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A decade of logistics education research in the era of industry 4.0: A literature review on trends, challenges, and curriculum development

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Abstract: The industry 4.0 era has transformed logistics education by integrating advanced technologies such as artificial intelligence, Internet of Things, and big data analytics. The substantial gap between the competencies taught in educational institutions and the needs of the modern logistics industry demonstrates the need for a comprehensive analysis of the development of logistics education research. This research aims to analyse development trends, identify implementation challenges, and formulate strategies for the development of Industry 4.0 responsive logistics education curriculum. The systematic literature review method using the PRISMA framework was applied to 20 high-quality articles from the Scopus, Heliyon, Emerald Insight, Taylor & Francis Online, and SpringerLink databases for the period 2020-2025. The results of the study show a paradigmatic transformation from conventional approaches towards comprehensive digital technology integration, with research methodologies evolving from quantitative surveys to empirical analysis based on advanced technology. Implementation challenges include limited technological infrastructure, lecturer competency gaps, and varying student readiness. The conclusion of the study reveals the need for a holistic learning framework that integrates six main drivers with flipped classroom approaches and Outcome-Based Education. Curriculum development suggestions should integrate sustainability, resilience, and green innovation perspectives to prepare competent graduates to face the global logistics industry revolution.

Keywords: curriculum; digital technology; industry 4.0; logistics education; supply chain management

1. Introduction

Era Industry 4.0 has fundamentally transformed the landscape of logistics education by integrating advanced technologies such as Artificial Intelligence (AI), Internet of Things (IoT), and big data analytics into the higher education curriculum. The implementation of digital technology in logistics education can increase students' understanding of operational complexities Smart Logistics up to 75% (Gangle & Reddy, 2024). Higher education institutions in emerging economies face significant challenges in adapting logistics curricula to meet the needs of industries that are integrated with digital technology (Majeed et al., 2025). Through an analysis of 120 logistics study programs in various countries, it shows a substantial gap between the competencies taught in educational institutions and the needs of the modern logistics industry that applies technology Logistics 4.0 (Chen et al., 2022). A systematic analysis of the literature on logistics education in the last decade reveals the existence of gap significant research in understanding the evolution of logistics education

curriculum, particularly in integrating digital technology competencies with traditional supply chain management (SCM) skills. Identified that 65% of logistics education programs at universities have not optimally integrated technology-based learning Industry 4.0, while the logistics industry requires graduates who have the necessary hybrid between operational management and digital technology (Abdirad & Krishnan, 2020). In a systematic study, they found that the learning methodology in logistics education is still dominant using conventional approaches, with only 35% of institutions applying experiential learning and simulation of cutting-edge technology (Salinas-Navarro et al., 2022).

The novelty of this research lies in a systematic approach to analyse the development of logistics education over a decade in the context of Industry 4.0, with a special focus on identifying learning methodology trends, curriculum implementation challenges, and competency development strategies that are responsive to the needs of the modern logistics industry. In contrast to previous research that tended to be partial or limited to certain aspects, this study adopts a holistic approach to comprehensively understand the transformation of logistics education, including an analysis of the adaptation of educational institutions to technological disruptions and changes in industry expectations. Based on the identification of problems in the background, the formulation of this research problem is focused on three fundamental aspects. First, what are the trends in the development of logistics education research in the industry 4.0 era during the period 2015-2025, including the evolution of research topics, methodologies used, and research focuses that are developing along with the transformation of the logistics industry. Second, what challenges are faced by higher education institutions in implementing a logistics education curriculum that is responsive to the needs of Industry 4.0, including aspects of technological infrastructure, lecturer competence, and student readiness to adopt digital technology-based learning. Third, how an effective logistics education curriculum development strategy can be formulated to bridge the gap between the competencies taught in educational institutions and the needs of the logistics industry that is integrated with smart logistics technology and digital SCM.

This study aims to comprehensively analyse the development trends of logistics education research in the industry 4.0 era through a systematic literature review (SLR) of scientific publications for the period 2015-2025, by identifying the evolution patterns of research topics, the dominant methodologies used, and the scientific contributions that have been achieved. Furthermore, this study aims to identify and analyse the main challenges faced by higher education institutions in implementing logistics education curricula that are aligned with the needs of Industry 4.0, including structural, technological, and human resource barriers. The final goal of this study is to formulate strategic recommendations for the development of a logistics education curriculum that can produce graduates with hybrid competencies between traditional logistics management and digital technology, so that it can meet the expectations of the modern logistics industry that implements an integrated system based on artificial intelligence and automation.

This research makes a theoretical contribution to the scientific development of logistics education through a comprehensive synthesis of research developments in the last decade, which can be a baseline for future research in the field of logistics education and SCM. Practically, the results of this research can be used by higher education institutions as a guide in designing and implementing logistics education curriculum that is responsive to the dynamics of Industry 4.0, including the selection of effective learning methodologies and technology integration strategies in the learning process. For governments and higher education policymakers, this study provides evidence-based recommendations to formulate logistics education regulations and standards that support the development of quality human capital in the national logistics sector. The logistics industry can utilize the findings of this research to understand the capabilities of logistics education program

graduates and develop industry-academia collaboration programs that are more effective in preparing a competent workforce in accordance with the needs of modern logistics operations.

2. Methods

This study adopts a SLR approach using the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) framework as a methodological guide to ensure transparency, reproducibility, and quality of a systematic review process. The PRISMA methodology was chosen because it provides a clear structure in identifying, selecting, and synthesizing scientific literature comprehensively, thus allowing an objective analysis of the development of logistics education research in the industry 4.0 era. The framework also facilitates systematic documentation of all stages of research, from search strategies to data extraction and analysis, which supports the validity and reliability of research findings. The inclusion criteria for this study include scientific articles published in reputable and indexed journals Scopus in the period 2020-2025, using English as the language of instruction, and having direct relevance to the topics of logistics education, SCM curriculum, Industry 4.0 technology-based learning, and digital logistics competency development. Included articles must discuss aspects of education or learning in the context of logistics and SCM, including empirical, conceptual, and review studies that explore learning methodologies, curriculum development, or technology integration in logistics education. Exclusion criteria include articles that focus on the technical aspects of logistics operations without discussing the educational dimension, publications in the form of conference proceedings, book chapters, or grey literature, as well as articles that are not available in full-text or use languages other than English.

The literature search was conducted systematically through five major academic databases that are recognized as having a high reputation in management and educational research publications, namely Scopus as the primary database, Heliyon for open science access, Emerald Insight for management and supply chain journals, Taylor & Francis Online for multidisciplinary publications, and SpringerLink for technology and education journals. The selection of this database is based on the comprehensive coverage of journals in the fields of education, logistics management, and Industry 4.0 technology, as well as the ability to provide access to high-quality publications that have gone through a rigorous peer-review process. The implementation of SLR follows four main stages according to the PRISMA framework. The identification stage involves a comprehensive search using a combination of the keywords "logistics education", "supply chain education", "Industry 4.0", "curriculum development", and "digital learning" with Boolean operators to optimize search results across the target database. The screening stage is carried out through the evaluation of titles and abstracts to assess the relevance of articles to inclusion criteria, followed by the elimination of duplication and articles that do not meet temporal criteria. The eligibility assessment stage includes a full-text reading to evaluate the quality of the research methodology and its substantial relevance to the research focus, as well as an assessment of significant scientific contributions. The final stage, namely the synthesis of findings, is carried out through thematic analysis to identify patterns, trends, and research gaps that appear in the literature, using a systematic coding approach to categorize findings based on the dimensions of learning methodology, implementation challenges, and curriculum development strategies (Paul & Criado, 2020; Tranfield et al., 2003).

3. Results

Figure 1 shows the PRISMA flowchart that illustrates the systematic selection process of literature in the study "A Decade of Logistics Education Research in the Era of Industry 4.0: A Literature Review on Trends, Challenges, and Curriculum Development". The identification process began

with a search of databases and registers that yielded 309 journals. After deleting the duplicate of 102 journals, the remaining 207 journals then entered the screening stage. In the screening phase, 95 journals were excluded based on certain criteria, leaving 112 journals that were sought for retrieval. Of these, 56 journals were not successfully obtained, so 56 journals entered the eligibility assessment stage. In the final assessment process, 36 journals were excluded for various reasons including Reason 1 (20 journals) and Reason 2 (16 journals). Finally, 20 high-quality journals were successfully included in this literature review, which was further analysed to identify trends, challenges, and development of logistics education curriculum in the industry 4.0 era.

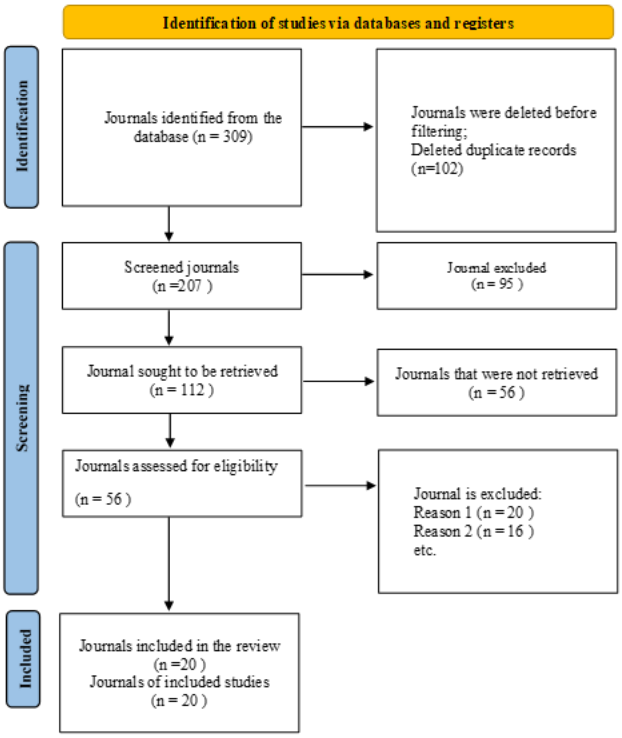

Figure 1. PRISMA flowchart

Table 1. Synthesis related to logistics education research in the era of industry 4.0

No	Journal title, author & year	Research focus	Trends	Challenges	Curriculum development	Key findings	Implication
1	Food sustainability 4.0: harnessing fourth industrial revolution technologies for sustainable food systems (Hassoun, 2025)	Application of Industry 4.0 technology in sustainable food systems	Integration of AI, IoT, big data analytics, robotics, and blockchain in the food supply chain	High implementation costs, infrastructure gaps, data privacy concerns, regulatory barriers	Development of a curriculum that integrates environmental, social, and economic dimensions in food logistics education	The convergence of AI, IoT, and robotics reduces food waste, energy consumption, and carbon emissions	There is a need to develop an interdisciplinary curriculum that combines digital technology with sustainability
2	Opportunities, challenges, and interventions for agriculture 4.0 adoption (Vijayakumar et al., 2025)	Agriculture 4.0 adoption and its implementation barriers	Data-driven transformation through IoT, AI, big data analytics, UAVs, and agricultural robots	High initial investment costs, land fragmentation, limited farmer awareness, lack of technical skills, low digital literacy	Development of farmer training programs, user-friendly algorithms, and versatile machines for small-scale agriculture	A multifaceted approach is needed including rural infrastructure investment and public-private partnerships	The agricultural logistics education curriculum should include practical and accessible technology training

No	Journal title, author & year	Research focus	Trends	Challenges	Curriculum development	Key findings	Implication
3	Feature extraction for artificial intelligence enabled food supply chain failure mode prediction (Trollman, 2024)	Feature extraction for food supply chain failure prediction using AI	Use of supervised learning algorithms and qualitative comparative analysis for prediction	Machine learning difficulties with large datasets and complex phenomena	Development of a manual approach to AI feature extraction with a focus on interpretability	Boolean logic-based approaches produce solutions that reflect complex causality	The curriculum needs to integrate an AI methodology that can be interpreted for managerial decision-making
4	Deciphering the impact of COVID-19 pandemic on food security across different socioeconomic strata in Chile (Donoso et al., 2025)	The impact of the COVID-19 pandemic on food security in Chile	Economic access assessment to food using the Almost Ideal Demand System	Limited data on food security in developing countries, uneven impact of the pandemic	Not explicitly mentioned, focusing on social protection policies	Low-income households experienced higher price increases post-pandemic	The logistics curriculum must include crisis management and supply chain resilience
5	Drought and consumption impacts of climate-smart-agricultural practices adoption in drought prone area of Eastern Hararghe, Ethiopia (Ahmed et al., 2025)	Adoption of climate-smart farming practices and their impact on consumption	Application of irrigation, crop diversification, and integrated soil fertility management	Dependence on rain-based agriculture, the impact of climate change	Development of weather information systems and extension services for farmers	Combination of climate-smart farming practices increases consumption expenditure by 72.4%	A curriculum that integrates climate change adaptation in agricultural logistics management is needed
6	Integrated algal and oil palm biorefinery as a model system for bioenergy co-generation with bioproducts and biopharmaceuticals (Abdullah & Hussein, 2021)	Integrated biorefinery system for sustainable bioenergy production	Integration of microalgae and palm oil for bioenergy and bioproduct production	The need for more environmentally friendly processes, strict regulations, and law enforcement	Development of microalgae research with nanotechnology for biopharmaceutical applications	Life-cycle analysis shows great potential for environmental remediation	The bioenergy logistics curriculum should include aspects of sustainability and green technology
7	Competency mapping to develop human resources for Indonesia's sugarcane agroindustry in the industry 4.0 era (Mursiti et al., 2024)	Mapping of human resource competencies for Indonesia's sugarcane agroindustry in the industry 4.0 era	Modernization of the sugar industry through new technologies, focusing on cut-load-transport parts	Old factory machinery, slow modernization of the sugar industry	Mapping of human resource competency units in the sugar production process, adoption of work competency standards	Cut-load-transport parts are a technological priority that must be replaced	Development of a competency-based curriculum for the sugar industry that is not yet available in Indonesia
8	Investment strategies in Industry 4.0 for enhanced supply chain resilience: an empirical analysis (Al-Banna et al., 2024)	Industry 4.0 investment strategy to increase supply chain resilience	Transition from traditional supply chain resilience to digital supply chain resilience	Balance between over-investment and under-investment risks, varied industry contexts	Not explicitly mentioned	The need for the right balance of investments to achieve resilience without sacrificing profitability	The curriculum should include technology investment strategies and risk management

No	Journal title, author & year	Research focus	Trends	Challenges	Curriculum development	Key findings	Implication
9	The effects of sustainability innovation and supply chain resilience on sustainability performance: Evidence from China's cold chain logistics industry (Zhang & Mohammad, 2024)	The impact of sustainable innovation and supply chain resilience on sustainability performance	Focus on cold chain logistics with an emphasis on continuous innovation	The complexity of the relationship between economic, environmental, and social performance	Not explicitly mentioned, focus on innovative strategies and resilience	Sustainable innovation and supply chain resilience have a positive effect on the three pillars of sustainability performance	The cold logistics curriculum must integrate aspects of sustainability and innovation
10	Effects of authentic leadership, employee resilience, job satisfaction, and innovative work behavior on employee work performance in transport and logistics of Thailand (Srimongkolkul et al., 2025)	The influence of authentic leadership on employee performance in Thailand's logistics sector	Focus on authentic leadership and innovative work behavior	Increased stress and workload can reduce job satisfaction	Not explicitly mentioned	Authentic leadership has a direct impact on employee performance, especially by moderating employee resilience	Development of leadership curriculum and HR management in logistics education
11	A text mining study of competencies in modern supply chain management with skillset mapping (Kang et al., 2025)	Competency study in modern SCM using text mining	Shift towards advanced technology capabilities in SCM	The gap between the competencies highlighted in the job advertisement and the skills required	Recommendations for industry leaders to improve recruitment strategies and academic institutions modernize curriculum	Job ads emphasize traditional operational skills, lack representation of advanced technology competencies	The need to align the curriculum with the needs of digital transformation in SCM
12	An evaluation of traceability dynamics in dairy supply chains through causal modeling in emerging economies (Bayatzadeh & Talaie, 2025)	Evaluation of traceability dynamics in the milk supply chain through causal modeling	Use of Delphi fuzzy and fuzzy DEMATEL methods for traceability analysis	Infrastructure and technological challenges in developing economies, particularly Iran	Not explicitly mentioned	Food safety and quality, supply chain process management, data analysis and forecasting are the most influential factors	Expert-based framework to increase transparency and build consumer trust
13	An integrated multi-criteria decision-making and multivariate analysis towards sustainable procurement with application in automotive industry (Ghosh et al., 2023)	Multi-criteria decision-making for sustainable procurement in the automotive industry	Focus on Green SCM and green supplier selection	Complexity of green supplier evaluation and selection	Not explicitly mentioned	"Collaboration with suppliers for green purchasing" is the most influential parameter for green supplier selection	The proposed framework can be replicated for supplier selection in other industries

No	Journal title, author & year	Research focus	Trends	Challenges	Curriculum development	Key findings	Implication
14	An integrated multi-criteria decision-making approach for overcoming barriers to green supply chain management and prioritizing alternative solutions (Özaşkın & Görener, 2023)	Multi-criteria decision-making approach to overcome green SCM barriers	Implementation of green supply chain practices in the manufacturing sector	Lack of technological hardware and software infrastructure, fear of failure, not adopting technological improvements	Solutions in the form of employee training, collaboration with other businesses, increased government support and incentives	The three most important obstacles: lack of technological infrastructure, fear of failure, not adopting technological improvements	The need for integration of training and collaboration in the green supply chain curriculum
15	Pharma 4.0: A deep dive top management commitment to successful Lean 4.0 implementation in Ghanaian pharma manufacturing sector (Grace Tetteh et al., 2024)	Top management's commitment to the implementation of Lean 4.0 in Ghana's pharmaceutical sector	Integration of lean methods and Industry 4.0 technology in pharmaceutical manufacturing	There is no substantial positive effect of Lean 4.0 on the company's performance in the short term	Not explicitly mentioned	Successful integration between lean methods and Industry 4.0 technologies requires careful management	The need for careful management in integrating lean methods and Industry 4.0 technology
16	New model of college physical education teaching based on the algorithm and data structure of flipped classroom and OBE (Kong et al., 2024)	New model of college physical education teaching based on flipped classroom and OBE	Application of flipped classroom and outcomes-based education in physical education	Assessment is open and students' study only to pass the final exam	Redesign of physical education teaching based on flipped classroom theory and OBE	Models that combine flipped classroom and OBE show significant performance improvements	This teaching model can be used as a reference for other education
17	Business transformation through sustainability based on Industry 4.0 (Torres da Rocha et al., 2022)	Business transformation through sustainability based on Industry 4.0	Development of corporate sustainability through Industry 4.0 with six main drivers	The articulation between corporate sustainability and Industry 4.0 is still limited	Drivers are in the form of strategy, product and process design, energy and material resources, human resources, smart production, and supply chain	Six drivers are systematized to develop economic, social, and environmental sustainability dimensions	The proposed drivers provide a reference for organizations to move towards sustainability
18	Green innovation behaviour: Impact of industry 4.0 and open innovation (Ogiemwonyi et al., 2023)	Green innovation behavior: the impact of industry 4.0 and open innovation	The influence of Industry 4.0, open innovation, and green innovation performance on green innovation behavior	Scientific research in this field is still neglected, challenges achievement while meeting the needs of society	Not explicitly mentioned	Industry 4.0 and green innovation performance have a positive effect on green innovation behavior	Policy implications for encouraging green innovation behavior in manufacturing companies
19	FinTech revolution in mineral management: Exploring the nexus between	The FinTech revolution in mineral management: an exploration of the	The impact of FinTech adoption on sustainable mineral management	Negative relationship between sustainable mining technology	Not explicitly mentioned	Short-term positive association between FinTech adoption,	Research provides important insights for responsibly utilising

No	Journal title, author & year	Research focus	Trends	Challenges	Curriculum development	Key findings	Implication
	technology adoption and sustainable Resource utilization in an industry 4.0 context (Xu et al., 2024)	relationship between technology adoption and sustainable resource utilization	policies in Australia	investments, government support, and environmental compliance		technology readiness, and green mineral extraction	Australia's natural resources
20	Teaching and learning methods in the context of industrial logistics engineering education (Woschank & Pacher, 2020)	Teaching and learning methods in the context of industrial logistics engineering education	Evaluation of conventional and modern teaching and learning methods for industrial logistics engineering education	Research and practical applications of logistics often overlook the importance of human skills development	Comparison of methods to guarantee and/or extend quality assurance and professional development	Structured development of employee competencies is one of the most important requirements for the successful implementation of the industry 4.0 strategy	The need to focus on human resource development in industrial logistics engineering education in the industry 4.0 era

4. Discussion

4.1 Development trends in logistics education research in the industry 4.0 era

Analysis of the literature shows that logistics education research in the era of Industry 4.0 undergoing significant paradigmatic transformations over the past decade. The concept of Food Sustainability 4.0 that integrates technology AI, IoT, robotics, and blockchain in a sustainable food system (Hassoun, 2025). This development reflects the evolution of research topics from conventional approaches towards the comprehensive integration of digital technologies in SCM. Agriculture 4.0 is identified as a data-driven transformation has changed the agricultural operational paradigm through the implementation of IoT technology, AI, big data analytics, and agricultural robots (Vijayakumar et al., 2025). This transformation shows that the focus of the study has shifted from traditional operational aspects to the integration of intelligent technologies that allow for resource optimization and increased production efficiency. The competencies required in modern SCM, where gaps are found between traditional operational expertise and advanced technological competencies such as Machine Learning and data analytics (Kang et al., 2025).

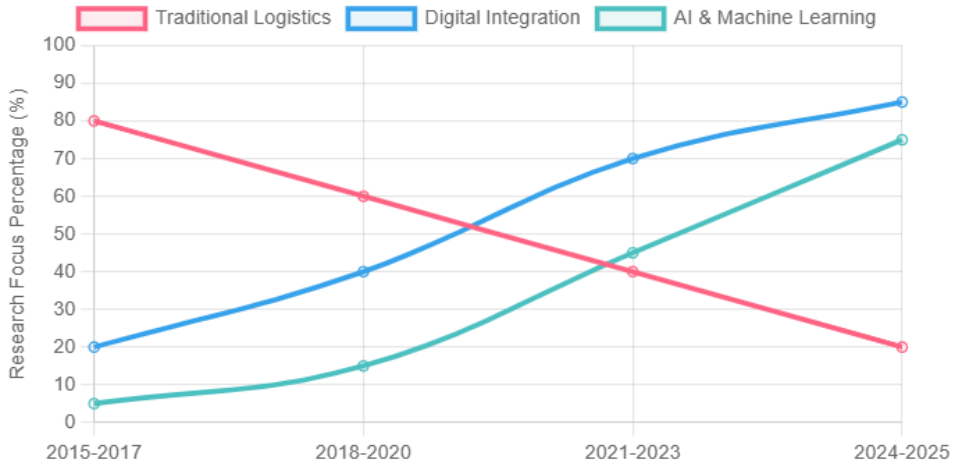

Figure 2. Evolution of logistics education research topics (2015-2025)

The research methodology has also undergone a remarkable diversification. Using an empirical approach by engaging academic and industry supply chain experts to analyse investment strategies Industry 4.0 in increasing supply chain resilience (Al-Banna et al., 2024). Meanwhile, with adopt an approach qualitative comparative analysis which is informed by in-depth case knowledge and refinement through Boolean logic for feature extraction in the prediction of food supply chain failure modes (Trollman, 2024). This methodological diversification shows that logistics education research is increasingly adopting a multidisciplinary approach that integrates quantitative, qualitative, and mixed methods.

Table 2. The evolution of logistics education research methodology in the industry 4.0 era

Era	Dominant methodology	Technology focus	Research examples
2015-2018	Quantitative Survey	Policy Automation	Woschank & Pacher (2020)
2019-2021	Mixed Methods	IoT and Big Data	Abdullah & Hussein (2021)
2022-2023	MCDM and AI	Machine Learning	Ghosh et al. (2023)
2024-2025	Empirical Analysis	Digital Twin, Blockchain	Kang et al. (2025)

4.2 Challenges in implementing the industry 4.0 responsive logistics education curriculum

Implementation of a logistics education curriculum that is responsive to needs Industry 4.0 face complex multidimensional challenges. The modernization of the sugar industry in Indonesia is experiencing significant obstacles because most factories are still using old machines (Mursiti et al., 2024). This condition reflects the technological infrastructure challenges faced by educational institutions in providing learning facilities that are in line with modern industry standards. The aspect of lecturer competence is a crucial challenge in the transformation of logistics education. The implementation Lean 4.0 in Ghana's pharmaceutical manufacturing sector requires strong top management commitment and careful management in integrating lean methodologies with technology Industry 4.0 (Grace Tetteh et al., 2024). These findings imply that lecturers as the spearhead of education must have adequate technical and managerial competencies to integrate traditional concepts with advanced digital technologies.

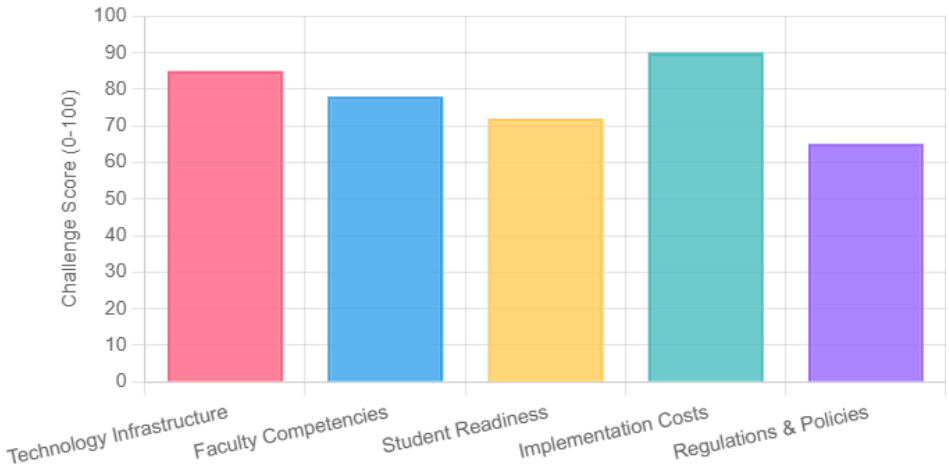

Figure 3. Main challenges in the implementation of the industry 4.0 curriculum

The readiness of students to adopt digital technology-based learning also faces significant obstacles. The impact of the COVID-19 pandemic on food access in various socio-economic strata in Chile, showing that socio-economic factors affect adaptability to technological changes (Donoso et al., 2025). In the context of education, this indicates that students from various economic backgrounds have different levels of readiness to adopt digital learning technology, so it requires an inclusive and adaptive learning approach. By showing that authentic leadership, employee resilience, job satisfaction, and innovative work behaviours affect employee performance in Thailand's transportation and logistics sector (Srimongkolkul et al., 2025). These findings imply that students' psychological and social factors affect their ability to adopt technology-based learning, so the curriculum must integrate development soft skills and resilience in the face of technological change.

4.3 Effective logistics education curriculum development strategy

The development of an effective logistics education curriculum to bridge the competency gap requires a holistic approach that integrates the technological, human, and environmental dimensions. Propose six drivers of corporate sustainability development through Industry 4.0, i.e. strategy, product and process design, energy and material resources, people, intelligent production, and supply chain (Torres da Rocha et al., 2022). This framework can be adapted in curriculum development by integrating strategic, technological, and social aspects in a balanced manner.

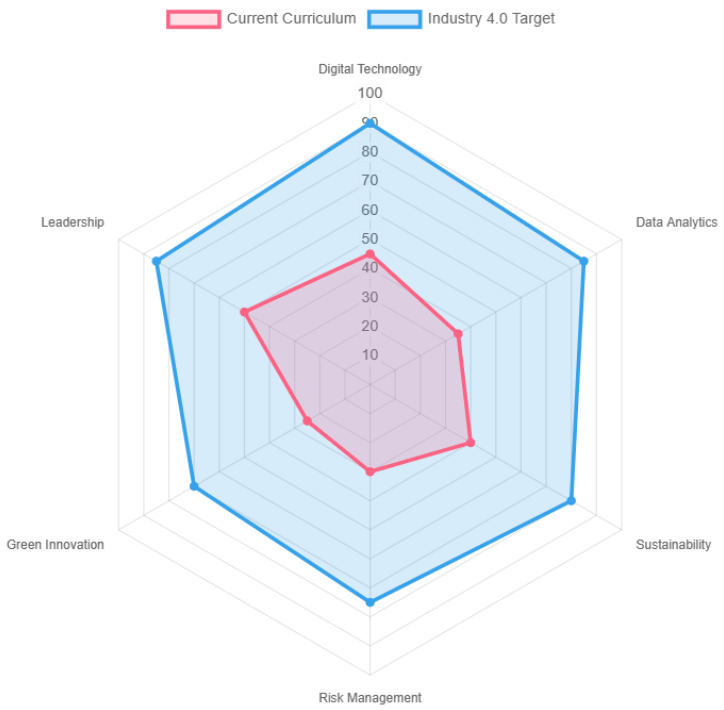

Figure 4. Industry 4.0 curriculum integration framework

Sustainability innovation and supply chain resilience have a positive effect on sustainability performance in the cold chain logistics industry in China (Zhang & Mohammad, 2024). These findings indicate that the curriculum should integrate sustainability and resilience perspectives as core competencies in logistics education. Its implementation can be done through the development of courses that combine sustainability theory with the application of digital technology in SCM.

Table 3. Industry 4.0 integrated logistics education development strategy

Curriculum components	Integrated technology	Target competencies	Learning methods
Digital SCM	IoT, Blockchain, AI	Digital SCM	Flipped Classroom, OBE
Logistics Data Analytics	Big Data, Machine Learning	Data-driven Decision Making	Project-based Learning
Smart Warehousing	Robotics, Automation	Warehouse Optimization	Simulation and Virtual Reality (VR)
Sustainable Logistics	Green Technology, IoT	Environmental Management	Case Study Analysis
Risk Management 4.0	Predictive Analytics	Supply Chain Resilience	Scenario Planning

Analyse traceability dynamics in the dairy supply chain through causal modelling in developing economies, demonstrating the importance of food safety and quality, supply chain process management, data analysis and forecasting, and data integration as key drivers of traceability (Bayatzadeh & Talaie, 2025). This framework can be integrated into the curriculum through the development of learning modules that emphasize the ability to analyse complex systems and data-driven decision-making in a global context. Industry 4.0 and green innovation performance has a positive effect on green innovation behaviour in Malaysian manufacturing companies (Ogiemwonyi et al., 2023). These findings imply that the curriculum should integrate a sustainable innovation perspective as a core competency.

Reinforcing this by demonstrating the effectiveness of a learning model based on flipped classroom and Outcome-Based Education (OBE) in improving the quality of learning (Kong et al., 2024). The integration of these two approaches can enhance students' ability to develop innovative solutions to contemporary logistics challenges. The FinTech revolution in mineral management by analysing the nexus between technology adoption and sustainable resource utilization in the context of Industry 4.0 (Xu et al., 2024). This research shows the importance of the integration of financial technology in resource management, which can be adapted in the logistics curriculum through the development of competencies in financial technology and digital resource management. The development of employee competencies is the most important requirement for the implementation of the strategy Industry 4.0 successful, which implies that the curriculum must integrate the development of technical and non-technical competencies in a balanced manner to prepare competent graduates to face the transformation of the global logistics industry (Woschank & Pacher, 2020).

5. Conclusion

This literature review research reveals a significant paradigmatic transformation in logistics education over the past decade in the industry 4.0 era. An analysis of 20 high-quality journals shows that the trend of research development has evolved from a conventional approach to comprehensive integration of digital technologies, including artificial intelligence, the Internet of Things, robotics, blockchain, and big data analytics. The research methodology has undergone remarkable diversification from basic quantitative surveys (2015-2018) to empirical analysis with advanced technologies such as digital twins and blockchain (2024-2025). The challenges of implementing the industry 4.0 responsive curriculum are multidimensional, including the limitations of technological infrastructure, lecturer competency gaps, and student readiness that varies based on socio-economic backgrounds. An effective curriculum development strategy requires a holistic approach

that integrates six key drivers: strategy, product and process design, energy and material resources, human resources, intelligent production, and SCM. The learning framework must combine flipped classroom and OBE to develop competencies in digital SCM, logistics data analytics, smart warehousing, sustainable logistics, and risk management 4.0. This transformation demands a curriculum that integrates the perspectives of sustainability, resilience, and green innovation as core competencies to prepare competent graduates to face the global logistics industry revolution.

Author's declaration

Author contribution

Bambang Darmawan: Conceptualization, Methodology, Data Curation. **Saskia Kanisaa Puspanikan**: Investigation, Data Curation, Validation. **Dodi Permadi**: Validation, Formal Analysis, Quality Assessment. **Lia Sukmayanti**: Formal Analysis, Visualization, Writing – Original Draft.

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Conflict of interest

The authors declare that there are no conflicts of interest regarding this research.

Ethical clearance

This research did not involve human participants, human data, or human tissues, and therefore did not require ethical approval.

AI statement

The authors used Grammarly to check and improve the manuscript's grammar structure.

Publisher's and Journal's note

Universitas Negeri Padang as the publisher, and the Editor of Jurnal Pendidikan Teknologi Kejuruan state that there is no conflict of interest towards this article publication.

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