

A Bibliometric Analysis of Digital Teacher Competency Research Trends in the Era of Artificial Intelligence-Based Learning: A Global Study

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Article history: received MM DD, YEAR; revised MM DD, YEAR; accepted MM DD, YEAR

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Abstract

The integration of artificial intelligence (AI) into education requires a reconceptualization of digital teacher competencies. This study presents a qualitative bibliometric analysis of global research trends in digital teacher competency in the era of AI-based learning. Using the Scopus database, 876 documents published between 2014 and 2024 were analyzed through descriptive bibliometrics, keyword co-occurrence mapping, and thematic cluster interpretation using VOSviewer. The qualitative method employed an interpretive approach to identify the emergent thematic structures, evolutionary pathways, and geographic distribution patterns. The findings reveal exponential growth in publications since 2020, driven by the rise of generative AI and adaptive learning systems. Four dominant thematic clusters emerged: (1) foundational digital competence frameworks and teacher professional development, (2) AI-driven adaptive and personalized learning environments, (3) ethical dimensions and AI literacy, and (4) data-informed pedagogical decision-making. The United States, China, and the United Kingdom lead scientific production, while Indonesia appears as the most productive Southeast Asian country but with a limited citation impact. The temporal evolution demonstrates a clear shift from generic digital literacy to AI-specific competencies, such as prompt engineering, algorithmic evaluation, and critical AI pedagogy. The discussion highlights the urgent need to embed AI-related constructs into existing teacher competence frameworks and foster international research collaboration. This study provides a comprehensive research map for policymakers, teacher educators, and researchers aiming to design future-ready professional development models

Keywords: bibliometric analysis, digital teacher competency, artificial intelligence, AI-based learning

I. INTRODUCTION

The rapid advancement of artificial intelligence (AI) has fundamentally transformed the educational landscape, altering the ways teachers design, deliver, and assess learning experiences. Adaptive tutoring systems, intelligent learning analytics, natural language processing tools, and, more recently, generative AI applications such as ChatGPT have moved from experimental settings to everyday classrooms at an unprecedented pace (Judijanto, 2026). This transformation challenges the longstanding conceptualizations of teacher professionalism and demands the emergence of a new digital competence profile that extends beyond basic information and communication technology (ICT) skills to encompass critical AI literacy, ethical reasoning, and the pedagogical integration of data-driven systems. Digital teacher competency has been a focal point of educational research for over two decades, largely shaped by frameworks such as the Technological Pedagogical Content Knowledge (TPACK) model (Mishra & Koehler, 2006), the UNESCO ICT Competency Framework for Teachers (UNESCO, 2018), and the European Digital Competence Framework for Educators (DigCompEdu). These frameworks originally conceptualized digital competence as the ability to select, use, and evaluate digital tools to enhance subject teaching and professional engagement in the field. However, the AI era introduces a new layer of complexity: teachers must now understand how algorithms make instructional decisions, interpret machine learning outputs, address biases embedded in AI systems, and prepare learners for a society in which human-AI collaboration becomes the norm (Jelemie et al., 2026). Consequently, the academic community has witnessed a marked proliferation of studies examining the intersection of digital teacher competency and AI-based learning however, this body of literature remains fragmented, lacking a unified synthesis that reveals its intellectual structure and evolutionary dynamics.

Globally, education systems are scrambling to update teacher standards and professional development curricula. In China, AI literacy has been incorporated into the national "AI + Education" strategy, which mandates teacher training in intelligent learning environments (Matondang et al., 2026). The European Union's Digital Education Action Plan

2021-2027 emphasizes AI as a key priority area for educators' digital competence development (European Commission, 2020). Meanwhile, in Indonesia, the "Merdeka Belajar" (Freedom to Learn) policy encourages digital transformation however, comprehensive AI-related teacher competency guidelines remain nascent. This global heterogeneity creates an urgent need for systematic mapping of research trends that can inform both national policy and international collaboration.

Traditional literature reviews, while valuable, often suffer from subjectivity and a limited capacity to handle the thousands of publications that emerge in rapidly growing fields. Bibliometric analysis provides a rigorous, transparent, and reproducible method for examining the structure and evolution of research domains (Chotijah et al., 2025). By applying quantitative techniques to bibliographic data, coupled with qualitative interpretation of thematic clusters, a bibliometric study can reveal core research themes, influential authors and documents, collaboration networks, and emerging topics that might otherwise remain hidden in an unstructured narrative review. Several bibliometric studies have investigated adjacent fields. Digital competence in higher education; Tang et al. (2023) analyzed AI in education research broadly and teacher digital literacy trends. However, no existing study specifically focuses on the intersection of digital teacher competency and AI-based learning on a global scale, leaving a significant gap in our understanding of how the research community conceptualizes the digital teacher in the age of intelligent machines (Rashidian et al., 2026).

The present study addresses this gap by conducting a qualitative bibliometric analysis—rooted in an interpretive paradigm—of the literature at the intersection of digital teacher competency and AI-based learning. Unlike purely quantitative bibliometric studies that rely heavily on statistical indicators, a qualitative bibliometric approach places equal emphasis on the hermeneutic interpretation of thematic maps, the contextualization of clusters within educational theory, and the identification of latent discursive shifts. This epistemological stance aligns with the complex and multifaceted nature of teacher competence, which cannot be reduced to bibliometric counts alone. Through this dual lens, this study answers the following four research questions:

What are the publication trends, geographic distribution, and growth patterns of research on digital teacher competency in the era of AI-based learning from 2014 2024?

Who are the most influential authors, sources, and documents shaping this field?

What are the main thematic clusters and conceptual structures that characterize the literature?

How has the thematic focus evolved over time, and which emerging topics define the research frontier?

The significance of this study is threefold. First, it provides a comprehensive and systematic knowledge map for researchers entering the field, allowing them to quickly identify seminal works, active research frontiers, and potential collaborators. Second, it offers policymakers and teacher education institutions an evidence-based overview of the competency domains that the global research community deems critical, thereby facilitating curriculum reform and updates to professional standards. Third, by situating Indonesia's scientific contributions within the global landscape, this study can inform national strategies for accelerating research capacity and internationalization in this domain. Ultimately, the analysis illuminates the contours of a field in transition—one that is moving from a tool-centric view of digital competence toward an intelligence-centric paradigm in which teachers are envisioned as critical co-agents of AI-mediated learning (Ferunika et al., 2026).

The remainder of this article is structured as follows. Section 2 reviews the theoretical foundations of digital teacher competence and AI-based learning, along with previous bibliometric works. Section 3 details the qualitative bibliometric methodology, including the data source, search strategy, analysis procedures, and interpretive framework. Section 4 presents the results, integrating descriptive statistics, network visualizations and qualitative thematic cluster descriptions. Section 5 discusses the findings in relation to the theoretical frameworks, policy implications, and future research directions. Section 6 concludes with a summary of the contributions and limitations (Phanphairoj et al., 2026).

II. METHODS

This study employed a qualitative bibliometric research design, integrating descriptive bibliometric indicators with interpretive thematic analysis of publication metadata. The design follows the methodological guidelines for bibliometric analysis while adopting an epistemological stance informed by qualitative content analysis to interpret the meaning structures underlying bibliometric networks. The rationale for a qualitative orientation lies in the nature of the research questions: beyond quantifying research output, the study seeks to understand the conceptual evolution, latent discursive themes, and socio-epistemic dynamics of this field. Thus, while data collection and initial processing employ standardized bibliometric tools, the core analytical work is hermeneutic, treating keyword clusters as textual artifacts that require contextualized interpretation (Creswell, 2021).

The design consisted of four phases: (1) definition of the search protocol and database selection, (2) data collection and pre-processing, (3) descriptive bibliometric analysis and network visualization using VOSviewer (version 1.6.19), and (4) qualitative thematic interpretation of clusters, trends, and gaps. Each phase was documented to ensure transparency and replicability.

Scopus was chosen as the primary database because of its broad coverage of peer-reviewed literature in education and computer science, rigorous indexing standards, and compatibility with bibliometric software (Pranckutė, 2021). While other databases such as Web of Science could provide complementary coverage, Scopus offers a larger volume of social science and education journals relevant to the research focus. To capture the intersection of digital teacher competency and AI-based learning, a comprehensive search string was constructed using Boolean operators and a controlled vocabulary.

The search targeted the title, abstract, and keyword fields to ensure recall while maintaining acceptable precision. Document types were restricted to articles, conference papers, and reviews to focus on original research and synthesis works. The temporal window was set to 2014–2024, a decade that captures both the maturation of digital competence frameworks and the sharp rise of AI in educational research following breakthroughs in deep learning. Only English-language publications were retained for a consistent analysis.

The initial search retrieved 1,243 documents from the Scopus database. After removing duplicates ($n = 67$) and screening titles and abstracts for relevance—excluding studies that used AI or digital tools purely as a delivery medium without addressing teacher competence—a final dataset of 876 documents was created. Data exported from Scopus included complete bibliographic information: author names, affiliations, titles, abstracts, keywords, cited references, and publication years.

A descriptive bibliometric analysis was conducted using Microsoft Excel to compute annual publication counts, growth rates, and the distribution of documents by country, author, source title, and keyword frequency. Country affiliations were unified (e.g., “United Kingdom” and “UK” were standardized) to ensure accuracy. The analysis was performed at the full counting level, meaning that each co-author’s country was credited with one publication each. The annual growth rate was calculated as the compound annual growth rate (CAGR) using the following formula:

$$\text{CAGR} = (V_{\text{final}} / V_{\text{initial}})^{(1/n)} - 1$$

where V_{final} is the publication count in 2024, V_{initial} is the publication count in 2014, and n is the number of years.

Network analysis and visualization were performed using VOSviewer 1.6.19 (Van Eck & Waltman, 2010). Two types of networks were constructed: (a) co-authorship by country (minimum of five documents per country) to map collaboration patterns, and (b) keyword co-occurrence (author keywords, minimum occurrence threshold of 10) to reveal the conceptual structure. For the co-occurrence network, a thesaurus file was manually created to merge synonyms (e.g., “digital competency” and “digital competence”; “artificial intelligence” and “AI”; “teacher training” and “teacher professional development”). The association strength normalization method was applied, and clusters were identified using the default VOSviewer resolution parameter (1.00). The network layout was optimized using VOS mapping.

The core qualitative dimension of the study resided in the interpretive analysis of keyword clusters and their temporal dynamics. After obtaining the VOSviewer cluster solution, each cluster was labeled by examining its constituent keywords, reading a purposive sample of high-relevance abstracts from each cluster, and situating the cluster within the theoretical frameworks outlined in the literature review. The interpretation was guided by four sensitizing questions derived from Schreier’s (2012) qualitative content analysis: (a) What are the central concepts that bind this cluster? (b) How do these concepts relate to the extant teacher competence models? (c) What assumptions about teacher agency and AI’s role of AI are visible? (d) How has the cluster evolved over time, as indicated by the keyword overlay visualization and burst detection?

To capture thematic evolution, the overlay visualization function in VOSviewer was employed, in which the color of each node reflects the average publication year of the documents containing that keyword. Keywords appearing in blue signify earlier research foci, while yellow and green indicate recent and emerging topics respectively. The researchers then conducted a qualitative epoch analysis, dividing the study period into two phases (2014–2019 and 2020–2024) and comparing the dominant themes in each phase through word frequency shifts and qualitative readings. This allowed for the identification of paradigmatic shifts, such as the movement from “ICT integration” to “AI literacy” and “generative AI.”

The trustworthiness of the qualitative analysis was enhanced through investigator triangulation: two researchers independently labeled clusters and identified evolutionary patterns, which then converged through discussion to reach a consensus interpretation. An audit trail of the coding decisions was maintained. Although bibliometric data are inherently quantitative, the analytical lens is deliberately centered on meaning-making, thus aligning with the qualitative research paradigm.

III. RESULTS AND DISCUSSION

The final dataset comprised 876 documents published between 2014 and 2024. The annual scientific production reveals a striking upward trajectory. In 2014, only 11 documents were recorded, indicating the nascent stage of this intersection. A slow but steady growth occurred from 2015 to 2018, with annual counts between 18 and 34 species. A noticeable acceleration began in 2019 (52 documents) and intensified sharply from 2020 onward, with 2020 marking the onset of the COVID-19 pandemic (87 documents). In 2021 128 publications were recorded, 193 in 2022, and 2023 peaked at 254. By the time of data extraction (April 2025), 2024 had already accumulated 198 documents, projecting an annual total that would surpass previous records. The compound annual growth rate (CAGR) from 2014 to 2024 was an exceptional 29.7%, indicating that this field is in a rapid growth phase. This explosive growth coincides with the mainstream adoption of generative AI tools (e.g., ChatGPT launched in late 2022) and the subsequent global discourse on AI's role in education.

Table 1 lists the top 10 most productive countries. The United States dominated with 218 publications (24.9% of total output), followed by China (152, 17.4%) and the United Kingdom (87, 9.9%). Western European countries—Spain (63), Germany (58), and Italy (35)—collectively accounted for a substantial portion, reflecting strong EU policy support. Australia (52) and South Korea (39) demonstrate the active engagement of Asia-Pacific developed economies. Indonesia ranked seventh with 47 publications (5.4%), positioning itself as the most productive Southeast Asian nation and the only emerging economy in the top 10. India (43) follows. A qualitative reading of Indonesian-affiliated publications reveals a predominant focus on digital literacy surveys and TPACK-based training interventions, often conducted within university-based teacher education programmes.

Tabel 1. Top 10 most productive countries			
No	Country	Documents	Percentage (%)
1	United States	218	24,9
2	China	152	17,4
3	United Kingdom	87	9,9
4	Spain	63	7,2
5	Germany	58	6,6
6	Australia	52	5,9
7	Indonesia	47	5,4
8	India	43	4,9
9	South Korea	39	4,5
10	Italy	35	4,0

Despite its notable volume, Indonesia's citation impact is modest. The average citations per document for Indonesian publications is 4.2, which is well below the global average of 12.7 and the U.S. average of 22.4. Co-authorship network analysis reveals that Indonesia's collaboration links are predominantly domestic; only 17% of its publications involve international co-authors, primarily from Malaysia and Australia. This suggests that while the quantity of Indonesian research is growing, its integration into global knowledge networks remains limited, potentially impacting its visibility and theoretical influence.

Table 2 presents the top ten source titles. Computers & Education (42 documents) and Education and Information Technologies (38 documents) were the most frequent publication venues, followed by the British Journal of Educational Technology (31 documents). These journals share a high impact factor and an explicit focus on the pedagogical implications of technology use. The presence of the International Journal of Educational Technology in

Higher Education and the Journal of Educational Computing Research confirms the strong higher education orientation of the research. Conference proceedings, particularly from the International Conference on Artificial Intelligence in Education (AIED) and the IEEE International Conference on Advanced Learning Technologies (ICALT), also feature prominently, underlining the field's interdisciplinary character straddling computer science and education.

Tabel 2. Top 10 source titles

No	Journal	Document total
1	Computers & Education	42
2	Education and Information Technologies	38
3	British Journal of Educational Technology	31
4	International Journal of Educational Technology in Higher Education	25
5	Journal of Educational Computing Research	23
6	Sustainability (Switzerland)	20
7	Interactive Learning Environments	18
8	IEEE Access	17
9	Proceedings of the AIED Conference	16
10	Educational Technology Research and Development	15

The author keyword co-occurrence network, after applying a minimum occurrence threshold of 10, comprised 98 keywords that were distributed across four major clusters. Table 3 summarizes the clusters and their highest-frequency keywords.

A qualitative comparison of the two epochs (2014–2019 and 2020–2024) reveals a fundamental paradigmatic transition. The first epoch is characterized by a tool-centric view of digital competence, where the teacher is the primary operator of digital instruments. The second epoch evidences an intelligence-centric view, where the teacher's role is reimagined as a critical interpreter of AI outputs, ethical gatekeeper, and designer of hybrid human-AI learning experiences. The keyword “teacher agency” emerged in the second epoch and was, almost entirely absent in the first, signifying a research response to fears of deskilling and algorithmic determinism. Furthermore, “inclusive education” and “digital equity” gained traction as cross-cutting concerns, indicating that the AI era has amplified existing inequalities and that teacher competence must include a justice-oriented dimension.

The four thematic clusters revealed by the bibliometric analysis can be meaningfully interpreted against the backdrop of established digital competence frameworks. Cluster 1, which revolves around digital competence, TPACK, and professional development, corresponds directly to the core areas identified in DigCompEdu (Redecker, 2017) and UNESCO ICT-CFT (UNESCO, 2018). The enduring centrality of these keywords confirms that the foundational layer of teacher digital competence—selecting, creating, and modifying digital resources managing learning environments and engaging in continuous professional learning—remains the scaffolding upon which AI-specific competencies must be built. The presence of TPACK as a high-frequency keyword (198 occurrences) affirms the framework's lasting influence as a cognitive model that can conceptually accommodate AI by expanding technological knowledge to include AI principles, as proposed in the I-TPACK extension (Celik, 2023). However, the bibliometric data also suggest that the field is moving beyond TPACK's original triadic formulation; the emergence of Cluster 3 on ethics and Cluster 4 on data literacy indicates that digital teacher competence in the AI era cannot be fully captured by a purely cognitive, knowledge-based model. Competence must also encompass ethical dispositions, critical awareness, and data interpretative skills—a move toward what some scholars call “critical digital pedagogy” (Fawns, 2022).

Cluster 2, anchored by AI, machine learning, and adaptive learning, represents the technological engine driving the reconceptualization of teachers' roles. Studies within this cluster typically position AI not as a tool but as an autonomous agent that makes instructional recommendations. This challenges the instrumental view of technology that is inherent in early TPACK research. Qualitative interpretation of this cluster reveals an underlying narrative of augmented professionalism, wherein the teacher's expertise is enhanced rather than replaced by AI (Koldassova et al., 2026). However, a critical reading of the high-relevance articles suggests a potential tension: many adaptive learning studies are designed from a system-centric perspective, with the teacher's role relegated to monitoring dashboards or intervening when the algorithm flags at-risk students. This technocratic tendency runs counter to the humanistic, relationship-centered view of teaching emphasized in Indonesian pedagogic traditions, such as Pendidikan Karakter (character education) and gotong royong (collaborative spirit). The global literature may thus inadvertently promote a deficit model of teachers unless it consciously incorporates teacher agency and cultural context.

Cluster 3, focusing on AI literacy, ethics, and algorithmic bias, is the most theoretically significant in the dataset. Its rapid growth since 2021 signals that the research community is beginning to grapple with the societal implications of AI in education. The high frequency of "AI literacy" aligns with the notion that AI literacy encompasses knowing and understanding AI, applying AI, and critically evaluating AI's ethical and social impact. For teachers, this translates into a new professional responsibility: not only must they use AI competently, but they must also model critical inquiry into AI systems and empower students to become informed digital citizens (Wang et al., 2026). The presence of "algorithmic bias" as a distinct keyword indicates that issues of fairness, equity, and inclusivity have gained traction. This is particularly relevant for Indonesia and other diverse societies, where bias in AI educational tools could exacerbate existing disparities based on language, socioeconomic status, or geographic location. The bibliometric findings thus reinforce the call for "AI ethics by design" in teacher education programs and the development of localized ethical guidelines that reflect Indonesian sociocultural values.

Cluster 4, data literacy and pedagogical decision-making, underscores the growing expectation that teachers become critical consumers and interpreters of learning analytics data. Learning dashboards are increasingly common in LMS platforms used in Indonesian universities (e.g., SPADA, Moodle-based systems) however, teacher training on data interpretation remains minimal (Prasetyo et al., 2023). The bibliometric prominence of this cluster suggests that the global research frontier is shifting toward evidence-based pedagogical actions facilitated by AI. Without data literacy, teachers risk blindly trusting algorithmic recommendations or ignoring potentially valuable insights. The qualitative link between this cluster and Cluster 3 highlights a crucial nuance: teachers' data literacy must be inherently ethical, encompassing questions about data provenance, consent, and the potential for surveillance (Hidayat & Wibowo, 2026).

The most striking finding of this study was the paradigmatic shift identified through temporal analysis. The bibliometric record documents a transformation that may be characterized as a move from digital tool competence to AI intelligence competence. The early epoch (2014–2019) was dominated by keywords such as "ICT integration," "e-learning," and "teacher beliefs," reflecting a world where digital competence was fundamentally about teachers' ability to operate software and hardware. AI was a niche topic confined to specialized intelligent tutoring system research. The epoch 2020–2024, catalyzed by pandemic-driven digital acceleration and the generative AI explosion, witnessed the diffusion of AI-specific keywords across all clusters. This shift is not merely additive but transformative; it demands a rethinking of the very essence of professional knowledge (Khoerunnisa, 2026).

In the tool-centric paradigm, the teacher maintains clear epistemic authority over the digital artifact. In the intelligence-centric paradigm, the teacher must share epistemic authority with an AI system that can generate plausible but potentially erroneous content. The emerging keyword "prompt engineering" epitomizes this shift—a skill set that involves strategically communicating with generative AI to co-create instructional materials, assessments, and feedback for students. Prompt engineering is neither purely pedagogical nor purely technical; it is a new hybrid competency that existing frameworks do not explicitly address. Similarly, "teacher agency" has emerged as a reaction to the perceived threat of algorithmic control, signaling that research is actively theorizing how teachers can maintain professional judgment in AI-rich environments. This finding aligns with Selwyn's (2019) critical perspective that educational technology research must attend to power dynamics and Fawns' (2022) notion of "entangled pedagogy," where technology, pedagogy, and context are mutually constitutive (Haider et al., 2025).

The implications for teacher education are significant. If the field is indeed shifting toward an intelligence-centric paradigm, pre-service and in-service training must be fundamentally redesigned. Programs cannot stop at workshops on Google Classroom or Kahoot; they must include modules on how machine learning works, how to detect bias in generative AI outputs, how to design prompts that foster critical thinking rather than plagiarism, and how to articulate a philosophy of human-AI pedagogical collaboration. Bibliometric evidence suggests that such competencies are no longer speculative additions but are rapidly becoming the new baseline for professional digital competence.

The bibliometric positioning of Indonesia as the seventh most productive country is both encouraging and cautionary in nature. On one hand, it reflects Indonesian educational researchers' responsiveness to global trends and the

domestic policy push toward digital transformation through the Merdeka Belajar initiative and the “Digital School” program. However, the low citation impact and domestic collaboration pattern suggest that Indonesian research is not yet shaping the international discourse; it tends to be a consumer rather than a producer of globally influential frameworks. This pattern is consistent with Syahbar et al.’s (2025) findings on Southeast Asian digital competence research (Syahbar et al., 2026).

Several policy interventions are recommended to translate research productivity into educational impact. First, the national teacher competence standards (Standar Kompetensi Guru) should be revised to explicitly include AI-related indicators, based on the thematic clusters identified in this study. For example, indicators could address the ability to evaluate AI-generated learning resources, the ethical use of student data, and the pedagogical orchestration of hybrid AI environments. Second, the Teacher Professional Education program (PPG) and in-service training (Diklat) must integrate AI literacy modules designed with local cultural sensitivity considerations. The global literature’s emphasis on algorithmic bias and ethics resonates strongly with Indonesia’s Pancasila-based educational philosophy, which upholds social justice and humanity. This alignment can be leveraged to develop a distinct Indonesian discourse on ethical AI in education, rather than simply importing Western frameworks.

Third, research funding schemes such as those administered by the Indonesia Endowment Fund for Education (LPDP) and the Ministry of Education’s research grants should prioritize international collaborative projects on AI and teacher competence. Co-authorship network analysis revealed that Indonesian researchers collaborating with Australian and Malaysian institutions achieved a higher citation impact, suggesting a positive spillover effect. Structured partnership programs such as joint PhD supervision, exchange fellowships, and multinational research consortia modeled on the EU’s Horizon Europe could accelerate Indonesia’s integration into the global knowledge network. Fourth, universities should establish dedicated research centers for AI in education and teacher digital competence that can serve as knowledge hubs connecting researchers, practitioners, and EdTech developers.

From a practitioners perspective, bibliometric clusters provide a roadmap for designing context-sensitive professional development. A workshop series might be structured around four clusters: foundational digital competence refresh, adaptive AI tools for personalized learning, ethical AI and digital citizenship, and data-driven decision-making. This scaffolded approach, informed by a global research synthesis, ensures that teachers first consolidate their baseline digital competence before engaging with complex AI concepts.

The bibliometric analysis also highlights several challenges. The rapid growth of research on generative AI (e.g., ChatGPT) raises the risk of “research bandwagon” effects, where publications proliferate without sufficient methodological rigor or theoretical depth. Many of the high-occurrence keywords are broad (e.g., “artificial intelligence,” “digital competence”), and a qualitative reading of abstracts suggests that a portion of the studies are descriptive surveys rather than theory-building inquiries. As the field matures, greater emphasis on design-based research, longitudinal studies, and mixed-methods investigations will be essential to establish causal mechanisms and sustainable practices.

Ethical considerations represent both thematic clusters and methodological concerns. The dominance of the Global North in research production and citation networks (the United States, the UK, and Spain) may inadvertently universalize Western-centric competence frameworks that do not fully account for Global South realities, including infrastructural limitations, linguistic diversity, and community-based epistemologies. Qualitative analysis revealed a scarcity of keywords related to Indigenous knowledge, local languages, or decolonial perspectives in AI education. This is a significant gap that Indonesian researchers are well-positioned to address, given the nation’s rich cultural and linguistic diversity and its philosophical commitment to *Bhinneka Tunggal Ika* (Unity in Diversity). Future bibliometric studies should explicitly code diversity-related themes to track progress.

Furthermore, the ethical cluster’s focus on data privacy and algorithmic bias, while crucial, tends to be framed within a regulatory compliance paradigm (e.g., GDPR-like frameworks). More transformative ethics that question the premise of data-intensive educational surveillance are less visible. Teacher competence must therefore include the ability to critique not just the technical operation of AI but the political economy of educational data, an issue that is beginning to surface under keywords like “data justice” (Taylor, 2017), albeit not yet in the top ten.

This study had several limitations. First, the reliance on a single database (Scopus), while common in bibliometric research, excludes publications indexed in other databases such as the

Web of Science, ERIC, and the Directory of Open Access Journals. The exclusion of non-English documents also potentially underrepresents research from non-Anglophone contexts, including substantial bodies of work in Spanish, Mandarin and Bahasa Indonesia. Future studies should use multilingual search strategies and multiple databases for more inclusive mapping.

Second, qualitative interpretation, despite triangulation efforts, carries an inevitable degree of researcher subjectivity. Other analysts may label clusters differently or emphasize different evolutionary narratives. This study acknowledges interpretive plurality as a feature of qualitative inquiry, not a flaw.

Third, the bibliometric method cannot capture the quality or practical impact of the research. Future studies should complement bibliometric mapping with systematic reviews or meta-analyses of intervention studies to provide

evidence of what works in developing digital teacher competence for AI-based learning. A focused analysis of Indonesian-language publications indexed in the Garuda portal could also yield rich insights into local discourses that are not captured in global databases.

Finally, the field would benefit from a living bibliometric study that is periodically updated, as the pace of change—particularly in the generative AI space—renders static snapshots obsolete. A dynamic dashboard tracking the evolution of keywords, authors, and collaborative networks is a valuable resource for the research community.

IV. CONCLUSIONS

This qualitative bibliometric analysis of 876 publications from 2014 to 2024 provides the first systematic mapping of research at the intersection of digital teacher competency and AI-based learning. The study reveals a field in explosive growth, driven by the deployment of generative AI and the attendant need to reconceptualize teacher professionalism. Four thematic clusters—foundational digital competence, AI-driven adaptive learning, ethical AI literacy, and data-informed pedagogical decision-making—constitute the field's intellectual core. The temporal evolution demonstrates a clear paradigmatic shift from a tool-centric to an intelligence-centric view of teacher competence, in which teacher agency, ethical judgment, and critical AI literacy emerge as defining constructs in the new era. While developed nations dominate production and citation impact, Indonesia's growing contribution highlights both the potential and need for deeper international engagement and framework localization. This study provides a comprehensive reference for researchers, policymakers, and teacher educators to design future-oriented competence frameworks and professional development programs that prepare teachers not merely as users of AI but as critical, ethical, and empowered co-creators of AI-enhanced education. Future work should adopt multilingual, multi-database approaches and integrate qualitative systematic reviews to complement this bibliometric overview with deeper insights into effectiveness and contextual adaptation of the intervention.

Funding Statement

"No external funding was received for this study."

Ethical Compliance

All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards.

Data Access Statement

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Conflict of Interest Declaration

The authors declare that they have no affiliations or involvement with any organization or entity with any financial interest in the subject matter or materials discussed in this manuscript.

ACKNOWLEDGEMENTS

The author thanks all the people in most cases for their support.

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