Journal of Management and Creative Business
Volume 4, Nomor 3, July 2026
E-ISSN : 2962-1119; P-ISSN : 2962-0856, Hal. 505-517
DOI: https://doi.org/10.30640/jmcbus.v4i3.6877
Tersedia: https://jurnaluniv45sby.ac.id/index.php/jmcbus

Employee Competence Development Strategies for Industry 4.0 Readiness

(A Case Study in the Manufacturing Sector)

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Abstract*. This study aims to analyze employee competence development strategies in facing the industry 4.0 era within the manufacturing sector. Industry 4.0 transformation has encouraged manufacturing companies to adopt digital technologies, automation, smart production systems, and data-driven decision-making. These changes require employees to possess not only technical skills but also digital literacy, analytical capability, adaptability, collaboration, and readiness for continuous learning. This study employs a qualitative approach with a case study design. Data were collected through in-depth interviews, observation, and documentation involving parties directly engaged in competence development, such as human resource managers, production managers, supervisors, training officers, and production employees. The data were analyzed using thematic analysis through data reduction, coding, theme categorization, interpretation, and conclusion drawing. The findings reveal that employee competence development strategies are implemented through competence needs mapping, technology-based technical training, digital literacy improvement, upskilling, reskilling, work-based learning, supervisor mentoring, and periodic competence evaluation. The findings also indicate that the main barriers to competence development include digital literacy gaps, resistance to change, limited training time, production target pressure, and differences in employees' adaptive capabilities. This study concludes that the success of Industry 4.0 transformation in the manufacturing sector is strongly determined by the alignment between technology strategy and human resource development strategy. The contribution of this study lies in strengthening the understanding that employee competence development should be viewed as a strategic, continuous, and integrated process rather than merely a short-term technical training program.*

Keywords*: Competence Development; Employee Competence; HR Strategy; Industry 4.0; Manufacturing.*

Abstrak. Penelitian ini bertujuan untuk menganalisis strategi pengembangan kompetensi karyawan dalam menghadapi era Industri 4.0 pada sektor manufaktur. Transformasi Industri 4.0 telah mendorong perusahaan manufaktur untuk mengadopsi teknologi digital, otomatisasi, sistem produksi cerdas, serta pengambilan keputusan berbasis data. Perubahan tersebut menuntut karyawan untuk memiliki tidak hanya keterampilan teknis, tetapi juga literasi digital, kemampuan analitis, kemampuan beradaptasi, kolaborasi, serta kesiapan untuk terus belajar secara berkelanjutan. Penelitian ini menggunakan pendekatan kualitatif dengan desain studi kasus. Data dikumpulkan melalui wawancara mendalam, observasi, dan dokumentasi yang melibatkan pihak-pihak yang secara langsung terlibat dalam pengembangan kompetensi, seperti manajer sumber daya manusia, manajer produksi, supervisor, petugas pelatihan, dan karyawan produksi. Data dianalisis menggunakan analisis tematik melalui tahapan reduksi data, pengkodean, kategorisasi tema, interpretasi, dan penarikan kesimpulan. Hasil penelitian menunjukkan bahwa strategi pengembangan kompetensi karyawan diterapkan melalui pemetaan kebutuhan kompetensi, pelatihan teknis berbasis teknologi, peningkatan literasi digital, upskilling, reskilling, pembelajaran berbasis pekerjaan (work-based learning), pendampingan oleh supervisor, serta evaluasi kompetensi secara berkala. Temuan juga menunjukkan bahwa hambatan utama dalam pengembangan kompetensi meliputi kesenjangan literasi digital, resistensi terhadap perubahan, keterbatasan waktu pelatihan, tekanan target produksi, serta perbedaan kemampuan adaptasi karyawan. Penelitian ini menyimpulkan bahwa keberhasilan transformasi Industri 4.0 pada sektor manufaktur sangat ditentukan oleh keselarasan antara strategi teknologi dan strategi pengembangan sumber daya manusia. Kontribusi penelitian ini terletak pada penguatan pemahaman bahwa pengembangan kompetensi karyawan harus dipandang sebagai proses strategis, berkelanjutan, dan terintegrasi, bukan sekadar program pelatihan teknis jangka pendek.

Kata kunci: Industri 4.0; Kompetensi Karyawan; Manufaktur; Pengembangan Kompetensi; Strategi SDM.

Naskah Masuk: 21 April 2026; Revisi:24 Mei 2026; Diterima: 24 Juni 2026; Terbit: 03 Juli 2026

1. LATAR BELAKANG

The development of Industry 4.0 has fundamentally transformed how manufacturing firms design production systems, manage employees, and build competitive advantage. Technologies such as the Internet of Things, big data analytics, artificial intelligence, robotics, cloud computing, and cyber-physical systems are no longer supplementary tools but have become central components of industrial transformation. In the manufacturing sector, this transformation is reflected in increasingly automated, flexible, interconnected, and da-ta-driven production processes. Such changes affect not only machines and production systems but also the competencies of employees who operate, monitor, and improve or-ganizational work processes (Kagermann et al., 2013; Lasi et al., 2014; Schwab, 2016; Frank et al., 2019; Ghobakhloo, 2020).

Amid rapid industrial digitalization, employee competence has become a strategic factor determining the success of manufacturing firms in responding to technological change. Industry 4.0 requires workers who possess not only technical skills but also digital, analytical, collaborative, adaptive, and innovative capabilities. Employees are expected to understand new production technologies, interpret operational data, solve complex problems, and adapt to rapidly changing work processes. The Future of Jobs Report 2025 indicates that skills gaps remain one of the major barriers to business transformation, while analytical thinking, technological literacy, resilience, flexibility, and lifelong learning are among the most critical skills toward 2030.

In manufacturing, employee competence should not be understood merely as a short-term technical training issue. Industry 4.0 transforms the relationship between hu-mans, machines, data, and organizations. Routine jobs are increasingly automated, while emerging roles require the ability to integrate technical knowledge with data-driven deci-sion-making. This condition encourages manufacturing firms to develop more systematic competence strategies through reskilling, upskilling, digital learning, work-based training, knowledge management, and the strengthening of organizational learning culture (Hecklau et al., 2016; Prifti et al., 2017; Sony & Naik, 2020; Kipper et al., 2021; Miah et al., 2024).

Employee competence development strategy is crucial because technological invest-ment cannot generate optimal performance without workforce readiness. Many firms are capable of purchasing advanced technologies, but not all are able to transform employee competencies, mindsets, and work behavior accordingly. From the perspective of human capital theory, employee knowledge and skills represent productive assets that must be continuously developed (Becker, 1964). Similarly, the dynamic capabilities perspective argues

that organizations must be able to sense change, seize opportunities, and reconfigure re-sources to remain competitive in rapidly changing environments (Teece, 2018). Thus, competence development should not be viewed only as a training activity, but as a strategic process for building organizational readiness in response to technological disruption.

Previous studies indicate that Industry 4.0 competencies include technical, methodological, social, and personal dimensions. Technical competencies refer to the ability to use digital tools, automation systems, smart production technologies, and data analytics. Methodological competencies include problem-solving, decision-making, and systems thinking. Social competencies involve communication, cross-functional collaboration, and leadership in digital work environments. Personal competencies include flexibility, willingness to learn, discipline, and readiness to face uncertainty (Hecklau et al., 2016; Prifti et al., 2017; Cimini et al., 2020; Flores et al., 2020; Kowal et al., 2022). Therefore, manufacturing firms need an integrated competence development approach aligned with business strategy, technology strategy, and human resource management strategy.

Recent studies on digital transformation and human resource management also emphasize that HR functions are no longer limited to administrative roles but have become strategic partners in building workforce readiness. Digital HRM, talent management, HR analytics, and technology-based learning are essential instruments for identifying compe-tence gaps and designing relevant development programs (Bresciani et al., 2021; Vrontis et al., 2022; Murugesan et al., 2023; Eger & Žižka, 2024). Eger and Žižka (2024) show that digital transformation and HRM in the Industry 4.0 context are increasingly studied as strategic issues linking technology, human capabilities, and organizational change.

Although studies on Industry 4.0 competencies have grown significantly, several research gaps remain. Many studies focus on identifying required competencies, but fewer explain how competence development strategies are implemented at the organizational level, particularly in manufacturing firms. Several studies are also conceptual or survey-based, leaving limited understanding of how competence strategies are practiced in real workplace settings. In fact, each manufacturing company has different technological conditions, organizational culture, workforce quality, and learning capacity. A case study approach is therefore relevant because it can reveal processes, barriers, managerial support, and actual practices of employee competence development in facing Industry 4.0 (Yin, 2018; Senge, 2006; Kolb, 1984; Tortorella et al., 2020).

Based on this background, this study aims to analyze employee competence development strategies in facing the Industry 4.0 era within the manufacturing sector. The main focus is not only on identifying the competencies required, but also on examining how manufacturing firms design, implement, and evaluate employee competence development strategies. This study is expected to provide theoretical contributions to the literature on digital transformation-based human resource management and practical contributions for manufacturing firms in developing adaptive, measurable, and sustainable human resource development strategies.

2. KAJIAN TEORITIS

The theoretical review of this study is grounded in the understanding that employee competence development in the manufacturing sector cannot be separated from structural industrial changes caused by Industry 4.0. Industry 4.0 refers to the integration of production systems with digital technologies such as cyber-physical systems, the Internet of Things, big data analytics, artificial intelligence, robotics, cloud computing, and intelligent automation systems. In manufacturing, these technologies create production systems that are more connected, flexible, predictive, and data-driven. This transformation requires firms not only to modernize technology but also to develop human capabilities to work effectively in digital production environments (Kagermann et al., 2013; Lasi et al., 2014; Schwab, 2016; Xu et al., 2018; Frank et al., 2019; Ghobakhloo, 2020). Recent studies also confirm that Industry 4.0 directly affects skill requirements, workforce employability, and employee readiness for digital transformation.

Theoretically, employee competence development can be explained through human capital theory. This theory views employee knowledge, skills, experience, and abilities as productive capital that contributes to individual and organizational performance (Becker, 1964). In the Industry 4.0 era, human capital is no longer measured only by conventional work experience, but also by the ability to learn new technologies, understand data, adapt to digital work systems, and solve complex problems. Therefore, corporate investment in training, reskilling, and upskilling becomes a strategic mechanism for maintaining produc-tivity and competitiveness (Autor, 2015; Acemoglu & Restrepo, 2020; Li, 2022; Miah et al., 2024).

This study is also relevant to dynamic capabilities theory. Teece (2007, 2018) explains that organizations survive in dynamic environments when they are able to sense changes, seize opportunities, and reconfigure resources. In the context of Industry 4.0, dynamic ca-pabilities

are reflected in the ability of manufacturing firms to identify technological change, formulate competence development strategies, and adjust work structures and production processes. Employee competence development is part of dynamic capability because suc-cessful digital transformation depends not only on technology but also on the organization's ability to build human readiness continuously (Teece, 2007; Teece, 2018; Warner & Wäger, 2019; Vial, 2019; Bresciani et al., 2021).

Employee competence in Industry 4.0 is multidimensional. Hecklau et al. (2016) classify Industry 4.0 competencies into technical, methodological, social, and personal competen-cies. Technical competencies include the ability to use digital technologies, automation, smart production tools, data security, and information analysis. Methodological competencies in-clude problem-solving, systems thinking, decision-making, and complexity management. Social competencies include communication, teamwork, leadership, and cross-functional collaboration. Personal competencies include flexibility, willingness to learn, responsibility, and adaptability to change (Hecklau et al., 2016; Prifti et al., 2017; Fitsilis et al., 2018; Cimini et al., 2020; Flores et al., 2020; Kowal et al., 2022). This competence model shows that em-ployee readiness for Industry 4.0 cannot be developed through technical training alone.

In the manufacturing sector, digital competence is one of the most important foun-dations. Employees are required to understand data-based production systems, operate digital tools, interpret machine-generated information, use production software, and un-derstand the basic principles of human-machine interaction. Digital competence also in-cludes technological literacy, digital security awareness, the ability to use information systems, and readiness to work with automation technologies. Mudzar and Chew (2022) emphasize that Industry 4.0 skill requirements can be categorized into high-level technical skills, high-er-order cognitive skills, and human-interpersonal skills.

Employee competence development strategy can be understood as an organizationally systematic process of identifying competence gaps, designing learning programs, imple-menting training, evaluating outcomes, and integrating new competencies into work prac-tices. This strategy may include reskilling, which equips employees with new skills to perform different jobs, and upskilling, which improves existing skills so employees can perform more effectively in their current roles. In Industry 4.0, both approaches are crucial because technological change may eliminate some old jobs while creating new work roles (Li, 2022; Sony & Mekoth, 2022; Rizki, 2024; Kartika et al., 2026). Studies on reskilling and upskilling emphasize the importance of continuous learning, digitally enabled training, and managerial involvement in building a future-ready workforce.

This review is also connected to the theory of learning organization. Senge (2006) argues that a learning organization is built through systems thinking, personal mastery, mental models, shared vision, and team learning. In manufacturing firms facing Industry 4.0, learning organization becomes essential because technological change requires continuous learning. Competence development will not succeed if it is treated merely as a short-term training activity. Firms need to build a learning culture, experimentation space, knowledge transfer mechanisms, and work-based learning practices. In this context, Kolb's experiential learning theory is also relevant because employees acquire competence through cycles of concrete experience, reflection, conceptualization, and repeated practice (Kolb, 1984).

From the perspective of human resource management, digital transformation changes the role of HR from an administrative function into a strategic partner. HR must map competence needs, manage digital learning, develop talent, use HR analytics, and ensure that employee development strategies are aligned with the firm's technology strategy. Eger and Žižka (2024) show that the relationship between Industry 4.0, digital transformation, and HRM has become an important research theme because technological transformation re-quires human readiness and organizational change.

Based on these theoretical foundations, employee competence development strategy in facing Industry 4.0 can be formulated through several key elements: competence gap mapping, digital training, reskilling, upskilling, work-based learning, learning culture de-velopment, leadership support, and continuous evaluation. This strategy should not only aim to improve technical skills but also develop adaptive, collaborative, analytical, and innovative capabilities. Therefore, the theoretical framework of this study assumes that the success of manufacturing firms in facing Industry 4.0 is determined by the alignment between tech-nology strategy, human resource strategy, and employee competence development strategy.

3. METODE PENELITIAN

This study employs a qualitative approach with a case study design. This approach is appropriate because the study aims to gain an in-depth understanding of employee com-petence development strategies in facing the Industry 4.0 era within the manufacturing sector. The study does not seek to test statistical relationships among variables, but rather to explore processes, practices, barriers, and supporting factors within the organizational context.

The object of this study is the strategy of employee competence development in the context of Industry 4.0 transformation. The research subjects include individuals directly involved in planning, implementing, and evaluating competence development programs, such as HR managers, production managers, supervisors, training officers, and production employees. Informants are selected using purposive sampling, based on their knowledge, experience, and direct involvement in competence development and manufacturing transformation.

Data are collected through in-depth interviews, observation, and documentation. Interviews are used to explore informants' perspectives on competence needs, training programs, upskilling and reskilling strategies, and barriers to competence development. Observation is conducted to examine work practices, technology usage, and employee involvement in digital-based production processes. Documentation is used to analyze com-pany documents, including training programs, competence standards, employee evaluation reports, and HR development policies.

The data are analyzed using thematic analysis. The stages include data transcription, data reduction, coding, theme categorization, interpretation, and conclusion drawing. Data va-lidity is maintained through source and technique triangulation by comparing interview results, observation findings, and documentary evidence. Through this method, the study is expected to provide a comprehensive understanding of employee competence develop-ment strategies in the manufacturing sector in facing Industry 4.0.

Table 1. Operationalization of Research Variables

Variable/Concept	Operational Definition	Dimension	Indicator	Data Collection Technique
Employee Competence Development Strategy	The company's systematic efforts to improve employee capabilities in line with Industry 4.0 requirements	Competence needs analysis	Skill gap identification, training needs mapping, alignment of competencies with new technologies	Interview, documentation
Employee Competence Development Strategy	The company's systematic efforts to improve employee capabilities in line with Industry 4.0 requirements	Training program	Technical training, digital training, technology-based safety training, automated machine operation training	Interview, observation, documentation
Employee Competence Development Strategy	The company's systematic efforts to improve employee capabilities in line with Industry 4.0 requirements	Upskilling and reskilling	Improvement of existing skills, acquisition of new skills, job rotation, technical mentoring	Interview, observation
Employee Competence	The company's systematic efforts to	Competence evaluation	Training outcome assessment, performance	Interview, documentation

Development Strategy	improve employee capabilities in line with Industry 4.0 requirements		improvement, ability to use technology, supervisor feedback	
Industry 4.0 Competence	Employees' ability to work effectively in a digital manufacturing environment	Technical competence	Mastery of automated machines, use of digital tools, understanding of production systems, data literacy	Interview, observation
Industry 4.0 Competence	Employees' ability to work effectively in a digital manufacturing environment	Methodological competence	Problem-solving, analytical thinking, decision-making, data-based work capability	Interview, observation
Industry 4.0 Competence	Employees' ability to work effectively in a digital manufacturing environment	Social competence	Communication, teamwork, cross-functional collaboration, work leadership	Interview, observation
Industry 4.0 Competence	Employees' ability to work effectively in a digital manufacturing environment	Personal competence	Adaptability, willingness to learn, discipline, responsibility, readiness for change	Interview, observation
Supporting Factors	Organizational conditions that support the success of competence development	Organizational support	Management commitment, training budget, technological facilities, learning culture	Interview, documentation
Inhibiting Factors	Conditions that hinder employee competence development	Internal and external barriers	Employee resistance, limited time, limited cost, digital literacy gap, rapid technological change	Interview, observation

4. HASIL DAN PEMBAHASAN

The results indicate that employee competence development in the manufacturing sector is not only conducted through formal training, but also through work-based learning, mentoring, technology adaptation, and gradual reskilling. The company recognizes that Industry 4.0 requires employees to master digital tools, automated machines, data-based production systems, and more adaptive work behavior. However, the implementation of competence development still faces several challenges, particularly differences in digital literacy, employee resistance, limited training time, and uneven access to learning facilities.

Table 2. Research Findings

Main Theme	Key Findings	Interpretation
Competence Needs Analysis	The company identifies skill gaps through supervisor evaluation, production performance reports, and technology implementation needs.	Competence development begins with practical needs in the production process, not only formal HR planning.
Technical Competence Development	Employees receive training on automated machines, digital production systems, safety procedures, and basic data recording.	Technical training is the most dominant strategy because manufacturing work is directly affected by automation.

Digital Literacy	Some employees are able to adapt quickly, while others still face difficulties using digital tools and production software.	Digital literacy gaps become a major barrier in Industry 4.0 transformation.
Upskilling and Reskilling	Upskilling is conducted through machine-operation training, while reskilling is applied to employees whose tasks are affected by automation.	The company attempts to retain employees by shifting their skills rather than replacing them immediately.
Work-Based Learning	Employees learn directly through practice, peer support, supervisor guidance, and problem-solving in daily production activities.	Informal learning plays an important role in accelerating competence development.
Organizational Support	Management provides training programs, mentoring, and gradual technology introduction.	Leadership support strengthens employee readiness for technological change.
Main Barriers	Barriers include resistance to change, limited time, age differences, lack of digital confidence, and production targets.	Competence development requires cultural and psychological readiness, not only technical training.
Evaluation of Competence	Evaluation is conducted through performance achievement, error reduction, machine operation ability, and supervisor feedback.	Evaluation remains practical and performance-oriented, but needs more systematic competency measurement.

The findings show that competence development in the manufacturing sector is closely related to the company's readiness to face Industry 4.0. The implementation of automation, digital production systems, and data-based monitoring has created new competency demands for employees. Employees are no longer expected only to perform repetitive production tasks, but also to understand machines, interpret basic production data, solve operational problems, and adapt to new work systems. This finding supports the view that Industry 4.0 requires a combination of technical, methodological, social, and personal competencies. The most dominant strategy found in this study is technical competence development. The company prioritizes training related to machine operation, production software, digital reporting, and safety procedures. This condition is understandable because manufacturing transformation is usually first felt at the operational level. When machines become more automated and production systems become more digital, employees must be able to operate, monitor, and respond to technological changes. Without technical competence, investment in Industry 4.0 technology cannot produce optimal performance.

The study also found that digital literacy is a critical issue. Employees with younger age, higher educational background, or previous exposure to digital tools tend to adapt more quickly. Conversely, employees who are accustomed to manual systems often need more intensive assistance. This indicates that competence development cannot be designed with a one-size-fits-all approach. Training programs should be adjusted based on employee skill levels, job characteristics, and technological complexity. Another important finding is the use

of upskilling and reskilling. Upskilling is used to improve employees' existing abilities, especially in operating new machines and using digital production systems. Reskilling is applied when certain job tasks change because of automation. This strategy is important because it allows the company to maintain its workforce while preparing employees for new roles. In this context, competence development becomes not only a training program, but also a strategy for workforce sustainability. Work-based learning also plays a significant role. Employees develop competence through direct practice, mentoring, peer learning, and supervisor guidance. This finding indicates that formal training alone is not sufficient. In manufacturing environments, many competencies are formed through daily work experience, repeated practice, and direct problem-solving. Therefore, companies need to combine classroom training, digital learning, mentoring, and practical assignments.

The findings further show that organizational support is essential. Management commitment, training budget, technological facilities, and supervisor involvement influence the success of competence development. When leaders provide clear direction and support, employees are more willing to learn and adapt. However, when training is only treated as a routine administrative activity, competence development becomes less effective.

The main barriers identified in this study include resistance to change, limited training time, production pressure, age differences, and low digital confidence. These barriers show that Industry 4.0 transformation is not only a technological issue, but also a human and organizational issue. Employees may feel anxious about automation, fear losing their jobs, or feel unprepared to learn new systems. Therefore, companies need to communicate the purpose of transformation clearly and position technology as a tool to improve work, not merely as a replacement for human labor. Overall, the results indicate that effective competence development in the manufacturing sector requires an integrated strategy. Companies need to conduct competence mapping, provide continuous training, strengthen digital literacy, implement upskilling and reskilling, build work-based learning systems, and evaluate competence development more systematically. These findings contribute to human resource management literature by showing that employee competence development in Industry 4.0 should be understood as a strategic, continuous, and organization-wide process.

The practical implication of this study is that manufacturing companies need to design employee competence development as part of their digital transformation strategy. Training should not be conducted only after new technology is introduced, but should begin from competence gap analysis, employee readiness assessment, and long-term workforce planning. Companies also need to develop different training paths for different employee groups,

especially between digitally ready employees and employees who still need basic digital assistance. In conclusion, the results show that employee competence development in facing Industry 4.0 requires technical training, digital literacy improvement, upskilling, reskilling, work-based learning, and strong organizational support. The success of this strategy depends on the company's ability to align technology implementation with human resource development. Thus, Industry 4.0 transformation in the manufacturing sector will be more sustainable when technological change is accompanied by systematic employee competence development.

5. KESIMPULAN DAN SARAN

This study concludes that employee competence development strategies in facing Industry 4.0 in the manufacturing sector must be planned, continuous, and integrated with the company's digital transformation strategy. Competence development should not rely solely on technical training, but must also include digital literacy, analytical capability, adaptability, collaboration, problem-solving, and employee readiness to respond to technological change. The findings indicate that effective strategies include competence needs mapping, technology-based training, upskilling, reskilling, work-based learning, supervisor mentoring, and periodic competence evaluation. The implication of this study emphasizes that the success of Industry 4.0 transformation is determined not only by technological investment, but also by human resource readiness as the main driver of organizational change.

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