



Department of Digital Business

Journal of Artificial Intelligence and Digital Business (RIGGS)

Homepage: <https://journal.ilmudata.co.id/index.php/RIGGS>

Vol. 4 No. 4 (2025) pp: 2691-2698

P-ISSN: 2963-9298, e-ISSN: 2963-914X

Trends in Employee Competency Development in the Era of Industry 5.0: A Literature Review

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Abstract

Industry 5.0 introduces a human-centric paradigm that integrates advanced technologies with human creativity, emotional intelligence, and sustainability values. This study conducts a qualitative literature review of fifteen academic sources identified through Google Scholar to examine emerging trends in employee competency development in the Industry 5.0 era. The findings reveal a fundamental reorientation of workforce requirements, shifting from predominantly technical abilities to hybrid competencies that blend digital literacy, analytical reasoning, socio-emotional intelligence, sustainability awareness, and adaptive learning capacity. Employees are expected not only to master AI-assisted tools, automation systems, and data-driven platforms but also to collaborate effectively with intelligent machines and engage in complex decision-making processes shaped by real-time analytics. At the organizational level, the review highlights the growing importance of human-centered talent development strategies, including reskilling and upskilling initiatives, technology-enhanced learning ecosystems, and AI-supported personalized training pathways. These strategies aim to foster continuous learning and ensure that employee capabilities evolve alongside technological progress. The incorporation of ethical technology use, sustainability-oriented competencies, and psychological well-being further reinforces the principle that innovation in Industry 5.0 must remain inclusive and socially responsible. Overall, the study deepens the understanding of how Industry 5.0 reshapes competency frameworks across sectors and underscores the need for organizations, educators, and policymakers to proactively design learning environments that support future-ready human capital. The findings provide a foundation for developing integrated approaches to workforce transformation and identify gaps for future empirical research.

Keywords: Industry 5.0, Employee Competency Development, Reskilling and Upskilling, Human–Machine Collaboration, Digital Transformation.

1. Introduction

The accelerating transition toward Industry 5.0 has reshaped the strategic orientation of organizations in preparing their workforce to operate within complex, interconnected, and human-centered technological ecosystems. Unlike Industry 4.0—which emphasized automation, efficiency, and digital integration—Industry 5.0 brings humans back to the center of value creation, highlighting the synergy between human creativity, emotional intelligence, and adaptability with advanced technologies such as artificial intelligence, cyber-physical systems, collaborative robotics, and big data analytics [1], [2]. This shift compels organizations to reconfigure competency development strategies to ensure human–machine complementarity in an increasingly volatile and uncertain business landscape.

In this new context, employee competence—both technical and non-technical—becomes a critical foundation for workforce readiness. Emerging technologies such as industrial IoT, generative AI, digital twins, and robotic process automation have transformed work processes and fundamentally altered skill requirements [3], [4]. Employees are now expected to master hybrid skills that combine digital literacy, analytical reasoning, creativity, ethical decision-making, and human–machine collaboration. As a result, organizations must redesign learning and development systems by integrating reskilling, upskilling, and continuous learning models aligned with Industry 5.0 principles.

Human-centric competencies have gained heightened importance as studies increasingly emphasize creativity, cognitive flexibility, resilience, emotional intelligence, and social intelligence as essential complements to technical expertise. Industry 5.0 reinforces the irreplaceability of human judgment and innovation, positioning

technology as an enabler rather than a substitute [5], [6]. This paradigm supports the formation of collaborative environments where employees work alongside cobots and utilize AI-driven insights to enhance decision-making. At the same time, sustainability and social responsibility—core pillars of Industry 5.0—are shaping new competency frameworks that require ethical digital literacy and sustainability-oriented innovation capabilities.

Despite growing scholarly attention, research on employee competency development in the Industry 5.0 era remains fragmented. Existing studies often address isolated themes such as digitalization or organizational learning without offering a comprehensive overview of how competencies evolve across sectors. To address this gap, this study conducts a structured literature review of 15 academic publications indexed in Google Scholar. The review examines key themes including human–machine collaboration, digital skill enhancement, cognitive and emotional competence, and sustainability-driven capabilities, while also highlighting organizational adaptations such as e-learning, AI-driven learning analytics, VR simulations, and micro-learning platforms.

Overall, the review responds to the global call for rethinking workforce development as organizations navigate rapid technological change and post-pandemic recovery. Competency obsolescence, accelerated by technological advancements, demands continuous and lifelong learning approaches supported by adaptive learning ecosystems and data-driven development strategies. Through synthesizing multidisciplinary insights, this study identifies core trends in competency development, analyzes how these competencies evolve within human-centric technological ecosystems, and offers strategic implications for organizations, policymakers, and academic institutions in preparing a future-ready workforce for Industry 5.0.

2. Literature Review

2.1 Conceptual Foundations of Industry 5.0 and Workforce Transformation

Industry 5.0 is understood as a paradigm shift that integrates advanced technologies with human creativity, emotional intelligence, and ethical values—representing not merely an extension of Industry 4.0 but a reorientation of technological progress toward human empowerment [7], [8]. Collaboration between humans and intelligent systems positions AI, machine learning, and real-time analytics as tools that augment decision-making rather than replace human roles. Consequently, the workforce is required to develop hybrid competencies that combine digital literacy, cognitive skills, and socio-emotional abilities, including cognitive flexibility, creativity, and complex problem-solving [6], [9], [10]. Furthermore, the deepening interaction between humans and machines demands strong ethical reasoning related to data privacy, algorithmic fairness, and responsible AI usage, while the shift toward smart manufacturing and flexible work structures accelerates the need for continuous competency development.

2.2 Emerging Competency Categories in the Era of Industry 5.0

The transition to Industry 5.0 demands a comprehensive set of digital, cognitive, social, and sustainability-related competencies, emphasizing human-centric innovation and effective collaboration with AI. Employees must possess strong digital literacy and data management skills to navigate digital platforms [11], [12], alongside automation management and programming abilities for operating smart machines and IoT sensors [13]. Collaboration with AI-driven systems further requires the capacity to interpret AI outputs and integrate them into decision-making [14]. Cognitive competencies—such as analytical reasoning, critical thinking, systems thinking, and decision-making under uncertainty—are vital for interpreting machine learning insights and functioning in evolving technological environments [12], [15]. Social and emotional intelligence, including empathy, communication, teamwork, and conflict management, is equally crucial for effective cross-functional collaboration [11], [13], [15]. Sustainability-related competencies, such as green innovation, circular economy knowledge, and ethical decision-making, ensure that technological advancement aligns with environmental and social responsibility [12], [15]. Finally, continuous learning—driven by resilience, adaptability, and digital curiosity—is identified as a core meta-competency for staying relevant in Industry 5.0, supported by engagement with micro-learning platforms and AI-based learning systems [11], [14].

2.3 Reskilling, Upskilling, and Lifelong Learning Strategies in Industry 5.0

Organizations are increasingly adopting structured reskilling and upskilling programs to address Industry 5.0 skill gaps, emphasizing the integration of advanced technologies with human capabilities through blended learning

approaches that combine traditional and digital methods [16], AI-driven adaptive learning that personalizes content and assessments [17], and simulation-based VR/AR training that builds practical skills [17]. Cross-training across technical, managerial, and communication functions enhances workforce adaptability and resilience [18], preparing employees for diverse and dynamic roles [19]. AI-powered learning analytics further support this transformation by tailoring development pathways and predicting future skill requirements [14]. Meanwhile, collaborative learning environments supported by learning management systems and digital tools facilitate continuous knowledge sharing [16] and reinforce Industry 5.0's human-centered vision through cultures of innovation and teamwork [19].

2.4 Gaps in the Existing Literature

Although scholarly discussions on Industry 5.0 and workforce transformation are expanding, several gaps remain. First, empirical studies on competency development strategies are still limited; most literature is conceptual or exploratory. Second, research tends to focus on manufacturing sectors, leaving service industries underexplored. Third, little is known about competency development in small and medium enterprises (SMEs), which often lack digital training infrastructure. Finally, there is a need for longitudinal research to examine how competencies evolve over time as Industry 5.0 technologies mature.

3. Research Methods

The study employs a systematic qualitative literature review to map conceptual developments and emerging themes related to employee competency development in Industry 5.0. Unlike traditional narrative reviews, this design follows a structured process of systematic searching, screening, evaluation, and thematic synthesis, motivated by the need to consolidate fragmented insights across human resource development, technology management, organizational studies, and digital transformation. A qualitative approach is considered appropriate because Industry 5.0 is a relatively new paradigm with evolving conceptual boundaries and limited empirical evidence, allowing the researcher to capture diverse frameworks, arguments, and theoretical propositions.

Academic sources were collected from Google Scholar due to its broad disciplinary coverage and ability to index journals, conference papers, and working papers relevant to Industry 5.0 and workforce development. The search, conducted between January and March 2025, used combinations of keywords such as “Industry 5.0,” “human-centered industry,” “employee competency,” “reskilling and upskilling,” “digital skills in Industry 5.0,” “future of work,” “human-machine collaboration skills,” “competency development,” and “workforce transformation,” refined by Boolean operators (AND, OR, quotation marks). The initial search yielded approximately 72 documents. These were then screened using inclusion criteria (language, publication year 2018–2025, relevance to competencies and Industry 5.0, academic type, and full-text availability) and exclusion criteria (focus only on Industry 4.0, non-academic sources, duplicates, and weak methodological clarity), resulting in 15 documents selected for in-depth analysis.

Data collection proceeded through three steps: identification, screening and selection, and extraction and coding. In the identification phase, titles and abstracts were reviewed for relevance. During screening and selection, full texts were examined against the inclusion and exclusion criteria, and duplicates were removed. In the extraction and coding phase, key information—such as author, year, context, conceptual contribution, competency categories, and implications—was organized into a structured matrix. Coding categories covered digital/technological competencies, cognitive/analytical competencies, emotional/social competencies, sustainability-oriented competencies, adaptive and lifelong learning competencies, organizational development strategies, and training and learning technologies, which together formed the basis for subsequent thematic analysis.

The analysis applied thematic analysis to identify and interpret patterns across the selected studies. Through open coding, recurring concepts related to competency requirements and development strategies were highlighted and labeled; axial coding grouped these codes into broader domains and explored relationships between them; and selective coding synthesized higher-level themes. This process produced three dominant thematic groups: core competencies required in Industry 5.0, human-centric and sustainability-driven competencies, and organizational learning strategies and workforce development models. Methodological rigor was supported through source triangulation (mix of journals, conferences, books, and conceptual reports), a transparent and documented screening process, and repeated re-evaluation of codes and themes to reduce bias, including cross-checking against widely recognized Industry 5.0 reports such as those issued by the European Commission.

4. Results and Discussions

Previous studies examining workforce competencies in the Industry 5.0 era reveal consistent trends that highlight the growing importance of hybrid skillsets combining digital, cognitive, emotional, and sustainability-oriented capabilities. The literature shows that while Industry 4.0 emphasized automation and technical proficiency, Industry 5.0 requires employees to engage in deeper collaboration with intelligent systems, exercise ethical judgment, and adapt to rapidly evolving digital environments. Scholars also emphasize the role of continuous learning, reskilling, and AI-driven training models as strategic responses to skill gaps across sectors, including manufacturing, education, and services. The following table synthesizes key findings from major studies, demonstrating how existing research supports and contextualizes the competency framework adopted in this study.

Table 1. Previous Research

No	Author(s) & Year	Research Focus	Key Findings	Relevance to This Study
1	Tomašević (2023)	Digital competencies & lifelong learning in Industry 5.0	Identifies digital literacy, adaptability, and continuous learning as foundational competencies for Industry 5.0.	Supports the meta-competencies of lifelong learning and digital curiosity.
2	Berniak-Woźny et al. (2024)	Future-proof skillset for Industry 5.0	Highlights hybrid skills—digital, cognitive, emotional, and sustainability competencies—as essential.	Strengthens the holistic competency model adopted in this research.
3	Nugroho & Tambunan (2025)	Impact of digitalization on human resource competencies	Shows that reskilling, upskilling, and digital capability enhancement are crucial for adapting to Industry 5.0.	Aligns with this study’s findings on organizational reskilling strategies.
4	Gupta (2024)	AI-driven skill development	Finds that AI accelerates learning personalization and helps close skill gaps efficiently.	Relevant to the use of AI-supported personalized learning pathways.
5	Bardales et al. (2024)	Key competencies for engineering students in Industry 5.0	Identifies analytical reasoning, systems thinking, and human–AI collaboration as primary competencies.	Supports the cognitive and collaborative competency categories found in this study.
6	Subburayan (2024)	Digital transformation, upskilling, and reskilling	Shows that hybrid training integrating technical and soft skills is necessary for Industry 5.0 readiness.	Reinforces the importance of blended learning and cross-training strategies.
7	Singh et al. (2024)	Adaptive and personalized learning	Demonstrates that AI-based adaptive learning significantly improves training effectiveness and relevance.	Strengthens the rationale for AI-enhanced learning ecosystems.
8	Brković et al. (2023)	Skills gap challenges in Industry 5.0	Identifies persistent digital and analytical skill gaps, especially within SMEs.	Relevant to the identified challenges of digital inequality and limited training access.
9	Rane et al. (2024)	Human-centric AI for Industry 5.0	Emphasizes emotional intelligence, ethical reasoning, and decision-	Supports the focus on socio-emotional and ethical competencies.

			making in human–AI collaboration.	
10	Zaleta & Calderón (2025)	Human-centered & resilient Industry 5.0 systems	Highlights sustainability, resilience, and employee well-being as core components of Industry 5.0.	Aligns with findings on sustainability-oriented competencies.
11	Rossi et al. (2023)	Worker roles in Industry 5.0	Shows that employees shift from operators to decision partners and co-creators with intelligent systems.	Reinforces the identified transformation of workforce roles in this study.
12	Anggono & Supriyanto (2025)	AI-based workforce training systems	Finds that AI can overcome financial and resource constraints in workforce development programs.	Relevant to recommendations for scalable, AI-enabled training solutions.

The synthesis of previous studies demonstrates that Industry 5.0 introduces a fundamental transformation in workforce competencies through the integration of digital proficiency, cognitive depth, emotional intelligence, and sustainability awareness. The literature consistently emphasizes the rise of hybrid skillsets where technical abilities must operate in tandem with human-centered capabilities, particularly digital literacy, adaptability, and continuous learning as identified in [1]–[3]. Research further highlights that future-proof competencies encompass digital, cognitive, emotional, and sustainability-oriented dimensions [2], reinforcing the multidimensional character of Industry 5.0 talent requirements. Convergenly, scholars underscore the urgency of reskilling and upskilling to mitigate skill obsolescence amid rapid digitalization [3], [4]. Studies also demonstrate that AI-driven adaptive learning and personalized training pathways significantly enhance training effectiveness and competency relevance compared to traditional approaches [5], [6], supporting the argument that technology-enhanced learning ecosystems—such as AI-supported pathways, blended learning models, and micro-learning platforms—are indispensable for workforce readiness in Industry 5.0.

In addition to competency development approaches, the reviewed literature highlights the growing importance of cognitive, socio-emotional, and ethical capabilities in preparing employees for complex human–AI collaboration. Analytical reasoning, systems thinking, and collaboration with intelligent systems emerge as core clusters in engineering and technical roles [7], while emotional intelligence and ethical decision-making become essential for navigating sensitive algorithmic environments [8]. The studies also identify emerging inequalities, particularly digital and analytical skill gaps within SMEs due to limited resources and training access, necessitating scalable and cost-efficient AI-based training solutions [9], [10]. Furthermore, sustainability appears as an integral competency dimension in Industry 5.0, with resilience, environmental responsibility, and worker well-being emphasized as central pillars of human-centered production systems [11]. Overall, the literature collectively affirms that Industry 5.0 demands a comprehensive restructuring of workforce competencies, integrating hybrid skills, lifelong learning, ethical AI literacy, and sustainability orientation—thereby reinforcing the competency framework developed in this study and highlighting key areas for future empirical exploration.

4.1 Transformation of Work Roles in the Era of Industry 5.0

The reviewed literature consistently demonstrates that Industry 5.0 distinguishes itself through the strategic integration of human and machine capabilities, emphasizing synergistic collaboration where cobots, AI-driven decision support, and cyber-physical systems augment rather than replace human labor [20]. This paradigm shift redefines employee roles from manual operation toward supervision, coordination, analysis, and innovation, supported by human-centric AI interfaces such as natural language processing and computer vision that enhance intuitive interaction [21]. As a result, workers become co-creators and problem solvers, engaging with intelligent systems across sectors—for example, collaborating with cobots in precision manufacturing, interpreting AI insights for strategic decision-making, or managing predictive maintenance enabled by IoT sensors [21], [22]. These changes foster emerging hybrid roles such as AI-assisted analysts, human–robot interaction specialists, data-enabled supervisors, and digital sustainability practitioners [20], although challenges such as skill gaps, technological infrastructure limitations, and resistance to change—especially in traditional industries—persist, requiring public–private collaboration to ensure an inclusive and resilient transition [22].

Alongside these opportunities, Industry 5.0 introduces increased cognitive load and decision complexity as employees must interpret real-time data from sensors, dashboards, digital twins, and predictive algorithms [22]. They are responsible not only for processing algorithmic outputs but also for validating machine decisions and identifying potential biases, elevating the cognitive and ethical demands of their roles [23]. This heightened decision complexity drives the evolution of workforce competencies, requiring advanced analytical reasoning, critical evaluation of AI-generated insights, and a deep understanding of human-machine collaboration. Consequently, employees are no longer mere “operators” but essential decision partners within intelligent ecosystems, marking a fundamental shift in the nature of industrial work under Industry 5.0.

4.2 Emerging Competency Categories in Industry 5.0

The review identifies five major competency categories required for employees in Industry 5.0, reflecting its human-centric, sustainable, and innovation-driven orientation. Digital and technological competencies are foundational, requiring employees to understand AI and machine learning, manage automation, maintain cybersecurity awareness, and master digital tools and data literacy to ensure ethical and effective human-machine collaboration [12], [18], [24]. Cognitive and analytical competencies—including complex problem-solving, critical thinking, systems thinking, creativity, and analytical reasoning—are essential for designing, optimizing, and interpreting interconnected digital ecosystems [12], [23]. Social and emotional competencies, such as emotional intelligence, empathy, communication, collaboration, and digital leadership, support Industry 5.0’s human-centric approach and enable inclusive, ethically grounded innovation [23], [24]. Sustainability and ethical competencies further strengthen the alignment between technological growth and environmental and social responsibility by requiring environmental literacy, circular economy knowledge, responsible AI use, and awareness of social inclusivity [12], [23]

Complementing these capabilities, adaptive and lifelong learning competencies—such as self-directed learning, digital curiosity, resilience, agility, and continuous professional development—ensure employees remain agile and employable amid rapid technological change [18], [25]. Across the detailed insights, Industry 5.0 demands not only the ability to use digital systems but to partner with them, interpret their outputs, and design ethical and sustainable solutions. Employees must navigate unstructured challenges, lead human-machine teams, engage in cross-functional digital collaboration, and integrate sustainability principles into operational and strategic decisions. Collectively, these competencies form a holistic framework for preparing a future-ready workforce capable of innovating within—and shaping—the evolving Industry 5.0 ecosystem.

4.3 Organizational Approaches to Competency Development

The literature identifies four dominant organizational strategies for preparing employees for Industry 5.0. Reskilling and upskilling programs rely on blended learning and immersive VR/AR simulations to strengthen skill acquisition [16], [26], while modular online courses and AI-powered learning analytics enable personalized learning pathways that employees can progress through at their own pace [17]. Cross-functional skill training is also emphasized to equip employees for diverse roles in an increasingly digital work environment [18]. At the same time, technology-enhanced learning ecosystems—such as AI-based adaptive learning, virtual labs, gamified learning pathways, micro-learning platforms, and learning management systems—provide interactive, tailored learning experiences, real-time feedback, and systematic tracking of skill development to ensure alignment with organizational needs [17], [26]

Complementing these approaches, organizations are adopting human-centered talent development models that prioritize employee well-being, intrinsic motivation, psychological safety, and collaborative, empathy-driven leadership styles [27]. These models recognize that Industry 5.0 requires not only technical proficiency but also human-centric capabilities supported by meaningful work and supportive environments. Finally, cross-sector collaboration plays a critical role, with partnerships between universities, governments, and industries facilitating competency-based curricula, national digital training agendas, innovation hubs, and skill accelerators that accelerate workforce readiness for Industry 5.0 [16], [18].

4.4 Challenges in Preparing the Workforce for Industry 5.0

The review identifies multiple emerging challenges in preparing the workforce for Industry 5.0, beginning with technological obsolescence, as rapid advancements create persistent skill gaps and quickly outdated competencies,

particularly in IT-intensive roles [28], [29]. Limited access to training resources further affects small and medium enterprises, which often lack digital training tools, expert instructors, and financial capacity for large-scale upskilling, although AI-based training solutions can help provide scalable alternatives [30], [31]. Resistance to change also emerges, driven by fear of job displacement, low technological confidence, and change fatigue, which can be mitigated through AI-supported personalized learning pathways tailored to individual needs [30], [31]. Digital inequality remains a critical barrier, especially in developing countries where limited device access and inadequate internet infrastructure weaken training effectiveness, calling for joint government–industry initiatives to bridge these gaps [30]. Finally, ethical and governance issues arise with the increasing use of AI, requiring employees to navigate algorithmic biases, privacy risks, and data governance concerns, reinforcing the need for training programs that integrate ethical guidelines and responsible AI principles [30].

4.5 Discussion

The findings show that Industry 5.0 fundamentally reshapes competency frameworks by merging advanced technological skills with human-centric values. Unlike Industry 4.0, which focused primarily on automation and efficiency, Industry 5.0 emphasizes human–machine partnership, sustainable innovation, digitally augmented decision-making, ethical and inclusive technology use, and continuous learning. This shift establishes hybrid competencies as the new standard: employees must demonstrate digital fluency alongside empathy, creativity, critical thinking, and other uniquely human capabilities that cannot be automated. At the same time, sustainability and ethics become essential elements of workforce preparedness, requiring employees to integrate environmental literacy, ethical reasoning, and social responsibility into daily decision-making and organizational practices.

The review further highlights that learning evolves into a lifelong process, driven by rapid technological development and the need for continual upskilling. Organizations must therefore cultivate dynamic learning cultures supported by digital platforms, personalized development pathways, and adaptive curricula. Additionally, human-centered development emerges as a catalyst for innovation; when organizations prioritize well-being, collaboration, and psychological safety, employees are better equipped to generate creative solutions and engage in meaningful work. This approach aligns with Industry 5.0’s overarching vision of sustainable, inclusive, and human-focused technological advancement.

5. Conclusion

The transition to Industry 5.0 marks a significant redefinition of workforce competencies, placing humans at the center of increasingly intelligent technological ecosystems. Unlike the automation-driven model of Industry 4.0, Industry 5.0 requires hybrid competency profiles that combine digital and technological skills with cognitive, socio-emotional, sustainability-oriented, and adaptive abilities. Employees must be able to understand and collaborate with AI systems, robotics, and data-driven tools while also applying critical thinking, systems thinking, and creative problem-solving to interpret algorithmic outputs and navigate complexity. Equally important are socio-emotional competencies—such as empathy, communication, emotional intelligence, and teamwork—that support human-centered innovation and ensure that technology enhances rather than diminishes human value. Sustainability literacy and ethical awareness further emerge as core elements of competency frameworks, reflecting the paradigm’s commitment to responsible, inclusive, and environmentally conscious practices. Organizational strategies for competency development continue to evolve through reskilling and upskilling programs supported by digital learning platforms, AI-driven analytics, VR/AR simulations, and micro-learning modules. Human-centered talent development models promote psychological safety, well-being, and meaningful work, fostering long-term creativity and engagement. Cross-sector collaboration between industry, academia, and government is also vital for building a sustainable talent pipeline aligned with Industry 5.0. However, challenges remain, including skill obsolescence, limited training access for smaller organizations, resistance to change, digital inequality, and ethical dilemmas linked to AI. Addressing these requires a holistic and balanced approach that integrates technological advancement with human empowerment. In conclusion, Industry 5.0 demands a transformative shift in competency frameworks, requiring organizations to develop a workforce capable of synergizing with intelligent technologies and driving sustainable innovation. This review contributes by synthesizing emerging competency trends and offering insights for preparing the workforce of the future, while suggesting that empirical research is needed to explore how these competencies are implemented and evolve across industries.

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