Teacher Effectiveness in the Age of Artificial Intelligence and Digitalization: The Trends, Intellectual Structures, And Future Research Directions

Noor Arifah Moider, Tengku Faekah Tengku Ariffin, Hasniza Nordin

Abstract - **Teacher effectiveness remains a central determinant of educational quality, yet its conceptualization is increasingly challenged by the rapid advancement of artificial intelligence (AI) and digitalization in education. While research in this field has expanded significantly, the evolving structure and direction of teacher effectiveness research in the context of AI-driven educational transformation remain insufficiently understood. This study addresses this gap by providing a comprehensive bibliometric analysis of teacher effectiveness research in the digital era. Data were retrieved from the Scopus database, resulting in a dataset of 1,286 peer-reviewed journal articles published between 1940 and 2025. The analysis examined publication trends, influential authors, citation structures, and global research contributions. OpenRefine was utilized for data cleaning, while VOSviewer was employed to visualize keyword co-occurrence and international co-authorship networks. The findings reveal a significant increase in research output since the early 2010s, reflecting the growing influence of digitalization and AI-related transformations in education. Although dominant themes remain centered on professional development, self-efficacy, instructional quality, and teacher education, digital-related constructs are still emerging and not yet fully integrated into the core discourse of teacher effectiveness. Importantly, the study identifies a critical conceptual gap in the incorporation of AI-driven pedagogical practices, digital well-being, and leadership-oriented frameworks into teacher effectiveness research. This suggests the need for future studies to move beyond traditional paradigms and develop integrative models that reflect the complexities of AI-enhanced educational environments. Overall, this study provides a systematic overview of the intellectual landscape and offers directions for advancing research, policy, and practice in teacher effectiveness within the age of artificial intelligence and digitalization.**

Keywords – **Artificial intelligence; bibliometric analysis; digitalization; teacher effectiveness; teacher quality**

I. INTRODUCTION

Teacher effectiveness has long been recognised as a central determinant of educational quality and student outcomes. Traditionally, the concept has been examined through pedagogical, psychological, and professional lenses, with a strong emphasis on instructional quality, teacher competence, and classroom practices (Muijs et al., 2014; Klassen & Tze, 2014). Over time, the field has evolved in response to educational reforms, accountability movements, and increasing demands for evidence-based teaching.

Noor Arifah Moider, Institute of Teacher Education Malaysia, Sultan Mizan Campus, Terengganu, Malaysia (noorarifah@ipgmksm.edu.my).
Tengku Faekah Tengku Ariffin, School of Education, UUM, Kedah, Malaysia (tfaekah@gmail.com)
Hasniza Nordin, School of Education, UUM, Kedah (Nizadin@uum.edu,my)

In recent decades, however, the rapid advancement of digital technologies and artificial intelligence (AI) has fundamentally reshaped the educational landscape. Teaching is no longer confined to traditional classroom interactions but increasingly occurs within digitally mediated and technology-enhanced environments. These transformations have introduced new dimensions to teacher effectiveness, including digital competence, adaptive pedagogy, and the ability to navigate AI-supported learning systems (Liu et al., 2025; Gonçalves et al., 2026). As a result, teacher effectiveness is progressively understood as a multidimensional construct influenced by the interaction between pedagogy, technology, and organizational contexts.

Despite these developments, the evolution of teacher effectiveness research has not occurred in a linear or fully integrated manner. Instead, the field has expanded across diverse thematic domains, including professional development, self-efficacy, instructional quality, and teacher education, often examined in isolation. At the same time, emerging constructs related to digitalization, artificial intelligence, and technology-mediated teaching remain relatively peripheral within the broader discourse. This uneven development suggests that while the field is growing rapidly, its conceptual foundations are still anchored in pre-digital paradigms.

Given the long historical trajectory of teacher effectiveness research, spanning from early pedagogical studies in the 1940s to contemporary AI-driven educational contexts, there is a need to systematically examine how the field has evolved over time. In particular, understanding publication trends, influential contributors, thematic structures, and global collaboration patterns is essential for capturing the intellectual development of the field.

Therefore, this study adopts a bibliometric approach to analyze teacher effectiveness research from 1940 to 2025. By addressing key questions related to publication growth (RQ1), authorship patterns (RQ2), citation impact (RQ3), country contributions (RQ4), thematic evolution (RQ5), and international collaboration (RQ6), the study provides a comprehensive and longitudinal mapping of the field. More importantly, by employing keyword co-occurrence and network visualization techniques, this study offers a structured perspective on how teacher effectiveness research is evolving within the context of digitalization and artificial intelligence.

II. PROBLEM STATEMENT

The rapid expansion of artificial intelligence (AI), digital platforms, and technology-mediated teaching has introduced significant complexity into the conceptualization of teacher effectiveness. Rather than developing into a cohesive body of knowledge, the field has become

increasingly fragmented, with research dispersed across multiple domains, including professional development, self-efficacy, instructional quality, and digital competence (Xia, 2026). Although each of these dimensions contributes to understanding teacher effectiveness, they are often examined in isolation, resulting in a lack of an integrated conceptual framework that explains their interrelationships within digitally mediated environments (OECD, 2026).

This fragmentation is further reinforced by the limitations of existing review approaches. While narrative and systematic reviews have contributed valuable insights, they are inherently constrained in their ability to capture large-scale intellectual structures, thematic evolution, and global collaboration patterns within a rapidly expanding body of literature (Susoy & Zarfsaz, 2025). As a result, the field lacks a macro-level analytical perspective capable of mapping how knowledge on teacher effectiveness is structured, interconnected, and evolving over time.

The absence of such a perspective is particularly problematic in the context of digital transformation and AI-driven education, where research is expanding rapidly but unevenly. As indicated by recent bibliometric evidence, there is a growing volume of studies; however, digital-era constructs such as AI-driven pedagogy, digital well-being, and technology-integrated teaching practices remain insufficiently embedded within the core intellectual structure of teacher effectiveness research (Fu et al., 2025). This suggests a misalignment between the rapid transformation of educational practice and the slower development of theoretical and conceptual frameworks.

Consequently, the lack of a comprehensive bibliometric synthesis limits the field's ability to strategically navigate emerging complexities and identify coherent research directions. Without a systematic mapping of longitudinal trends, intellectual structures, and thematic developments, it remains difficult to understand how teacher effectiveness research has evolved and how it should progress in response to digitalization and artificial intelligence.

Therefore, there is a critical need for a longitudinal bibliometric analysis that systematically examines the evolution, structure, and emerging directions of teacher effectiveness research. Such an approach is essential not only for consolidating fragmented knowledge but also for providing a strategic foundation for future research, theory development, and educational practice in the age of AI and digitalization.

III. METHODOLOGY

This study adopted a bibliometric approach to systematically examine scholarly work on teacher effectiveness in the digital era. Bibliometrics enables the structured collection, organization, and analysis of publication data, allowing researchers to map patterns, trends, and intellectual structures within a research field (Alves et al., 2021; Assyakur & Rosa, 2022; Verbeek et al., 2002). Beyond descriptive indicators such as publication outlets, publication years, and influential authors the analysis also employed advanced techniques, including document co-citation analysis, to capture deeper conceptual linkages across studies (Wu & Wu, 2017).

The review process followed an iterative and reflective procedure, beginning with the careful refinement of keywords, followed by comprehensive database searching and detailed analytical screening. This stepwise approach was essential for constructing a coherent and reliable bibliographic corpus (Fahimnia et al., 2015). In line with the study's objective to understand the theoretical foundations of the field, priority was given to high-impact publications that offer substantive conceptual and empirical contributions.

To ensure consistency and data reliability, SCOPUS was selected as the primary database, given its rigorous indexing standards and extensive coverage of high-quality journals (Al-Khoury et al., 2022; Di Stefano et al., 2010; Khiste & Paithankar, 2017). Only peer-reviewed journal articles were included to maintain academic rigor, while books and lecture materials were intentionally excluded (Gu et al., 2019). The data were retrieved from the Scopus database in January 2026. While the search results included publications indexed up to early 2026, the analysis was limited to publications from 1940 to 31 December 2025 to ensure completeness and avoid bias due to indexing delays.

Data cleaning was conducted using OpenRefine, involving keyword normalization, removal of duplicates, and author name disambiguation to ensure dataset consistency. The use of Scopus as the primary database ensures data reliability due to its rigorous indexing standards and broad disciplinary coverage.

This study relies on publicly available bibliographic data; therefore, no ethical approval was required.

IV. DATA ANALYSIS

The bibliometric analysis in this study was conducted using VOSviewer, a widely recognized and user-oriented software developed by Nees Jan van Eck and Ludo Waltman at Leiden University, the Netherlands (van Eck & Waltman, 2010, 2017). VOSviewer is extensively applied in bibliometric research to visualize and analyze scientific literature through network-based representations. The software is particularly effective in constructing network visualizations, identifying clusters of related items, and producing density maps that reveal the intellectual structure of a research field. Its functionality supports the analysis of co-authorship, co-citation, and keyword co-occurrence networks, thereby enabling a comprehensive exploration of research patterns and thematic developments. The interactive design and regular updates further facilitate efficient handling and interpretation of large bibliographic datasets.

A key strength of VOSviewer lies in its ability to convert complex bibliometric data into visually accessible maps and graphical representations. By emphasizing network visualization, the software allows researchers to identify relationships among publications, authors, and keywords through clustering and co-occurrence analysis. Its intuitive interface supports both novice and experienced users in navigating research landscapes systematically. Continuous refinement of the software ensures its relevance in contemporary bibliometric studies, offering flexible options for metric computation and visual customization. Moreover, its compatibility with multiple bibliographic data formats

reinforces its value as a robust analytical tool for examining complex and evolving research domains.

For this study, bibliographic datasets containing information on publication year, article title, authorship, journal source, citation counts, and keywords were retrieved from the Scopus database in January 2026. The dataset comprised publications indexed between 1940 and 31 December 2025, ensuring a complete longitudinal analysis across more than eight decades of research development. These datasets were subsequently analyzed using VOSviewer version 1.6.19. Full counting was applied to ensure equal weight was assigned to each occurrence of authors, keywords, and documents in the network analysis.

The software's clustering and mapping techniques were employed to generate visual representations of the data. As an alternative to the Multidimensional Scaling (MDS) approach, VOSviewer positions items within a low-dimensional space such that the distance between any two items reflects the strength of their relatedness (van Eck & Waltman, 2010). While this approach shares conceptual similarities with MDS (Appio et al., 2014), it differs in its methodological foundation. Unlike MDS, which typically relies on similarity measures such as cosine similarity or the Jaccard index, the VOS approach applies a more appropriate normalization technique for co-occurrence data, namely association strength (AS_{ij}) (van Eck & Waltman, 2007). Association strength is calculated as follows:

$$AS_{ij} = \frac{C_{ij}}{w_i w_j}$$

which C_{ij}represents the number of co-occurrences between items i and j, and w_i and w_j denote the total occurrences of items i and j, respectively (van Eck & Waltman, 2007).

V. DATA SEARCH STRATEGY

The data retrieval process for this bibliometric study was conducted using the Scopus database through an advanced search strategy designed to ensure both relevance and disciplinary focus. The search covered all years available in the Scopus database for the selected query, spanning from 1940 to December 2025, representing the full historical development of teacher effectiveness research. The search string TITLE (Teacher effectiveness) AND (LIMIT-TO (LANGUAGE , "English")) AND (LIMIT-TO (SUBJAREA , "SOCI")) was applied to capture publications in which teacher effectiveness constitutes the central analytical focus, rather than a peripheral concept. To maintain linguistic consistency and analytical coherence, the search was limited to English-language publications. In addition, the subject area filter SOCI (Social Sciences) was applied to align the dataset with educational, organizational, and socio-pedagogical perspectives, which are most relevant for examining teacher effectiveness within digitally transforming educational systems. This structured filtering strategy was intended to balance breadth and precision, ensuring that the retrieved literature meaningfully reflects scholarly discourse in education and related social science fields.

Following the application of these criteria, a final dataset of 1,286 publications was obtained and deemed suitable for bibliometric analysis. This volume indicates sustained and growing scholarly attention to teacher effectiveness as a core issue within contemporary educational research. The dataset provides a robust foundation for mapping publication trends, identifying influential authors and journals, and examining thematic evolution related to digitalization, pedagogy, and professional practice. By restricting the dataset to high-quality, peer-reviewed Scopus-indexed sources, the study ensures analytical rigor while enabling a comprehensive exploration of the intellectual structure and research trajectories shaping the field of teacher effectiveness in the digital era.

VI. RESULTS AND DISCUSSIONS

The findings of this study provide a longitudinal and structural understanding of how teacher effectiveness research has evolved within the context of digital transformation and artificial intelligence. Rather than merely reflecting growth in publication output, the results reveal a fundamental shift in the intellectual landscape of the field.

RQ1. What are the temporal publication trends and growth patterns in research on teacher effectiveness over time?

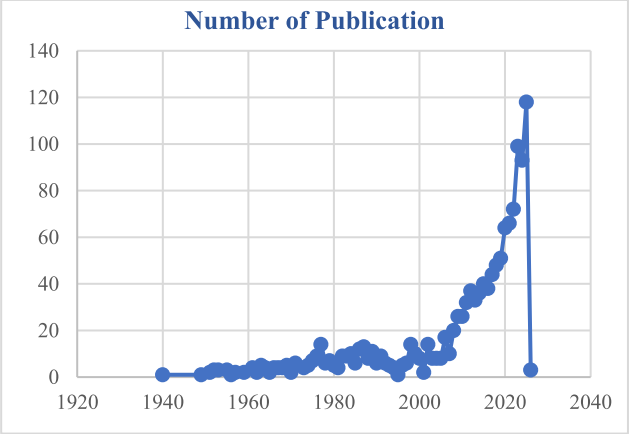


Figure 1: Trend of research in teacher effectiveness by years

The longitudinal trend indicates that research on teacher effectiveness remained relatively underdeveloped until the early 2000s, followed by a sharp increase after 2010. This acceleration reflects a structural transition driven by digitalization, the expansion of educational technologies, and more recently, AI-mediated learning environments. The surge in publications after 2020 further suggests that global disruptions, particularly the COVID-19 pandemic, have intensified the need to understand teacher effectiveness within digitally mediated contexts.

Importantly, this trend highlights that teacher effectiveness is no longer a static pedagogical construct but a dynamic concept shaped by technological transformation.

RQ2. Who are the most prolific authors contributing to the literature on teacher effectiveness, and how is their scholarly productivity distributed?

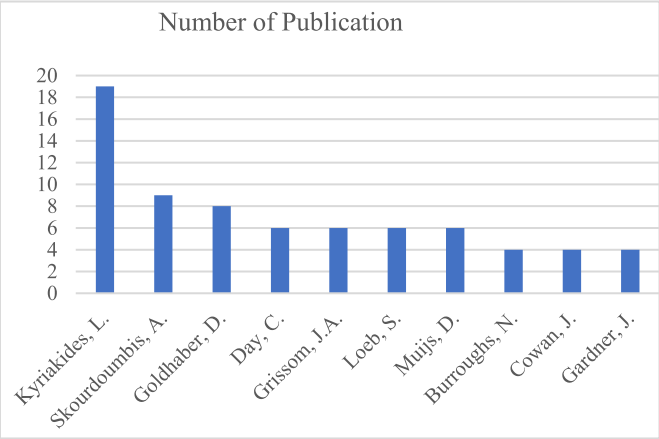


Figure 2: Trend of Research in Teacher Effectiveness by the Top Authors

TABLE I: THE MOST PROLIFIC AUTHORS CONTRIBUTING TO THE LITERATURE ON TEACHER EFFECTIVENESS.

No.	Author Name	Number of Publication
1	Kyriakides, L.	19
2	Skourdoumbis, A.	9
3	Goldhaber, D.	8
4	Day, C.	6
5	Grissom, J.A.	6
6	Loeb, S.	6
7	Muijs, D.	6
8	Burroughs, N.	4
9	Cowan, J.	4
10	Gardner, J.	4

Figure 2 and Table 1 reveal a relatively concentrated pattern of scholarly contribution within the field of teacher effectiveness. A small group of researchers, led by Kyriakides, dominates publication output, followed by scholars such as Skourdoumbis, Goldhaber, and Day

This centralization of scholarly productivity indicates that knowledge production in teacher effectiveness research is shaped by a limited number of influential contributors who have consistently engaged in areas such as school effectiveness, teacher evaluation, and educational leadership.

The dominance of established scholarly networks based on prolific authors suggests that the development of teacher effectiveness research is strongly guided by established scholarly communities rooted in traditional educational paradigms. While this continuity contributes to theoretical stability, it may also limit the diversification of perspectives, particularly in relation to emerging areas such as artificial intelligence and digital pedagogy.

From a digitalization perspective, this pattern implies that the field's evolution is path-dependent, where existing experts continue to shape research directions. Consequently, the integration of AI-related constructs may be slower, as new interdisciplinary contributions are not yet fully embedded within the dominant authorship structure.

RQ3. Which publications constitute the most influential works in the field of teacher effectiveness, as indicated by citation impact?

TABLE II: THE MOST CITED AUTHOR OF TEACHER EFFECTIVENESS.

	Authors	Title	Year	Source title	Cited
1	Klassen, R.M.; Tze, V.M.C. (Klassen & Tze, 2014)	Teachers' self-efficacy, personality, and teaching effectiveness: A meta-analysis	2014	Educational Research Review	817
2	Gu, Q.; Day, C. (Q. Gu & Day, 2007)	Teachers resilience: A necessary condition for effectiveness	2007	Teaching and Teacher Education	613
3	Hamre, B.K. et al. (Hamre et al., 2013)	Teaching through interactions: Testing a developmental framework of teacher effectiveness in over 4,000 classrooms	2013	Elementary School Journal	523
4	Kane, T.J. et al. (Kane et al., 2008)	What does certification tell us about teacher effectiveness? Evidence from New York City	2008	Economics of Education Review	457
5	Darling-Hammond, L. Et al. (Darling-Hammond et al., 2005)	Does teacher preparation matter? Evidence about teacher certification, teach for America, and teacher effectiveness	2005	Education Policy Analysis Archives	449
6	Muijs, D. Et al. (Muijs et al., 2014)	State of the art - teacher effectiveness and professional learning	2014	School Effectiveness and School Improvement	360
7	Day, C.; Gu, Q. (Day & Gu, 2007)	Variations in the conditions for teachers' professional learning and development: Sustaining commitment and effectiveness over a career	2007	Oxford Review of Education	352
8	Stronge, J.H. et al. (Stronge et al., 2011)	What makes good teachers good?: A cross-case analysis of the connection between teacher effectiveness and student achievement	2011	Journal of Teacher Education	320
9	Robertson-Kraft, C.; Duckworth, A. (Robertson-Kraft & Duckworth, 2014)	True grit: Trait-level perseverance and passion for long-term goals predict effectiveness and retention among novice teachers	2014	Teachers College Record	267

10	Feldman, K.A. (Feldman, 1987)	Research productivity and scholarly accomplishment of college teachers as related to their instructional effectiveness: A review and exploration	1987	Research in Higher Education	259

Table II shows the citation analysis indicates that the most influential publications in teacher effectiveness research are largely grounded in psychological, pedagogical, and policy-oriented perspectives. Highly cited works, such as those by Klassen and Tze (2014), Gu and Day (2007), and Hamre et al. (2013), emphasize constructs including self-efficacy, resilience, teacher–student interaction, and instructional quality.

Notably, many of these foundational studies were published prior to the widespread adoption of digital technologies in education.

The dominance of pre-digital, highly cited works suggests that the intellectual foundation of teacher effectiveness research remains anchored in traditional theoretical frameworks. While these constructs continue to provide valuable insights, they do not fully capture the complexities introduced by AI-driven and digitally mediated learning environments.

This indicates a critical gap between the historical knowledge base and contemporary educational realities. Although research output has increased significantly in the digital era, the core theories shaping the field have not evolved at the same pace. As a result, current studies may extend existing frameworks rather than fundamentally rethinking teacher effectiveness in the context of artificial intelligence and digitalization.

Addressing this gap requires a shift towards integrating digital competence, AI-supported pedagogy, and technology-mediated teaching practices into the conceptual core of teacher effectiveness research.

RQ4. Which countries are the leading contributors to research on teacher effectiveness in terms of publication output and citation impact?

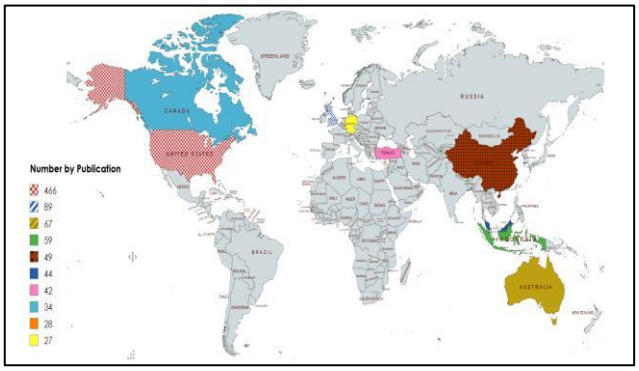


Figure 3: The leading countries that contributes to research on teacher effectiveness

Figure 3 shows the geographical distribution of research, which highlights a strong concentration in developed countries, particularly the United States, the United Kingdom, and Australia. These contexts benefit from advanced research infrastructure and strong policy emphasis on teacher effectiveness.

However, the increasing contribution from emerging countries such as China, Indonesia, and Malaysia reflects the global expansion of digital education and the growing importance of teacher effectiveness in rapidly transforming educational systems.

This pattern suggests that digitalization is not only reshaping teaching practices but also influencing the global production of knowledge, raising important questions about equity, representation, and contextual relevance in AI-driven education.

RQ5. What are the dominant and emerging research themes in the field of teacher effectiveness, as reflected through keyword co-occurrence analysis?

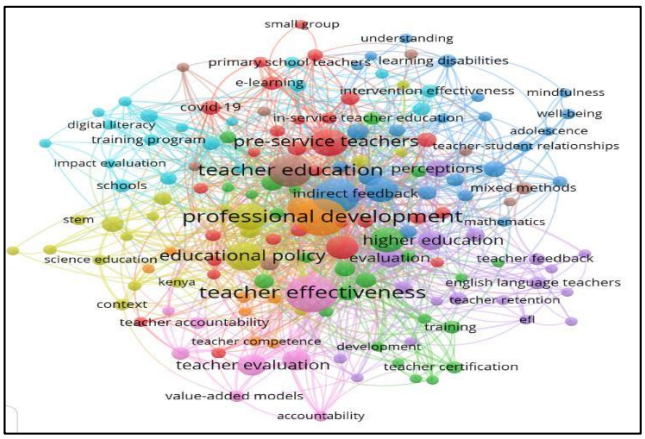


Figure 4: Network visualization map of co-occurrence by keywords

Keyword co-occurrence analysis reveals that dominant themes in teacher effectiveness research continue to revolve around professional development, self-efficacy, and instructional quality. While these themes indicate a strong foundation in educational leadership and professional learning, they also highlight a critical gap.

Specifically, digital-era constructs such as artificial intelligence, digital well-being, and technology-mediated pedagogy remain weakly integrated into the core research clusters.

This finding suggests that although educational practice has rapidly evolved in response to digitalization, the conceptual development of teacher effectiveness has not progressed at the same pace, resulting in a misalignment between theory and practice.

RQ6. How do international co-authorship networks shape scholarly collaboration in teacher effectiveness research across countries?

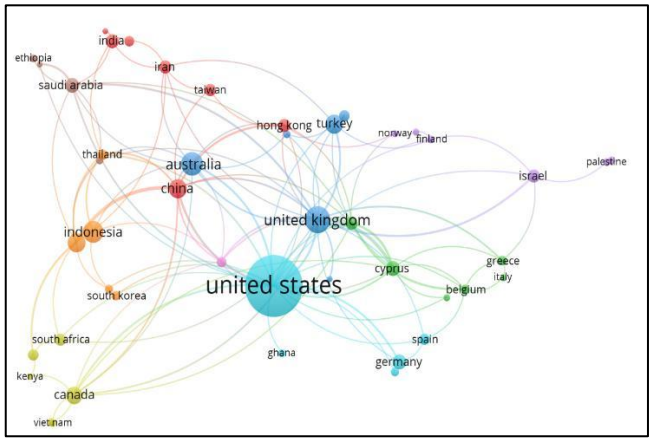


Figure 5: Network visualization of co-authorship by countries

Figure 5 shows the co-authorship network analysis, which demonstrates that teacher effectiveness research is increasingly shaped by international collaboration, with countries such as the United States and the United Kingdom acting as central knowledge hubs.

At the same time, emerging countries are becoming more actively involved in global research networks, reflecting the growing internationalization of educational challenges, particularly those related to digital transformation and AI.

This shift indicates that future research on teacher effectiveness is likely to become more interdisciplinary and cross-contextual, requiring integrative approaches that account for diverse educational systems and technological realities.

VII. CONCLUSION

This study provides a comprehensive bibliometric analysis of teacher effectiveness research, offering a longitudinal and structural perspective on its evolution from 1940 to 2025. The findings reveal a significant shift in the field, transitioning from slow conceptual development towards rapid expansion driven by digitalization and global educational transformations.

However, despite this growth, the intellectual structure of teacher effectiveness research remains largely anchored in pedagogical and psychological traditions. This indicates a critical misalignment between the rapid advancement of digital and AI-driven educational practices and the slower evolution of theoretical frameworks underpinning the field.

The analysis further suggests that teacher effectiveness research has progressed across three major phases: an early pedagogical phase, a reform-driven phase, and a contemporary phase shaped by digitalization and emerging AI-related practices. Yet, the integration of digital-era constructs, including artificial intelligence, remains limited within the core intellectual structure.

Overall, this study highlights the need to reconceptualize teacher effectiveness as a multidimensional construct that reflects the complexities of AI-mediated and digitally interconnected learning environments.

VIII. SUGGESTION FOR FUTURE STUDY

Future research should focus on developing integrative frameworks that incorporate artificial intelligence, digital pedagogy, and technology-mediated teaching into the conceptualization of teacher effectiveness. In this regard, digital well-being should be positioned as a critical construct in understanding how teachers sustain effectiveness in digitally intensive environments.

Moreover, future studies should move beyond individual-level perspectives by examining the role of organisatioZnal support, leadership, and systemic conditions in shaping teacher effectiveness. Finally, cross-national and context-sensitive research is essential to capture the diverse realities of digital transformation in education and to develop more globally relevant models of teacher effectiveness.

ACKNOWLEDGEMENT

The authors wish to thank their colleagues and academic peers for their constructive feedback and insightful discussions that enhanced the quality of this research.

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