporation of open educational resources into formal learning paths.
Funding & Incentive Structures	Create dedicated financing instruments (such as educational cheques, or performance grants) for first course university system ratios	Increase access for working adults and underrepresented learners
Labour Market Alignment	Map and co-develop learning content with new skills bodies and sectoral skills councils	Improve the employability and relevance of programmes to the market reality at any moment in time
Programme Evaluation & Quality	Establish mechanisms for programme evaluation including tracking of graduates, feedback from learners and indicators for transversal and technical competences.	Facilitate iterative refinement and relevance of up-skill programs
Infrastructure & Faculty Capacity	Invest in digital landscapes (such as LMS and credentialing platforms) and upskill academic staff on modular, tech-enabled learning	Facilitate scalability, customization and legitimacy of learning pathways via institutional readiness

Each aspect is associated to a practical suggestion and a systemic effect. The framework should be adaptable to national and institutional circumstances and collecting evidence to evaluate provision can be used as the basis for policy planning, institutional roadmaps or for benchmarking purposes at both European and global levels. Such recommendations are intended to assist the alignment of microcredentials with qualification frameworks; support sustainable funding models; improve engagement with industry; and enable the quality and relevance of learning outcomes with strong data and infrastructure systems.

CONCLUSION

This study has highlighted the central role of higher education institutions (HEIs) in preparing learners for the dual transitions, the digital and green transitions, which are transforming the global labour market. Mapping these institutional responses through more flexible formats such as micro-credentials, hybrid learning and immersive technologies, we have demonstrated that not only is higher education responding pedagogically to contemporary labour market needs, it is also responding structurally. The results confirmed that successful upskilling initiatives need to go beyond technical training only. They must be drivers of cross-disciplinary or even transversal competences – like systemic thinking, digital ethics, intercultural co-operation and adaptive learning – which are key for coping with volatile job conditions. The move away from transmission teaching towards learner-focussed, modular learning pathways represents a reconceptualisation of academic agency: learners, increasingly, are becoming curators of their own portfolios of competences beyond the years of transition, across school and national borders. Further, our conceptualization suggests a six-factor framework to develop, implement, and assess upskilling initiatives at the university level. Among them we can mention the labour-market co-creation, pedagogical innovation, the ethical orientation, the digital infrastructure and successful impact assessment systems. The escalated emphasis on fusion (technical + social-emotional + cognitive) skills, in light of recent global policy literature (e.g., UNESCO-EIU 2023), indicates that preparing graduates for the AI-driven and sustainability-oriented economy demands not only narrow-crusted technical training but holistic intelligence development. Another important observation is the absence of longitudinal monitoring frameworks in HE upskilling initiatives. However, rapid growth of such short-cycle qualifications leave us with scant assessment of their impact on career trajectories or longterm resilience. As such, in future educational policy there is a need to build in from the outset comprehensive, evidence-based evaluation systems that integrate learner feedback with employment tracking and skills recognition systems. Upon analysis, a word cloud was created to map the core concepts regarding the conceptual frame of the study (Fig. 11).

Fig. 11 Word cloud as a conceptual synthesis of higher education's response to digital transformation

The word cloud could be used as a general overview of the key research categories and strategic areas of activity of the higher education therein in relation to the digital and green transformation in the labour market. The words presented in the artwork represent both the present practices of curriculum-building and the skills we anticipate future graduates will bring with them into professional settings. The concepts found are grouped in three main areas:

(1) anticipation of the future,

(2) universities' institutional responses,
(3) education and employment technological metamorphosis processes.

Terms such as upskilling, microcredentials, fusion skills, AI, and ESG highlighting the complex and multilayered nature of modern education strategies, combining labour market needs with pedagogical innovation and systemic institutional responses. Their appearances in the academic literature and strategic policy documents reveal the growing trend of linking higher education to the demands of Industry 4.0 and the larger sustainable development agenda.

Research limitations: It is the product of theoretical conceptualization, secondary data sources, institutional cases examples, and global policy frameworks. Despite offering a comprehensive framework for upskilling initiatives in HE, it does not feature original empirical research (e.g. large-scale survey, ethnography and controlled intervention). The bibliometric analysis provides a window on thematic clusters but is an incomplete picture of national or institutional backgrounds, especially in the Global South. In addition, it would be useful to pilot the framework in individual HEIs and to validate it with comparative case studies. Finally, this study fails to account for cost-effectiveness or the institutional preparedness necessary to bring such disruptive models to scale.

Future directions: Based on the developed framework and analysis, future research and institution initiatives are encouraged to test and further develop the strategic upskilling model as proposed in this manuscript. An increasing area of concern is to think about how universities can scale institutionalizing modular learning ecosystems-in part by the development of open education resources (OERs), OER-agnostic interoperable microcredentialing systems and AI-supported personalization tools. In addition, longitudinal studies are needed to estimate the true labour market effects of microcredentials and hybrid learning pathways. Further, the identification follows on to studies tracking career paths and market-relevance of job-skills for program graduates and the nature of the recognition of SHC qualifications across sectors and national borders. Additional studies should also investigate the overlap between upscaling initiatives and questions of equity, digital inclusivity, and the agency of the learner, especially for adult learners and marginalised groups. Comparative policy studies – across global North-South, or across HE systems – would help shed light on other implementation models and institutional preparedness.

Practical implications: The strategy developed in this case study provides a complete and practical strategy for HEIs striving for better preparedness for lifelong learning and workforce upskilling in the fourth industrial revolution and continuous eco- and digital transitions. It offers conceptual direction as well as a concrete route map for institutional self-examination and planning. On a policy level, the results of this study can also contribute to the development of national and international education policy principles that serve as a guide for ministries, funders and innovation agencies in creating future-ready education systems. It would also assist the discussion by constructively informing the institutional strengths and gaps, informing evidence based interventions at institutional level driving inclusive and sustainable skills systems. The presented quality evaluation matrix provides a useful tool for HEIs which implement upskilling policies in their internal quality assurance. Connecting strategic pillars – digital infrastructure, co-creation with actors in the labour market and ethical competences – the matrix provides implementation focus points for an institution. Lastly, the study reinforces the relationship between the HEIs and the labour market by identifying priority areas for collaboration. It leads to a more strategic and proactive upskilling approach grounded in evidence, policy coherence, and shared responsibility among stakeholders.

Potential biases of the results: Nevertheless, this study has several limitations that could influence the generalizability and interpretation of the findings. The case studies selected are of innovative and forward-looking institutions, which might be out of line with a more diverse range of practices, in particular in non-resource endowed HEIs. This may lead to bias in favor of advanced institutional approaches. The bibliometric analysis was based only on the Scopus database. While Scopus is a reliable and high-quality source of peer-reviewed literature, however, it might not capture certain insights published in other regional, interdisciplinary or policy-oriented outlets, primarily not in English. A further limitation to our study is that, while our data synthesis draws on three data sources (policy documents, case studies and bibliometric clusters), this is still a qualitative interpretation, and therefore it may have some level of subjectivity despite its theoretical robustness. Although the interpretation process is methodologically transparent, it is critically reflexive of the researcher's positionality. Lastly, the time frame covered by the Scopus dataset (1989-2025) combines past and upcoming publications that may mask temporal trends and potentially hamper the longitudinal patterns comparison.

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Joanna Rosak-Szyrocka
ORCID ID: 0000-0002-5548-6787
Czestochowa University of Technology
Faculty of Management
Al. Armii Krajowej 19b, 42-200 Czestochowa, Poland
e-mail: joanna.rosak-szyrocka@wz.pcz.pl