



How the Literature Frames Teachers' Digital Competence? A Bibliometric Exploration of Scopus Publications

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ABSTRACT

This study employs bibliometric analysis to map the scholarly landscape of research on teachers' digital competence in Scopus-indexed publications from 2020 to 2026. It aims to examine trends in publication growth, citation dynamics, influential sources, collaboration patterns, and the conceptual and thematic structure of the field. Bibliographic data were retrieved from the Scopus database and analyzed using Biblioshiny (R-bibliometrix) and VOSviewer for performance analysis and science mapping. The dataset comprises 1,797 documents published across 505 sources, indicating that teachers' digital competence is a relatively recent and rapidly expanding research area. The findings reveal a steady increase in scientific production between 2020 and 2024, reflecting heightened academic attention following the acceleration of digital transformation in education. Citation analysis shows higher average citations for earlier publications, largely due to citation time-lag effects. Conceptual structure and co-word analyses demonstrate an integrated and multidimensional research domain centered on digital competence, closely connected to teacher training, teaching practices, digital literacy, and e-learning, with emerging trends related to professional development, preservice teachers, and artificial intelligence in education. The findings indicate a clear shift toward more holistic, contextual, and future-oriented approaches to teacher professional development.

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1. INTRODUCTION

Digital transformation in education has positioned teachers' digital competence as a key prerequisite for delivering effective and relevant learning experiences (Egan et al., 2025). Teachers are no longer expected merely to use digital technologies, but also to integrate them pedagogically, critically, and ethically into teaching and learning processes (Papić et al., 2022). As scholarly attention to this issue has increased, research on teachers' digital competence has expanded and now encompasses a wide range of disciplinary perspectives.

Despite this growing body of research, the conceptualization of teachers' digital competence remains ambiguous and heterogeneous (Skantz-Åberg et al., 2022). The concept is frequently employed without consistent operational definitions, complicating efforts to systematically map and measure it. Previous studies have identified several recurring dimensions, including technological competence, pedagogical competence, attitudes toward technology use, cultural awareness, critical perspectives, and professional engagement. Moreover, teachers' digital competence is often framed as a transdisciplinary competence linked to other professional competencies, such as diversity competence and research and development competence, further highlighting the complexity of teachers' roles in digitalized educational contexts (Smestad & Gillespie, 2020).

In response to this complexity, various conceptual frameworks and models have been developed, including TPACK, PEAT, and DigCompEdu (McDonagh et al., 2021; Horváth et al., 2025; Johannesen et al., 2024). Among these, DigCompEdu has emerged as one of the most widely adopted and empirically validated frameworks across diverse international educational contexts (Li et al., 2024). However, the proliferation of frameworks also reflects the lack of strong consensus regarding the core dimensions and operationalization of teachers' digital competence. This challenge is further compounded by the dominance of self-reported measurement approaches (Claro et al., 2024), which, while practical, continue to raise concerns related to validity and measurement precision (Cabero-Almenara et al., 2020; Smestad et al., 2023).

Furthermore, teachers' digital competence is shaped by a range of individual and structural factors (Martín-Párraga et al., 2023; Cisneros-Barahona et al., 2024), including the availability of digital infrastructure, institutional policies, and access to continuous professional development opportunities (Godhe, 2023; Jiang & Yu, 2024; Zhang et al., 2025). Consequently, despite the expanding literature on teachers' digital competence, significant research gaps remain in understanding how this concept is mapped, conceptualized, and evolves across the scholarly landscape in a comprehensive manner.

The present study aims to systematically map and examine how teachers' digital competence is conceptualized in the literature using a bibliometric approach. By analyzing conceptual structures, thematic clusters, and topic trends, this study seeks to provide a comprehensive overview of the research landscape on teachers' digital competence and to identify potential directions for future research.

2. METHODS

This study employs bibliometric analysis to map the scholarly landscape of publications on teachers' digital competence in Scopus-indexed documents from 2020 to 2026. The Scopus database was selected as the data source because it is one of the most comprehensive peer-reviewed journal databases and is widely used in bibliometric research. Data were retrieved by searching the title, abstract, and keyword fields using the following query: (TITLE-ABS-KEY("Digital Competence") AND TITLE-ABS-KEY("teacher")) AND PUBYEAR > 2019 AND

PUBYEAR < 2027. All metadata (authors, affiliations, publication years, sources, keywords, references, and citation data) were downloaded and processed after removing duplicate records and screening for relevance.

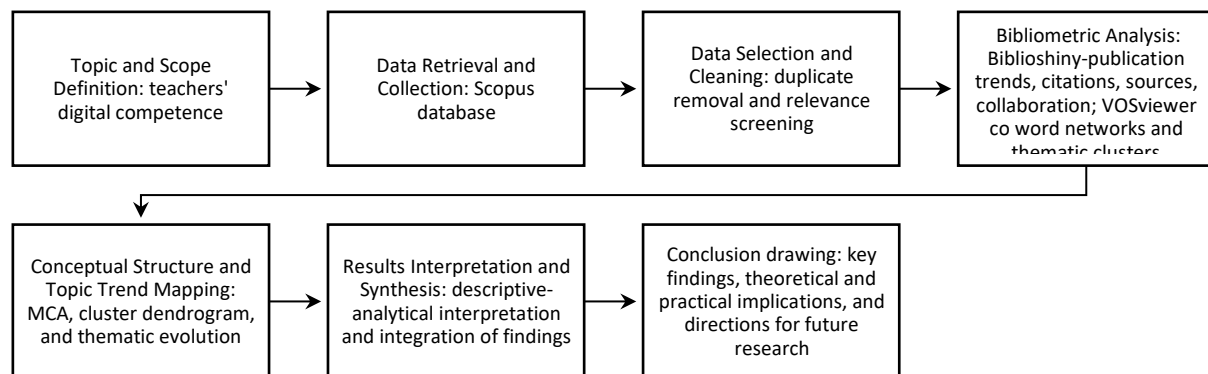


Figure 1. Research stages

The bibliographic data were exported in CSV format and analyzed using Biblioshiny (R-bibliometrix) to generate quantitative indicators, including annual publication trends, document type distribution, most relevant sources, citation analysis, and scientific collaboration patterns. In addition, VOSviewer was used to visualize and analyze bibliometric maps, particularly co-word networks and thematic clusters. Less relevant keywords were filtered to enhance the clarity of the conceptual structure. The overall research procedure is summarized in **Figure 1**.

3. RESULTS AND DISCUSSION

3.1. General Characteristics of Publications

Table 1 presents the general characteristics of the publications analyzed in this study, including the time span, number of documents and sources, authorship patterns, and indicators of scientific collaboration. During the period 2020–2026, research on teachers' digital competence produced 1,797 documents distributed across 505 sources (journals, conference proceedings, books, and others). The average document age of 2.31 years indicates that this research field is relatively recent and has been developing rapidly. This trend is closely aligned with the accelerated digitalization of education during the COVID-19 pandemic (Papic et al., 2022), which positioned teachers' digital competence as a central focus in educational policy, teacher training, and classroom practice (Tondeur et al., 2023; Cabero-Almenara et al., 2021), thereby driving increased scholarly attention and research output in this area.

The bibliometric dataset covers publications from 2020 to 2026, comprising 1,797 documents indexed in 505 sources, including journals, books, and conference proceedings. This wide distribution of sources reflects the multidisciplinary nature of research on teachers' digital competence. The average age of documents is 2.31 years, indicating that this research area is relatively recent and continues to evolve rapidly. The dataset shows an average of 11.71 citations per document, suggesting a moderate level of scholarly impact within the field. Although the annual growth rate appears negative (-59.27%), this value should be interpreted cautiously, as it is influenced by incomplete publication data for the most recent years (2025–2026) and delays in indexing.

In terms of authorship, 4,151 authors contributed to the publications, with an average of 3.21 co-authors per document, highlighting a collaborative research pattern. International co-

authorship accounts for 16.53% of the documents, indicating a moderate level of global collaboration. Journal articles represent the dominant document type (1,275), followed by conference papers (312) and review articles (61), reflecting both empirical development and theoretical consolidation in the field.

Table 1. Main information

Description	Results
Main Information about Data	
	2020:202
Timespan	6
Sources (Journals, Books, etc)	505
Documents	1797
Annual Growth Rate %	-59.27
Document Average Age	2.31
Average citations per doc	11.71
References	11747
Document Contents	
Keywords Plus (ID)	2255
Author's Keywords (DE)	3375
Authors	
Authors	4151
Authors of single-authored docs	174
Authors Collaboration	
Single-authored docs	229
Co-Authors per Doc	3.21
International co-authorships %	16.53
Document Types	
article	1275
book	4
book chapter	107
conference paper	312
conference review	25
data paper	1
editorial	8
erratum	2
letter	1
note	1
review	61

The average number of citations per document is 11.71, indicating a relatively strong level of scholarly visibility. This level of impact can be attributed to the multidimensional and cross-contextual relevance of teachers' digital competence, which encompasses technical, pedagogical, ethical, and learner-empowerment dimensions. Emerging frameworks such as DigCompEdu, HeDiCom, and TPACK attempt to capture these multiple dimensions; however, inconsistencies in definitions and operationalization across frameworks remain evident (McGarr, 2024).

The research corpus involves 4,151 authors, with an average of 3.21 authors per document, indicating that research on teachers' digital competence is predominantly conducted through collaborative efforts. Nevertheless, the proportion of international collaboration remains relatively modest (16.53%), suggesting considerable potential for strengthening cross-national research networks. The need for cross-country and longitudinal

studies to more robustly track competence development and educational impacts implicitly calls for more intensive international collaboration.

In terms of document types, publications are dominated by journal articles (1,275) and conference papers (312), followed by book chapters (107) and other document categories. The predominance of journal articles and conference proceedings reflects two key dynamics: first, the positioning of teachers' digital competence as a central discourse within education and educational technology research; and second, the rapid pace of technological change, which encourages the early dissemination of emerging findings through conference forums before they are further developed into journal articles. Such rapid technological evolution may outpace framework updates and empirical validation processes, resulting in highly dynamic scholarly communication that closely follows emerging issues in the field.

3.2. Trends in Scientific Production and Citation Dynamics

The analysis of annual scientific production indicates a consistent increase in the number of publications from 2020 to 2024. The number of articles rose from 219 publications in 2020 to 365 publications in 2024, reflecting growing academic attention to the issue of teachers' digital competence. This trend highlights the increasing relevance of digital competence within educational research. The decline in publication output observed for 2025 and 2026 should not be interpreted as a reduction in research interest, but rather as a consequence of indexing limitations for the most recent and forthcoming years. In bibliometric research, fluctuations in the final years of analysis are commonly influenced by delays in database indexing and ongoing metadata updates.

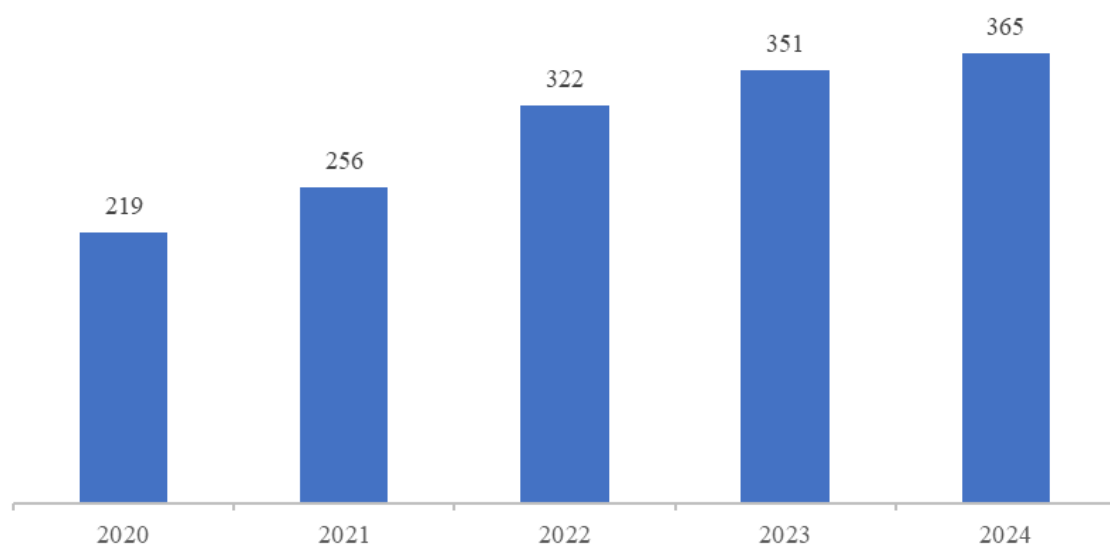


Figure 2. Annual scientific production

Meanwhile, the analysis of average citations per year reveals a decline in MeanTCperArt from 36.45 in 2020 to 0.90 in 2025. This pattern represents a common phenomenon in bibliometric studies and is primarily attributable to the citation time-lag effect, whereby more recent publications have not yet had sufficient time to accumulate citations. Earlier publications therefore function as the intellectual foundation of the field, while more recent studies primarily contribute to the expansion and diversification of research themes. Although average citation levels for the most recent years remain relatively low, these publications are nonetheless important, as they reflect shifts in research focus and the renewal of research agendas within the field of teachers' digital competence.

Table 2. Average citations per year

Year	MeanTCperArt	N	MeanTCperYear	CitableYears
2020	36.45	219	6.08	6
2021	21.06	256	4.21	5
2022	11.70	322	2.92	4
2023	6.42	351	2.14	3
2024	3.84	365	1.92	2
2025	0.90	283	0.90	1

3.3. Most Relevant Publication Sources

The results show that Education Sciences is the most productive source with 71 articles, followed by Education and Information Technologies (62 articles) and Sustainability (Switzerland) (44 articles). The prominence of these journals indicates that research on teachers' digital competence sits at the intersection of education, educational technology, and sustainability-related agendas. In addition to journals, substantial contributions also come from conference proceedings and book series such as CEUR Workshop Proceedings and Communications in Computer and Information Science, highlighting the dynamic and innovation-driven nature of this field and its continued development through international scholarly forums.

Tabel 3. Most relevant sources

Sources	Articles
Education Sciences	71
Education and Information Technologies	62
Sustainability (Switzerland)	44
Ceur Workshop Proceedings	41
Communications in Computer and Information Science	37
Lecture Notes in Educational Technology	35
Pixel-Bit, Revista De Medios Y Educacion	31
Eduotec	27
Frontiers in Education	24
Lecture Notes in Computer Science	24

3.4. Most Globally Influential Documents

The analysis of the most highly cited documents indicates that articles published in the early years of the study period, particularly 2020, have had a strong global influence. König (2020) is identified as the most influential publication with 823 citations, followed by Falloon (2020) and Fraillon (2020). These foundational studies have played a key role in shaping the conceptual basis of the field, particularly in defining teachers' digital competence, informing the development of related frameworks, and clarifying teachers' roles within digital education ecosystems. Meanwhile, more recent publications such as Basilotta Gómez-Pablos (2022) and Fernández-Batanero (2022) exhibit high normalized citation values, suggesting strong relevance and rapid uptake within the academic community despite their relatively recent publication dates.

Tabel 4. Most global cited documents

Paper	Total Citations	TC per Year	Normalized TC
König, 2020, Eur. J. Teach. Educ.	823	137.17	22.58
Falloon, 2020, Educ. Technol. Res. Dev.	651	108.50	17.86
Zhao, 2021, Comput. Educ.	349	69.80	16.57
Fraillon, 2020, Character(0)	305	50.83	8.37
Starkey, 2020, Camb. J. Educ.	288	48.00	7.90
Basilotta Gómez-Pablos, 2022, Int. J. Educ. Technol. High. Educ.	262	65.50	22.40
Nouri, 2020, Educ. Inq.	253	42.17	6.94
Fernández-Batanero, 2022, Eur. J. Teach. Educ.	226	56.50	19.32
Angeli Valanides, 2020, Comput. Hum. Behav.	219	36.50	6.01
Spiteri, 2020, Technol. Knowl. Learn.	204	34.00	5.60

3.5. Conceptual Structure and Thematic Clusters

The analysis of the conceptual structure using Multiple Correspondence Analysis (MCA) and hierarchical clustering indicates that research on teachers' digital competence forms a relatively integrated conceptual field. From a theoretical perspective, this is expected, as teachers' digital competence is understood as a multidimensional construct encompassing knowledge, skills, attitudes, pedagogical strategies, as well as ethical considerations and learner empowerment. Given this complexity, research topics tend to be closely interconnected, such as teacher training, pedagogical integration, digital literacy, and digital learning, resulting in thematic clusters that are interrelated rather than sharply delineated.

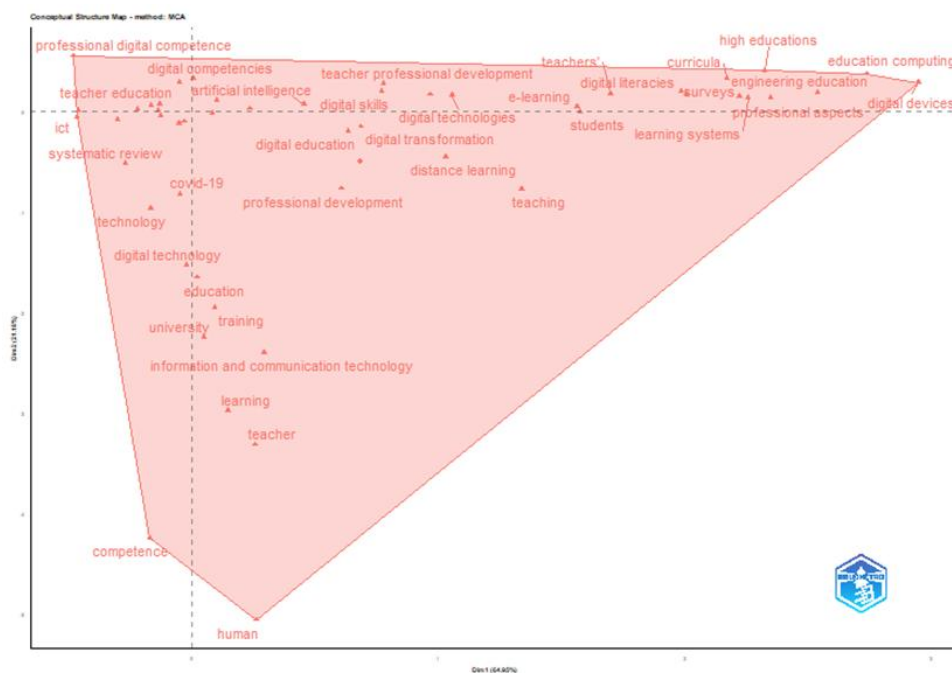


Figure 3. Conceptual structure map of research on teachers' digital competence based on Multiple Correspondence Analysis (MCA)

adoption of emerging technologies. This staged interpretation aligns with broader trends in the literature that advocate integrating technical, pedagogical, and socio-educational dimensions within teacher competence development programs.

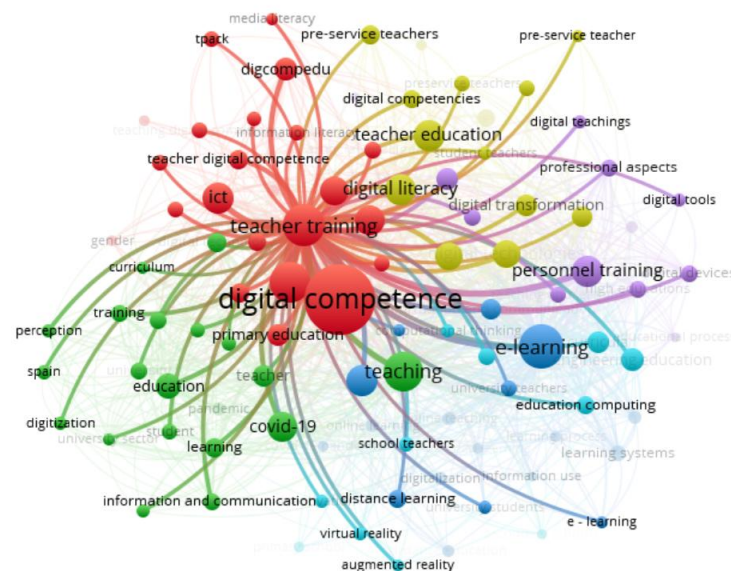


Figure 5. Co-word co-occurrence network map of research on teachers' digital competence

The co-word co-occurrence network map (Figure 5) was used to identify core themes and inter-topic relationships in research on teachers' digital competence. In this visualization, digital competence appears as the most dominant node and is strongly connected to key themes such as teacher training, teaching, digital literacy, and e-learning. This pattern suggests that digital competence functions as an overarching concept that integrates pedagogical research, teacher professional development, and the implementation of educational technologies.

The presence of several color-coded clusters indicates differentiated research foci; however, these clusters remain embedded within a single, interconnected conceptual ecosystem. From a practical perspective, this finding reinforces recommendations in the literature that teachers' digital competence development should be holistic and context-sensitive. Accordingly, it should not be limited to technical training, but should also incorporate pedagogical dimensions, digital ethics, and learner empowerment.

The MCA results, hierarchical dendrogram, and co-word network map demonstrate that research on teachers' digital competence constitutes an integrative and multidimensional field, characterized by close links among pedagogical, professional, and technological aspects. These findings support the view that strategies for enhancing teachers' digital competence should be designed as sustained development programs that are responsive to contextual needs and rapid technological change.

3.6. Evolution and Trends of Research Topics

The analysis of topic evolution was conducted to examine shifts in the research focus on teachers' digital competence based on the occurrence of authors' keywords across the publication period. The results reveal three main phases of development (Table 5). During the initial phase (2020–2021), research was dominated by foundational and methodological themes, such as construct validity, surveys, ecosystems, and European countries. This focus reflects early efforts to validate measurement instruments, map digital education

ecosystems, and understand the contextual implementation of digital competence. The emergence of topics related to ICT and students also indicates early links between technology, learners, and instructional practices. In the development phase (2021–2023), the research focus shifted toward the implementation and strengthening of digital competence. Topics such as digital competence, e-learning, teacher training, higher education, students, and teaching became dominant and sustained. This trend suggests that research increasingly emphasized the application of digital competence through online learning, teacher training initiatives, and the integration of technology into instructional processes.

Table 5. Trend topics

Topic	Frequency	Start Year (Q1)	Median Year	End Year (Q3)
Construct Validity	6	2020	2020	2023
Ecosystems	6	2020	2020	2021
European Countries	6	2020	2020	2021
Information And Communication Technology	30	2021	2021	2023
Surveys	30	2020	2021	2022
Student	28	2020	2021	2024
E-Learning	262	2021	2022	2023
Teacher Training	230	2021	2022	2024
Students	163	2021	2022	2024
Digital Competence	675	2021	2023	2024
Higher Education	219	2021	2023	2024
Teaching	199	2021	2023	2025
Professional Development	54	2021	2024	2025
Artificial Intelligence	32	2024	2024	2025
Preservice Teachers	28	2022	2024	2025
Structural Equation Modeling	10	2022	2025	2025
Artificial Intelligence In Education	9	2024	2025	2025
Educational Robots	6	2024	2025	2025

In the most recent phase (2024–2025), more innovative and future-oriented themes emerged, including professional development, preservice teachers, artificial intelligence, artificial intelligence in education, educational robots, and advanced analytical methods such as structural equation modeling. This pattern indicates a deepening and diversification of research toward preservice teacher readiness, continuous professional development, and the integration of intelligent technologies in education. Overall, the evolution of research topics demonstrates a clear transition from conceptual and methodological studies toward more applied and innovative approaches, highlighting teachers' digital competence as a dynamic professional competence that must continuously evolve in response to advances in educational technology.

The bibliometric findings of this study confirm that the research landscape on teachers' digital competence is shaped by a variety of interconnected conceptual frameworks, with DigCompEdu emerging as the dominant reference framework frequently used for self-assessment, professional development, and policy alignment (González-Medina et al., 2025).

The presence of other frameworks, such as TPACK, HeDiCom, SAMR, and the UNESCO ICT Competency Framework, indicates that teachers' digital competence is understood as a multidimensional construct encompassing the integration of technology, pedagogy, and content knowledge, as well as digital literacy, ethics, and learner empowerment (González-Sanmamed et al., 2017; Park, 2023; Bećirović, 2023; Tondeur et al., 2023). The conceptual mapping results obtained through MCA, hierarchical cluster dendrograms, and co-word networks further demonstrate that the field is evolving from a predominantly technical focus toward more holistic and context-sensitive approaches. Nevertheless, the literature continues to highlight critiques related to techno-centric tendencies and the lack of consistency in definitions and operationalization across frameworks. Consequently, while the diversity of frameworks can be viewed as a strength due to their flexibility and adaptability, it also represents a challenge, as it may hinder consistency in measurement, policy implementation, and the design of standardized teacher training programs (Mattar et al., 2022; McGarr, 2025; Meyerhofer-Parra & González-Martínez, 2024).

On the other hand, empirical evidence from previous studies indicates that the development of teachers' digital competence is influenced by the interaction of internal factors, such as attitudes, motivation, self-efficacy, and prior ICT training experiences (Agustina et al., 2020; Almås et al., 2021; Shen et al., 2024), and external factors, including school leadership support, the availability of digital infrastructure, and collaborative, needs-oriented professional development programs (Schmitz et al., 2023; Nurhadi et al., 2024; Zeng et al., 2025; Yang et al., 2024). Reported educational impacts are generally positive, particularly with regard to student engagement in online and blended learning environments, enhanced teacher self-efficacy, and increased work engagement and resilience (Alarfaj & Alrashidi, 2025). However, the literature also underscores persistent methodological limitations, notably the continued reliance on self-report instruments, limited cross-cultural validation, and research gaps in inclusive and special education contexts (Fang et al., 2016). Accordingly, the findings of this study reinforce the urgency of advancing future research that integrates performance-based assessment, more context-sensitive approaches, and the exploration of emerging technologies, such as AI-based assessment tools, to capture teachers' digital competence in a more authentic manner and to better respond to future educational demands.

4. CONCLUSION

This study provides a comprehensive bibliometric overview of the research landscape on teachers' digital competence in Scopus-indexed publications from 2020 to 2026. The findings indicate that teachers' digital competence is a rapidly growing research field, with increasing scientific production reflecting heightened academic attention following the acceleration of digital transformation in education. Conceptual mapping and thematic clustering reveal that the field is inherently integrative and multidimensional, linking pedagogical practices, professional development, and educational technology within a single conceptual ecosystem. The evolution of research topics demonstrates a clear transition from foundational and methodological studies toward more applied and innovative approaches, including continuous professional development, preservice teacher readiness, and the integration of emerging technologies such as artificial intelligence in education. Despite this progress, the literature continues to face challenges related to conceptual ambiguity, diverse frameworks, and the predominance of self-reported assessment methods. Therefore, future research is encouraged to adopt more consistent and context-sensitive conceptualizations, strengthen international and longitudinal collaboration, and develop performance-based and

technologically enhanced assessment tools to better capture teachers' digital competence in response to evolving educational demands.

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