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Digital leadership in the era of digital transformation: a bibliometric analysis of intellectual structure and thematic evolution (2005–2025)

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ABSTRACT

The accelerating pace of digital transformation has intensified scholarly interest in understanding how leadership practices evolve in technology-driven organizational environments. This study provides a comprehensive bibliometric analysis of digital leadership research by examining 1,325 peer-reviewed articles indexed in the scopus database covering the period 2005–2025. Employing a dual analytical approach combining bibliographic coupling and co-word analysis using vosviewer, the study maps the intellectual structure and thematic evolution of the field. the bibliographic coupling analysis reveals four major research clusters: digital transformation and ai-driven leadership innovation; organizational behavior and workplace leadership dynamics; educational and distributed leadership systems; and digital collaboration and knowledge integration in complex organizational settings. the co-word analysis further identifies three dominant thematic streams: digital transformation and technological leadership ecosystems; agile organizational behavior and leadership practices; and educational leadership and instructional digital innovation. publication trends indicate a strong and sustained growth trajectory, particularly after 2015, reflecting the increasing recognition of digital leadership as a strategic organizational capability in the industry 4.0 era. building on prior fragmented studies in digital leadership and organizational transformation, this research provides a unified, dual-framework bibliometric map that clarifies the intellectual structure, dominant themes, and emerging research directions in the field. the findings contribute to both theory and practice by offering a comprehensive knowledge architecture for understanding how digital leadership enables organizational adaptation, innovation, and performance in digitally intensive environments.

Keywords: Digital Leadership; Digital Transformation; Artificial Intelligence; Industry 4.0; Bibliometric Analysis; Organizational Performance.

INTRODUCTION

Digital leadership has emerged as a pivotal construct in the era of digital transformation, emphasizing the role of leadership in enabling organizations to effectively navigate technological disruption and complex digital ecosystems (Cortellazzo et al., 2019). In contemporary organizational settings, digital leadership is increasingly recognized as a strategic capability that shapes how leaders align technological innovation with organizational goals and adaptive performance outcomes (W. Li et al., 2016). The evolution of leadership theory in digital contexts has shifted from traditional hierarchical perspectives toward more dynamic and practice-oriented approaches, such as leaderful and distributed leadership paradigms (Raelin, 2011), reflecting the increasing complexity of organizational environments where leadership is no longer centralized but shared across networks and teams in knowledge-intensive and digitally mediated settings (Bolden et al., 2009). In virtual and technology-mediated environments, leadership effectiveness is strongly dependent on communication structures and collaborative mechanisms that enable coordination across distributed teams (Hambley et al., 2007), while distributed leadership further strengthens coordination between academic, executive, and professional actors in higher education institutions (B. Jones et al., 2023). Empirical studies consistently demonstrate that digital leadership plays a critical role in enhancing organizational digital capability and improving performance outcomes in digitally intensive environments (J.-H. Shin et al., 2023), and significantly moderates the relationship between digital workplace practices and organizational performance, highlighting its strategic importance in technology-driven transformation processes (D. Chatterjee et al., 2023). Within the broader digital transformation discourse, leadership is conceptualized as an integrative mechanism that aligns strategic direction with technological implementation across organizational levels (Imran et al., 2021), while e-leadership practices have been identified as essential enablers of strategic alignment between digital infrastructure and organizational processes, particularly in small- and medium-sized enterprises undergoing digital adoption (W. Li et al., 2016). In public and institutional contexts, digital leadership significantly influences organizational effectiveness in government systems undergoing digital modernization and administrative reform (Wu & Trottier, 2021), and in educational environments it plays a crucial role in shaping institutional adaptability and enhancing teachers' digital competencies during periods of rapid technological change (Karakose et al., 2021). From a bibliometric perspective, digital leadership research is highly multidisciplinary, spanning management, information systems, education, and organizational studies (Tigre et al., 2023), yet despite this expansion the literature remains fragmented across theoretical perspectives, empirical contexts, and methodological approaches (Bolden et al., 2008), indicating the need for systematic knowledge synthesis approaches capable of uncovering latent intellectual structures and thematic evolution patterns.

Two critical gaps persist. First, a methodological gap exists in that narrative-based reviews, while valuable for theoretical synthesis, are limited in their ability to reveal latent intellectual structures, research stream interconnections, and thematic clustering patterns emerging from large-scale citation and keyword networks. Bibliometric methods offer a complementary, data-driven approach that enables systematic mapping of these hidden structures through quantitative analysis of citation networks and keyword co-occurrences, providing insights that cannot be captured through traditional qualitative synthesis approaches. Second, a comprehensive mapping gap remains, as existing studies rarely provide an integrative bibliometric perspective that simultaneously connects intellectual structure (citation-based analysis) and conceptual structure (keyword-based analysis), and few studies adopt a dual analytical framework

combining bibliographic coupling and co-word analysis to explain how digital leadership knowledge domains evolve across organizational, educational, and technological contexts.

Building on these gaps, this study analyzes 1,325 peer-reviewed articles indexed in the Scopus database covering the period 2005–2025 to map the intellectual and thematic structure of digital leadership research. Accordingly, the objectives of this study are:

(1) to identify the current intellectual structure and thematic clusters of digital leadership research based on bibliographic coupling analysis; and
(2) to examine emerging research trends and future directions in digital leadership studies using co-word analysis.

By employing bibliographic coupling and co-word analysis using VOSviewer, this study provides both a retrospective mapping of knowledge structures and a prospective identification of emerging thematic trajectories.

The remainder of this paper is organized as follows. Section 2 presents the methodological framework, including data collection and bibliometric techniques. Section 3 presents the results of the analysis. Section 4 discusses theoretical and practical implications. Section 5 outlines limitations of the study. Section 6 proposes future research directions, and Section 7 concludes the study.

METHODOLOGY

Bibliometric approach

This study employs bibliometric analysis as a quantitative and systematic methodology for mapping the intellectual structure, knowledge production, and thematic evolution of research domains within scientific literature (Donthu et al., 2021; Marrone et al., 2025). In line with established methodological frameworks, bibliometric analysis is recognized as a third stream of literature review techniques that complements systematic literature reviews and meta-analyses by enabling objective, reproducible, and large-scale mapping of scholarly communication patterns and research development trajectories (Standing et al., 2018). In this study, the bibliometric dataset consists of 1,325 peer-reviewed articles retrieved from the Scopus database covering the period 2005–2025, focusing specifically on digital leadership research as the analytical domain. The study applies performance analysis and science mapping techniques to identify publication trends, intellectual structures, and conceptual dynamics, thereby providing a comprehensive overview of the evolution of digital leadership scholarship.

To achieve the objectives of this study, two complementary science mapping techniques are employed, namely bibliographic coupling and co-word analysis, which are widely recognized in contemporary bibliometric and management research (Fauzi et al., 2024). Bibliographic coupling is used to examine the intellectual structure of the field by identifying relationships between documents that share common references, where stronger coupling strength indicates higher thematic similarity and intellectual proximity among studies (Kessler, 1963; Donthu et al., 2021). This technique enables the identification of core research clusters and the underlying intellectual foundations that shape the development of digital leadership scholarship. In parallel, co-word analysis is applied to examine the conceptual structure of the field by analyzing the frequency and co-occurrence patterns of keywords extracted from titles, abstracts, and author-defined keywords (Cobo et al., 2011; Van Eck & Waltman, 2014). High co-occurrence

relationships indicate strong conceptual linkages between themes, allowing the identification of emerging research trends and thematic evolution patterns. Together, these complementary techniques provide a robust and comprehensive mapping of both intellectual and conceptual structures in digital leadership research, enabling a deeper understanding of how the field has evolved over time and how future research directions may emerge.

Research design and data collection procedure

We searched the scopus database, selected for its extensive coverage of peer-reviewed journals and standardized bibliographic metadata (e.g., author keywords, abstracts, and citation references), which enables consistent and reliable construction of bibliometric networks for co-occurrence and bibliographic coupling analyses. scopus is widely recognized for its comprehensive indexing and robust citation-tracking functionality, making it particularly suitable for science mapping studies that require accurate computation of link strengths and network relationships. in this study, the search strategy was implemented using the TITLE-ABS-KEY field to ensure comprehensive retrieval of relevant publications across titles, abstracts, and keywords while maintaining thematic relevance to digital leadership research. the search string employed was:

> Search String: TS = ("digital leadership" OR "digital-leadership" OR "e-leadership" OR "eleadership" OR "electronic leadership" OR "virtual leadership" OR "online leadership" OR "cyber leadership" OR "technology leadership" OR "technolog* leadership" OR "IT leadership" OR "information technolog* leadership" OR "digital transformation leadership" OR "digital-era leadership" OR "leadership 4.0" OR "Industry 4.0 leadership" OR "smart leadership" OR "agile leadership" OR "remote leadership" OR "virtual team leadership" OR "distributed leadership").

The search procedure applied strict inclusion criteria to ensure data quality and analytical consistency. specifically, only english-language publications were included, and the document type was restricted to journal articles, excluding books, book chapters, conference proceedings, and editorial materials to ensure peer-reviewed academic rigor. in addition, only open-access journal publications were retained to ensure transparency and accessibility of the analytical corpus. the initial search yielded 5,313 documents, which were subsequently refined by applying temporal boundaries (2005–2025), resulting in a final dataset of 1,325 journal articles representing the core scholarly contributions in the field of digital leadership. all records were exported in csv and ris formats, including full bibliographic information and cited references, enabling comprehensive bibliometric analysis. data analysis was conducted using vOSviewer software (version 1.6.20), selected for its advanced capabilities in constructing and visualizing bibliometric networks, including co-authorship, co-citation, and co-word analysis, which are essential for mapping the intellectual and conceptual structure of scientific fields (Van Eck et al., 2011).

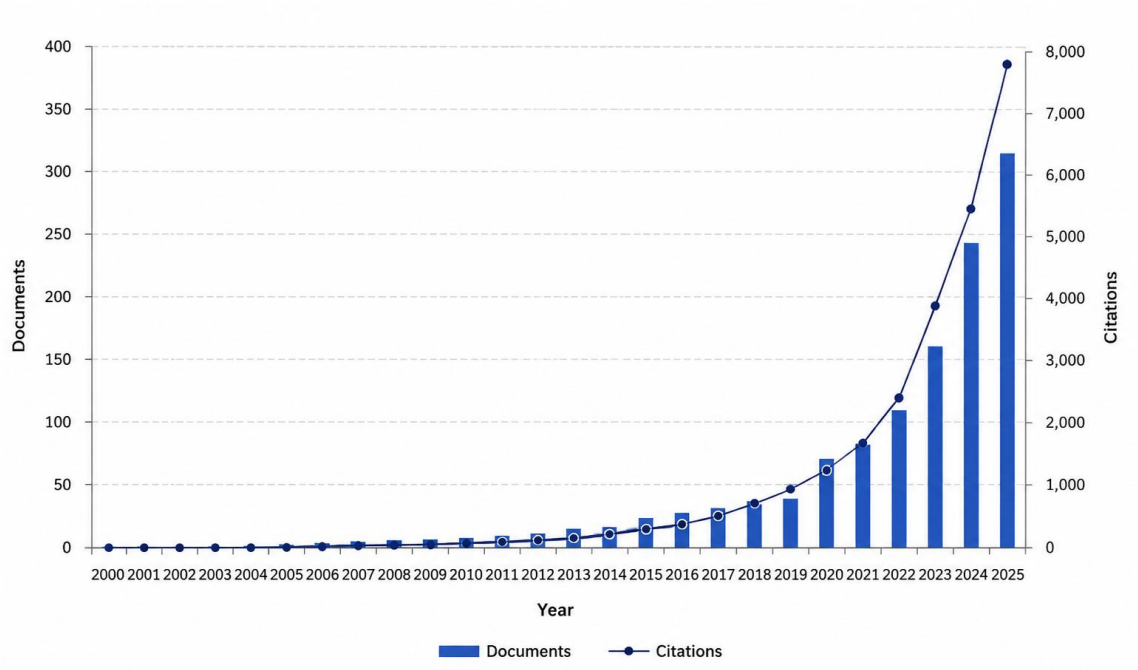
RESULT AND DISCUSSION

A comprehensive bibliometric search was conducted in the Scopus database using the TITLE-ABS-KEY field, yielding 5,313 initial documents related to digital leadership research. Following the systematic application of quality and inclusion criteria restricted to English-language publications, journal articles only, open-access status, and temporal boundaries between 2005 and 2025 the final dataset comprised 1,325 peer-reviewed articles. This curated dataset represents the core scholarly contributions to the digital leadership domain across organizational, technological, and educational contexts. The sustained growth in publication output indicates an increasingly consolidated research agenda rather than isolated or episodic scholarly contributions, highlighting the maturation of digital leadership as a research field and underscoring the necessity for a systematic mapping of its intellectual structure and thematic evolution.

Publications and citations on cultural intelligence research

The annual scientific output on digital leadership research shows a clear and accelerating upward trajectory across the analyzed period, with a total of 1,325 Scopus-indexed journal articles (2005–2025) included in the dataset. In the early phase (2000–2016), publication activity remained relatively modest, indicating an emerging and still fragmented research area. A notable growth inflection begins around 2017, with 22 documents and 467 citations, reflecting increasing scholarly attention to digital transformation and leadership in technology-driven environments. This growth continues steadily in subsequent years, particularly from 2018–2019, where both publication output and citation impact expand in parallel, signaling strengthening academic engagement with digital leadership as a distinct research domain.

The most significant acceleration occurs during the period 2020–2025, where the field experiences exponential growth in both publications and citations, driven by global digital transformation, remote work adoption, and Industry 4.0 transitions. During this phase, annual publications increase substantially year by year, contributing to a cumulative citation surge reaching tens of thousands of citations in total across the dataset (28,436 citations overall in Scopus citation overview), with the steepest rise observed after 2021 as citation accumulation intensifies alongside publication growth. This pattern indicates that digital leadership has transitioned from an emerging topic to a highly consolidated and influential research domain. The slight fluctuations observed in the most recent years (2024–2025) are likely due to indexing delays and incomplete citation accumulation in bibliometric databases, rather than an actual decline in scholarly interest. Overall, the trend confirms that digital leadership has become a rapidly expanding field with increasing global academic impact and strategic relevance in contemporary organizational research.



Source: Scopus Citation Overview (15 May 2025). Search query on digital leadership terms; limited to English, journal articles, open access, and final publication status (2005–2025).

Figure 1. Annual publications and citations on Digital leadership in the era of digital transformation research (2005–2025). Source: authors' own work, 2025.

Bibliographic coupling

Threshold determination employed iterative testing across citation ranges from 30 to 90 citations to ensure network stability and interpretive clarity in the bibliographic coupling analysis of digital leadership research. the optimal threshold of 87 citations was selected, resulting in the inclusion of 50 documents from a total of 1,325 articles, thereby balancing analytical precision with sufficient representativeness of the intellectual structure. this configuration ensures that only highly influential and strongly connected publications are retained, minimizing noise while preserving thematic coherence within the digital leadership knowledge base. total link strength (tls) is used as the primary metric to measure the intensity of inter-document relationships, reflecting the degree of intellectual proximity and thematic alignment among studies. table 1 presents the most influential publications within the bibliographic coupling network, ranked by citation count and total link strength, with the top contributions including cortellazzo (2019) with 612 citations and tls 41, raelin (2011) with 297 citations and tls 34, bolden (2009) with 275 citations and tls 50, tian (2016) with 245 citations and tls 79, and chatterjee (2023) with 227 citations and tls 30. these highly cited works form the intellectual backbone of digital leadership research, particularly in relation to digital transformation, leadership adaptation, and organizational innovation in technology-driven environments.

Figure 2 visualizes the bibliographic coupling network and identifies four thematic clusters in digital leadership literature. These clusters focus on strategic digital transformation and

leadership capability, virtual and distributed leadership, technological adaptation and organizational innovation, and agile Industry 4.0 leadership. The network shows strong intellectual integration across clusters, indicating that digital leadership research is developing as a consolidated interdisciplinary field with increasing theoretical maturity.

Table 1.
Top 10 documents in bibliographic coupling analysis

No	Document	Citations	Total Link Strength (TLS)
1	Hulpia (2011)	131	192
2	Hulpia (2009)	110	158
3	Hulpia (2009)	98	133
4	Hulpia (2010)	100	133
5	Tian (2016)	245	79
6	Bolden (2008)	154	72
7	Spillane (2010)	120	66
8	Thorpe (2011)	149	58
9	Fitzsimmons (2022)	131	57
10	Tigre (2023)	196	54

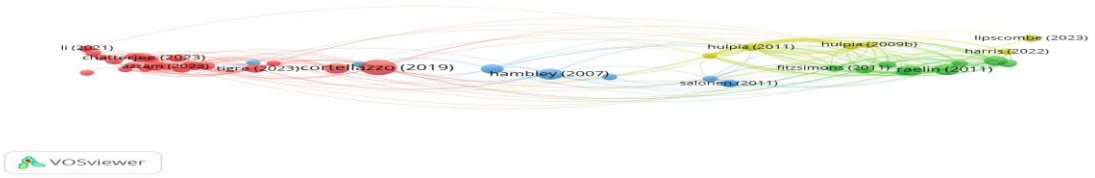


Figure 2. Network visualization of bibliographic coupling. Source: vosviewer, authors' own work

Table 2.
Bibliographic coupling analysis on

Cluster No and color	Cluster label	Number of publications	Representative publication
1 (red)	Digital Leadership Transformation, Organizational Innovation, and Adaptive Management in Technology-Driven Ecosystems	23	(AlAjmi, 2022; Aldianto et al., 2021; Azzam et al., 2023; Bastardoz et al., 2023; S. Chatterjee et al., 2022, 2023; Cortellazzo et al., 2019; Dubey et al., 2024; Hussein et al., 2024; Imran et al., 2021; Karakose et al.,

Cluster No and color	Cluster label	Number of publications	Representative publication
			2021, 2022; J. Li et al., 2021; W. Li et al., 2016; Niccum et al., 2017; Niu et al., 2022; Sarfraz et al., 2022; Shaikh et al., 2023; J. Shin et al., 2023; Tigre et al., 2023; Wang et al., 2022; Zhu et al., 2022; Zulu & Khosrowshahi, 2021).
2 (green)	Distributed Leadership, Organizational Learning, and Leadership Practice in Educational and Organizational Settings	9	(Bolden et al., 2008, 2009; Fitzsimons et al., 2011; Gosling et al., 2009; S. Jones et al., 2012; Raelin, 2011; Spillane & Healey, 2010; Thorpe et al., 2011; Tian et al., 2016).
3 (blue)	Digital Collaboration, Virtual Work Practices, and Knowledge Translation in Complex Organizational Systems	8	(Hambley et al., 2007; Martin et al., 2009; Peterson et al., 2006; Rycroft-Malone et al., 2016; Salonen, 2011; Strode et al., 2022; Trottier et al., 2008; Wasono & Furinto, 2018).
4 (yellow)	Distributed Leadership Structures, Educational Leadership, and Organizational Effectiveness Measurement	6	(Harris et al., 2022; Hulpia et al., 2011; Hulpia, Devos, & Rosseel, 2009; Hulpia, Devos, & Van Keer, 2009; Hulpia & Devos, 2010; Lipscombe et al., 2023).

Cluster 1 (red): with 23 publications, this cluster is labeled "Digital Leadership Transformation, Organizational Innovation, and Adaptive Management in Technology-Driven Ecosystems". the studies in this cluster converge on examining how digital leadership practices enable organizational transformation, innovation capability, and adaptive management across diverse contexts such as education, healthcare, and business environments under conditions of rapid technological change. key contributions such as cortellazzo (2019), tigre (2023), chatterjee (2022; 2023), and dubey (2024) emphasize the strategic role of digital leadership in fostering organizational agility, innovation performance, and resilience in digitally disrupted environments. complementary studies including karakose (2021; 2022), wang (2022), zhu (2022), and shin (2023) highlight the importance of digital competence, remote leadership practices, and technology-enabled coordination in improving institutional effectiveness and

workforce adaptation. further empirical works by alajmi (2022), aldiano (2021), imran (2021), and niu (2022) extend this discussion by demonstrating how digital leadership integrates technological tools with managerial decision-making to enhance organizational learning and performance outcomes. methodologically, this cluster is dominated by quantitative empirical studies employing survey-based designs, structural equation modeling, and cross-sectional data analysis to examine causal relationships between digital leadership dimensions and organizational outcomes. theoretically, the cluster integrates digital transformation theory, adaptive leadership theory, and socio-technical systems perspectives, collectively illustrating how digital leadership functions as a critical enabler of innovation, organizational change, and sustainable performance in Industry 4.0 and post-digital organizational contexts.

Cluster 2 (green): with 9 publications, this cluster is labeled "Distributed Leadership, Organizational Learning, and Leadership Practice in Educational and Organizational Settings". this cluster examines how distributed leadership structures, leadership practices, and organizational learning processes shape effectiveness, collaboration, and decision-making across educational institutions and organizational environments. foundational contributions such as bolden (2008; 2009), spillane (2010), and raelin (2011) emphasize leadership as a distributed and socially constructed practice, highlighting how leadership is shared across individuals rather than concentrated in a single authority figure, thereby improving collective capacity and organizational adaptability. complementary studies including fitzsimmons (2011), gosling (2009), jones (2012), thorpe (2011), and tian (2016) extend this perspective by exploring how leadership development, reflective practice, and collaborative governance enhance organizational learning and institutional performance in complex environments. methodologically, this cluster is primarily characterized by qualitative case studies, mixed-method approaches, and conceptual-theoretical analyses that investigate leadership processes within real organizational and educational contexts. theoretically, the cluster integrates distributed leadership theory, organizational learning theory, and practice-based leadership perspectives, collectively illustrating how leadership is enacted through social interaction, shared responsibility, and collaborative structures that strengthen organizational effectiveness and adaptability in dynamic environments.

Cluster 3 (blue): with 8 publications, this cluster is labeled "Digital Collaboration, Virtual Work Practices, and Knowledge Translation in Complex Organizational Systems". the studies within this cluster coalesce around examining how digital collaboration practices, virtual teamwork, and knowledge translation processes influence organizational effectiveness across healthcare, education, information systems, and organizational management contexts. foundational contributions such as hambley (2007), martin (2009), and peterson (2006) emphasize the dynamics of virtual team interaction, communication quality, and technology-mediated coordination in shaping team performance outcomes. complementary studies including rycroft-malone (2016), salonen (2011), strode (2008), trotter (2008), and wasono (2018) extend this perspective by highlighting implementation processes, knowledge integration, and digital work practices that enhance organizational learning and decision-making in complex and interdisciplinary environments. methodologically, this cluster is characterized by qualitative case studies, mixed-method approaches, and implementation science frameworks, particularly within healthcare and information systems research. theoretically, it integrates

socio-technical systems theory, knowledge translation theory, and virtual team effectiveness perspectives, demonstrating how digital leadership-enabled collaboration and knowledge integration processes improve performance, coordination, and adaptability in digitally mediated organizational settings.

Cluster 4 (yellow): with 6 publications, this cluster is labeled "Distributed Leadership Structures, Educational Leadership, and Organizational Effectiveness Measurement". this cluster focuses on the conceptualization, measurement, and application of distributed leadership within educational institutions and organizational systems. core contributions such as hulpia (2009a; 2009b; 2010; 2011) and lipscombe (2023) examine how leadership distribution across formal and informal actors influences school effectiveness, teacher collaboration, and organizational performance outcomes. additional studies such as harris (2022) extend this discourse by emphasizing the role of leadership distribution, capacity building, and collaborative governance in improving institutional effectiveness and sustaining organizational improvement. methodologically, this cluster is dominated by quantitative survey-based studies, psychometric scale development, and structural modeling approaches aimed at validating distributed leadership constructs and measurement frameworks. theoretically, it integrates distributed leadership theory, educational leadership theory, and organizational effectiveness frameworks, collectively illustrating how leadership shared across multiple actors enhances collective capacity, school improvement, and sustainable organizational performance in educational and institutional contexts.

Table 2 provides a comprehensive summary of each cluster's characteristics, including cluster labels, publication counts, and representative works that define each research stream.

Co-word Analysis

The keyword extraction process identified 5,259 unique terms from titles, abstracts, and author keywords across the Scopus dataset on digital leadership research. Following iterative threshold testing, a minimum occurrence threshold of 17 was selected as optimal, resulting in a stable co-word network comprising 56 high-frequency keywords while filtering low-occurrence terms to reduce noise and preserve conceptual coherence. this configuration enables a balanced representation of dominant research directions in digital leadership while maintaining analytical clarity in the thematic structure. table 3 presents the most frequently co-occurring keywords, highlighting the interconnected nature of core concepts such as digital transformation, leadership effectiveness, organizational performance, innovation, and technology adoption, which collectively define the intellectual backbone of the field. figure 3 illustrates the network visualization of the co-word analysis, revealing three distinct thematic clusters that represent the main research streams within digital leadership scholarship. based on inductive interpretation, these clusters reflect (i) digital transformation and organizational change, (ii) leadership practices in technology-enabled and virtual environments, and (iii) innovation, performance, and strategic adaptation in Industry 4.0 contexts. overall, the co-word structure demonstrates a highly interconnected and evolving research domain, where emerging keywords increasingly converge around technology-driven leadership capabilities and organizational adaptability in digitally intensive environments.

Table 6.

Top 15 keywords

Rank	Keyword	Occurrences	Total Link Strength
1	Leadership	334	1375
2	Adult	80	739
3	Digital leadership	254	423
4	Distributed Leadership	274	376
5	Middle aged	29	336
6	Digital Transformation	122	258
7	Organization and management	23	180
8	Workplace	18	169
9	Health care personnel	17	159
10	Innovation	63	141
11	Organizational culture	24	138
12	Organizational	18	129
13	Job satisfaction	25	122
14	Knowledge	19	116
15	Artificial intelligence	38	104

Source: authors' own work.

Table 7.
Summary of co-word analysis on Digital leadership in the era of digital transformation.

Cluster No and color	Cluster label	No. of keywords	Representative Keywords
1 (red)	Digital Leadership, Digital Transformation, and AI-Enabled Organizational Innovation Ecosystem	14	artificial intelligence, digital leadership, digital transformation, digitalization, e-leadership, e-learning, industry 4.0, innovation, knowledge management, sustainability, sustainable development, technology , technology leadership, and virtual leadership.
2 (green)	Organizational Behavior, Leadership Practice, and Workplace Management in Digital Era Contexts	13	Adult, agile leadership, decision making, health care personnel, job satisfaction, knowledge, leadership, management, middle aged, organization, organization and management, organizational culture, and workplace
3 (blue)	Educational Digital	9	distributed leadership,

Cluster No and color	Cluster label	No. of keywords	Representative Keywords
	Leadership, School Improvement, and Professional Development		educational leadership, instructional leadership, professional development, school improvement, school leadership, teacher leadership, technological leadership, and transformational leadership

Source: authors' own work.

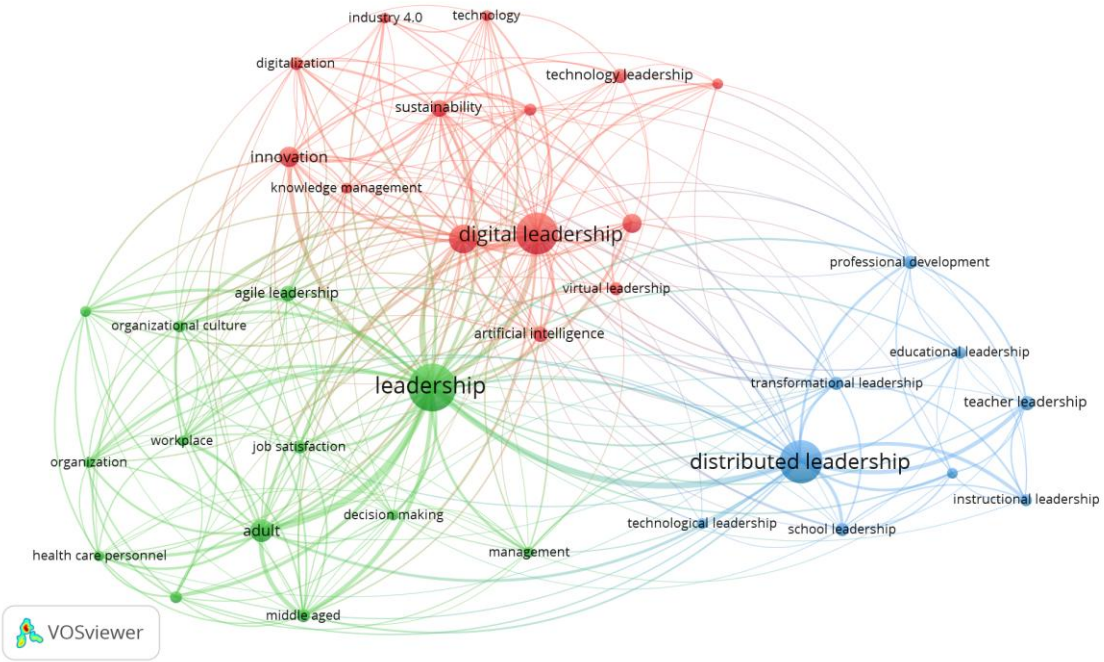


Figure 6. Network visualization of co-word analysis. Source: authors' own work

Cluster 1 (red): Cluster 1, comprising 14 keywords, is labeled *"Digital Leadership, Digital Transformation, and AI-Driven Organizational Innovation Ecosystem"*. This cluster represents the core intellectual foundation of the digital leadership literature, emphasizing how leadership practices evolve in response to rapid technological disruption, particularly through artificial intelligence, Industry 4.0, and digital transformation initiatives. The studies in this cluster converge on the strategic role of digital leadership in enabling organizational adaptation, innovation capability, and knowledge management in technology-intensive environments. Key themes include artificial intelligence, digital transformation, digitalization, e-leadership, virtual leadership, and Industry 4.0, which collectively illustrate how leadership is increasingly

mediated through digital technologies and data-driven decision-making processes. For instance, research on AI and digital leadership highlights how leaders integrate intelligent systems into organizational workflows to enhance decision-making efficiency and innovation outcomes, while studies on e-leadership and virtual leadership emphasize leadership effectiveness in remote and digitally mediated work environments. Furthermore, works addressing knowledge management and sustainability demonstrate how digital leadership supports long-term organizational resilience by aligning technological adoption with sustainable development goals. Complementing these perspectives, studies on technology leadership and innovation underscore the role of leaders in orchestrating digital ecosystems that foster continuous learning (e-learning), agile adaptation, and organizational culture transformation. Methodologically, this cluster is dominated by conceptual frameworks and empirical studies using organizational survey data to examine leadership effectiveness in digitally transformed contexts. Theoretically, it integrates digital transformation theory, socio-technical systems perspectives, and innovation management literature, positioning digital leadership as a central driver of organizational competitiveness in the Industry 4.0 era.

Cluster 2 (green): consisting of 13 keywords, is labeled *"Organizational Behavior, Leadership Practice, and Workplace Management in the Digital Era"*. This cluster emphasizes the human and organizational dimensions of leadership within digitally transforming workplaces, focusing on how leadership styles, organizational culture, and employee-related outcomes interact in shaping effective management practices. The keywords in this cluster—such as agile leadership, decision making, management, organizational culture, workplace, job satisfaction, leadership, organization, and health care personnel—indicate a strong emphasis on leadership effectiveness in operational and behavioral contexts rather than purely technological transformation. The studies within this cluster collectively explore how leadership approaches, particularly agile and adaptive leadership, influence employee satisfaction, decision-making quality, and organizational performance across various sectors, including healthcare and public organizations. For example, research on agile leadership highlights its role in enhancing flexibility and responsiveness in dynamic organizational environments, while studies on job satisfaction and workplace dynamics demonstrate how leadership behavior directly affects employee motivation and retention. Furthermore, investigations into organizational culture and middle management underscore the importance of leadership alignment in fostering cohesive work environments and improving coordination across organizational levels. Health care personnel studies further extend this discussion by showing how leadership practices shape workforce engagement and service quality in high-pressure environments. Methodologically, this cluster is largely dominated by quantitative survey-based studies examining leadership–outcome relationships across organizational settings. Theoretically, it integrates organizational behavior theory, leadership contingency perspectives, and workplace motivation frameworks, positioning leadership as a critical determinant of employee well-being and organizational effectiveness in digitally evolving environments.

Cluster 3 (blue): consisting of 9 keywords, is labeled *"Educational Digital Leadership, School Improvement, and Instructional Transformation."* This cluster reflects a distinct research stream within digital leadership literature that focuses on the role of leadership in enhancing educational quality through digital integration, instructional innovation, and school-level

transformation. The keywords distributed leadership, educational leadership, instructional leadership, transformational leadership, school leadership, technological leadership, teacher leadership, professional development, and school improvement collectively indicate that leadership in education is increasingly conceptualized as a shared, adaptive, and technology-enabled process aimed at improving teaching and learning outcomes. Studies within this cluster emphasize that distributed leadership enhances collaboration among teachers and administrators in implementing digital learning strategies, while instructional leadership strengthens curriculum delivery and pedagogical quality in technology-enhanced classrooms. Transformational leadership further contributes by fostering vision-driven change that supports digital adoption and continuous school improvement. Moreover, research on teacher leadership and professional development highlights the importance of capacity building in enabling educators to effectively integrate digital tools into instructional practices. Technological leadership and school leadership studies extend this discussion by demonstrating how school leaders mediate institutional readiness for digital transformation, ensuring alignment between policy, infrastructure, and pedagogical innovation. Methodologically, this cluster is primarily dominated by quantitative and mixed-method studies examining leadership effects on educational outcomes across school contexts. Theoretically, it integrates distributed leadership theory, transformational leadership frameworks, and educational change theory, positioning digital leadership as a critical driver of sustainable school improvement and instructional effectiveness in the era of digital education.

Discussion

While the previous sections (Table 2 and Figure 2) delineate the intellectual structure of digital leadership research through bibliographic coupling, and Table 3 and Figure 3 illustrate its thematic configuration via co-word analysis, a deeper synthesis of both mappings reveals important cross-cluster linkages that are not fully visible when each analytical perspective is interpreted in isolation. Across the bibliographic and thematic structures, two dominant explanatory pathways emerge. The first is a *digital adaptation pathway*, where constructs such as digital transformation, artificial intelligence, and e-leadership converge to explain how organizations respond to technological disruption through leadership-mediated adaptation processes (Chatterjee et al., 2023; Dubey et al., 2024; Zulu et al., 2021). The second is a *leadership capability pathway*, where digital leadership, transformational leadership, and distributed leadership operate as enabling mechanisms that translate technological change into organizational learning, innovation, and performance outcomes (Bolden et al., 2008; Spillane et al., 2010; Raelin, 2011). Importantly, although these pathways are conceptually interconnected, the empirical literature remains fragmented, as few studies explicitly integrate individual leadership competencies with organizational-level digital capability development, creating a persistent cross-level integration gap in digital leadership scholarship.

Further analysis also reveals conceptual inconsistencies in how digital leadership is defined and operationalized across contexts. As shown in Figure 3, technological and AI-driven leadership studies (e.g., Azzam et al., 2023; Wang et al., 2022) typically conceptualize digital leadership as a strategic organizational capability enabling innovation, knowledge management, and Industry 4.0 transformation. In contrast, educational leadership studies within Cluster 3 (e.g., Hambley, 2007; Peterson, 2006; Trottier, 2008) frame digital leadership more as a distributed and instructional process, emphasizing teacher leadership, professional development,

and school improvement outcomes. Meanwhile, workplace-oriented studies in Cluster 2 (e.g., Thorpe, 2011; Tian, 2016; Gosling, 2009) highlight behavioral and cultural dimensions such as job satisfaction, decision-making, and organizational culture. This divergence indicates an unresolved construct boundary problem, where digital leadership is simultaneously treated as a technological capability, a behavioral leadership style, and an organizational development mechanism, raising concerns regarding conceptual consistency and measurement equivalence across domains. Taken together, these findings suggest that digital leadership research is transitioning from isolated thematic streams toward an emerging integrative framework; however, a unified theoretical model linking technological capability, leadership practice, and organizational outcomes remains underdeveloped, limiting cumulative theory building in this field.

STUDY IMPLICATIONS AND LIMITATION

Theoretical implication

The bibliographic coupling analysis and co-word analysis presented in Table 2 and Table 3, as well as Figure 2 and Figure 3, provide a convergent theoretical foundation for understanding how digital leadership is structured across intellectual and thematic domains. A key theoretical implication emerging from this convergence is the alignment between the digital transformation–innovation leadership stream (Cluster 1, bibliographic coupling) and the technology-enabled leadership ecosystem (Cluster 1, co-word analysis). This alignment suggests that digital leadership should be conceptualized not only as an adaptive response to technological disruption but also as an organizational capability embedded within innovation systems, artificial intelligence adoption, and Industry 4.0 transformation processes (Chatterjee et al., 2023; Dubey et al., 2024; Zhu et al., 2022). Extending this perspective, the findings reinforce socio-technical systems theory by demonstrating that leadership effectiveness in digital contexts emerges from the interaction between technological infrastructures and leadership cognition, rather than from either dimension independently. Moreover, the integration of knowledge management, sustainability, and digital transformation within this cluster highlights that digital leadership functions as a boundary-spanning construct linking innovation governance with long-term organizational resilience.

A second theoretical implication arises from the convergence between the organizational behavior and workplace leadership stream (Cluster 2, co-word analysis) and the distributed and educational leadership stream (Cluster 3). This linkage indicates that leadership in digital contexts operates across multiple levels of analysis, from workplace behavior and organizational culture to institutional and educational transformation (Hambley, 2007; Thorpe, 2011; Peterson, 2006). In this sense, digital leadership extends beyond technological competence to include behavioral adaptability, cultural alignment, and distributed decision-making structures. This supports contingency leadership theory by suggesting that leadership effectiveness in digital environments is contingent upon contextual factors such as organizational culture, job design, and institutional structure. At the same time, the presence of distributed leadership, instructional leadership, and transformational leadership within the educational cluster implies that digital leadership is increasingly conceptualized as a shared and relational process rather than a purely hierarchical function (Spillane et al., 2010; Raelin, 2011). Consequently, a key theoretical advancement is the recognition that digital leadership operates as a multilevel construct that

integrates individual behavioral adaptation, organizational culture formation, and institutional transformation.

Taken together, the mapped clusters across both bibliographic coupling and co-word analysis indicate that digital leadership theory is gradually evolving toward a more integrated, multilevel framework. However, the findings also highlight a persistent theoretical fragmentation between technological-capability perspectives, behavioral leadership models, and institutional leadership approaches. Addressing this fragmentation requires future theorizing to explicitly integrate micro-level leadership behaviors, meso-level organizational processes, and macro-level digital transformation outcomes into a unified explanatory model. This would strengthen cumulative theory development in digital leadership research by clarifying how leadership practices translate technological change into sustainable organizational and educational performance outcomes across contexts.

Practical implications

The integrated findings presented in Table 2 and Table 3, as well as Figure 2 and Figure 3, offer several actionable implications for organizations seeking to strengthen digital leadership capabilities in response to ongoing technological disruption. First, the dominance of the digital transformation and innovation cluster (Cluster 1, bibliographic coupling and co-word analysis) suggests that organizations should prioritize the development of structured digital leadership capability frameworks that explicitly integrate artificial intelligence, Industry 4.0 technologies, and knowledge management systems into leadership development programs (Chatterjee et al., 2023; Dubey et al., 2024; Wang et al., 2022). Practically, this implies that human resource systems should move beyond generic leadership training and instead design targeted digital competency development pathways that enhance leaders' ability to manage data-driven decision-making, technological adoption, and innovation ecosystems. Furthermore, organizations should institutionalize digital leadership assessment mechanisms that evaluate leaders' readiness to manage sustainability-driven transformation agendas and technological complexity, ensuring alignment between leadership capability and organizational digital maturity (Zhu et al., 2022; Azzam et al., 2023).

Second, the workplace and organizational behavior cluster (Cluster 2) highlights the importance of embedding digital leadership within daily management practices, particularly in relation to employee engagement, job satisfaction, and organizational culture. This finding suggests that organizations should implement agile and adaptive leadership development programs that strengthen leaders' behavioral flexibility and decision-making responsiveness in dynamic work environments (Thorpe, 2011; Gosling, 2009). In practice, this can be achieved through continuous leadership coaching, real-time feedback systems, and agile team-based structures that enable rapid adaptation to change. Moreover, organizations operating in high-pressure sectors such as healthcare and service industries should prioritize leadership interventions that enhance workplace well-being and strengthen culture-driven performance systems, ensuring that digital transformation does not undermine employee satisfaction but rather reinforces it (Harris, 2022; Bolden et al., 2008).

Third, the educational leadership cluster (Cluster 3) provides important implications for schools, universities, and training institutions seeking to enhance instructional quality through digital leadership practices. The prominence of distributed, instructional, and transformational leadership suggests that educational institutions should adopt shared leadership models that

empower teachers and academic staff to actively participate in digital transformation initiatives (Spillane et al., 2010; Raelin, 2011). Practically, this requires investment in continuous professional development programs focused on digital pedagogy, technology integration, and collaborative instructional design. School administrators should also strengthen teacher leadership structures to ensure that digital innovation is embedded within classroom practices and supported through sustained professional learning ecosystems (Hambley, 2007; Peterson, 2006; Lipscombe, 2023). Collectively, these strategies indicate that digital leadership in education is most effective when it is distributed, capacity-building oriented, and directly linked to school improvement and instructional enhancement outcomes.

Limitation

This study acknowledges several limitations that may influence the comprehensiveness and interpretation of the findings presented in Table 2, Table 3, Figure 2, and Figure 3. First, the analysis relies exclusively on data retrieved from the Scopus database, which, although widely recognized for its extensive coverage of peer-reviewed literature, may still exclude relevant publications indexed in other databases such as Web of Science, Google Scholar, or discipline-specific repositories (Donthu et al., 2021; Zupic & Čater, 2015). As a result, certain emerging studies on digital leadership—particularly those published in regional or non-indexed journals—may not be fully captured within the current bibliometric mapping, potentially limiting the generalizability of the identified intellectual and thematic structures.

Second, the study is restricted to English-language journal articles and open-access publications only, which may introduce language and accessibility bias by excluding potentially significant contributions published in other languages or behind paywalls. This limitation is particularly relevant in the context of digital leadership research, where contextual and culturally embedded insights may vary across regions and institutional settings. Finally, while bibliometric techniques such as bibliographic coupling and co-word analysis provide robust quantitative mapping of knowledge structures, they are inherently limited in their ability to capture deeper theoretical nuance, methodological diversity, and contextual richness embedded within individual studies (Donthu et al., 2021; Zupic & Čater, 2015). Consequently, the findings should be interpreted as a macro-level representation of intellectual structure rather than a comprehensive qualitative synthesis of the digital leadership literature.

CONCLUSION

This study provides a comprehensive bibliometric mapping of digital leadership research by analyzing 1,325 peer-reviewed articles indexed in Scopus (2005–2025), using bibliographic coupling and co-word analysis as complementary science mapping techniques. As presented in Table 2 and Figure 2, the bibliographic coupling analysis reveals four major intellectual clusters, namely digital transformation and AI-driven leadership innovation, organizational behavior and workplace leadership practices, educational and distributed leadership systems, and digital collaboration and knowledge integration in complex organizational environments. Meanwhile, Table 3 and Figure 3 demonstrate that co-word analysis identifies three dominant thematic streams, including digital transformation and technological leadership ecosystems, organizational behavior and agile leadership practices, and educational leadership and

instructional digital innovation. The convergence of these two analytical perspectives indicates that digital leadership scholarship is increasingly structured around the integration of technological capability, leadership practice, and organizational adaptation across multiple contexts.

Overall, the findings demonstrate that digital leadership has evolved from fragmented and context-specific studies into a more consolidated and multidimensional research domain that spans technological, behavioral, and institutional perspectives. The strong interconnection between digital transformation, leadership agility, and organizational performance highlights the growing recognition of digital leadership as a strategic capability for navigating Industry 4.0 and post-digital environments. The co-existence of educational, organizational, and technological leadership streams further confirms that digital leadership is not confined to a single domain but operates as a cross-level construct influencing individual, team, and organizational outcomes. This integrated knowledge structure provides a foundation for future research to develop more unified theoretical models that connect leadership competencies with digital transformation outcomes in diverse settings.

This study also acknowledges several limitations that may affect the interpretation and generalizability of the findings presented in Table 2, Table 3, Figure 2, and Figure 3. First, although Scopus provides extensive coverage of peer-reviewed literature, the exclusive reliance on this single database may exclude relevant studies indexed in other sources such as Web of Science or Google Scholar (Donthu et al., 2021; Zupic & Čater, 2015). Second, the restriction to English-language and open-access journal articles may introduce selection bias, limiting the representation of studies published in other languages or behind paywalls. Finally, while bibliometric techniques provide robust macro-level insights into intellectual structure and thematic evolution, they cannot fully capture the contextual depth, theoretical nuance, and methodological diversity present in individual studies, requiring careful interpretation of the results as a structural rather than interpretive synthesis of the digital leadership literature.

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