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Transforming Teacher Pedagogical Competence in the Digital Era: A Bibliometric Analysis

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ABSTRACT: The rapid advancement of digital technology has transformed educational practices and reshaped the competencies requires of teachers in the 21st century. In this context, teacher pedagogical competence is increasingly expected to integrate digital literacy, adaptability, and innovative instructional approaches to meet evolving educational demands. This research aims to map and examine the trajectory of teacher pedagogical competence transformation in the digital era through a bibliometric analysis of Scopus-indexed scientific publications from 2016 to 2025. A total of 404 documents were analyzed using performance analysis and science mapping approaches, utilizing the keyword search “Pedagogical Competence” AND “Teacher” within the title, abstract, and keyword fields. The PRISMA procedure was employed for document screening, while VOSviewer was utilized to generate visualizations of author collaboration networks, geographical distributions, and keyword mapping. The results indicate a significant surge in publications after 2020, driven by the accelerated digital transformation triggered by the COVID-19 pandemic. Indonesia, China, Spain, Russia, and Ethiopia emerged as the most prolific contributing countries, while institutions such as Universitas Pendidikan Indonesia and the University of Valencia were identified as hubs of scientific productivity. Keyword analysis revealed five primary research clusters: Digital Pedagogy and TPACK, Teacher Professional Development, Pre-service Teacher Training, Curriculum & Policy Reform, and 21st Century Skills. The transition from “pedagogical competence” to “digital competence” and “teacher readiness” signifies a global conceptual shift that regards teachers as adaptable, innovative, and technologically proficient digital learning designers. These findings emphasized that TPACK mastery, continuous professional development, and digital readiness constitute the essential foundations of pedagogical competence in the Society 5.0 era. This study contributes to the global understanding of teacher competence evolution and provides strategic recommendations for educational policy, including the strengthening of teacher digital upskilling programs, AI literacy, and curriculum innovation.

1. INTRODUCTION

Twenty-first-century education is undergoing a rapid transformation driven by advancements in digital technology, which significantly influence how teachers design, implement, and evaluate instruction (D’mello, 2021; Hooker et al., 2011).

Consequently, essential 21st-century skills, such as creativity, problem-solving, and technological literacy, require teachers to possess adaptive and innovative pedagogical competencies to navigate these ongoing shifts (Almerich et al., 2016). Furthermore, the accelerated adoption of technology during the COVID-19 pandemic has further emphasized the urgency of digital readiness in teaching practices, particularly within distance and hybrid learning models that have now become permanent fixtures of the global educational ecosystem (Al-Qashouti, 2024; Nurkhin et al., 2023). It is no longer sufficient for teachers to master subject matter alone; they must also be capable of continuously integrating pedagogical, technological, and content knowledge, as emphasized in the Technological Pedagogical Content Knowledge (TPACK) framework (Mishra & Koehler, 2006). Thus, digital teaching proficiency serves as the foundation for educators to design relevant, interactive, and contextual learning experiences in an ever-evolving technological era.

Although studies on teacher pedagogical competence have been extensive, most research continues to focus on TPACK enhancement, digital literacy, or ICT integration in isolation, without examining the holistic relationships between these variables (Masoumi & Noroozi, 2025; Suárez-Rodríguez et al., 2018). Furthermore, reviews of Scopus-indexed literature indicate that the majority of studies are descriptive, case-based, or involve localized experiments, resulting in fragmented findings oriented toward narrow contexts (Widyastuti et al., 2024). Consequently, these disparate studies have yet to be comprehensively synthesized within the broader framework of teacher pedagogical competence in the digital age (Dahal & Khadka, n.d.). Moreover, there is a significant lack of bibliometric-based scientific mapping capable of uncovering collaboration networks, thematic trends, and the conceptual evolution of pedagogical competence to bridge these diverse findings into a systematic representation.

Drawing upon the UNESCO (2022) framework and the European Framework for the Digital Competence of Educators (DigCompEdu), digital pedagogical competence has emerged as a pivotal dimension of teacher professionalism in the 21st century. Theoretically, the TPACK model underscores that successful technology-enhanced learning hinges upon the teacher's ability to seamlessly integrate pedagogical, technological, and content knowledge (Mishra & Koehler, 2006). Furthermore, various empirical studies emphasize the necessity for educators to foster creativity, adaptability, and technological literacy as core components of pedagogical ability relevant to the digital learning ecosystem (Almerich et al., 2016; Asad et al., 2021). Global policies, such as the OECD Digital Education Outlook (2021), position technology-based pedagogical competence as a prerequisite for educational reform in the era of artificial intelligence and big data.

The paradigm shift from traditional methods to media-based education necessitates a fundamental redefinition of teacher pedagogical competence. While extensive, current research remains largely fragmented, focusing on TPACK, digital literacy, or ICT integration in isolation rather than examining the holistic relationships between these variables (Fernández-Batanero et al., 2022; Suárez-Rodríguez et al., 2018). Furthermore, these developments have not yet been synthesized within a global framework capable of representing the comprehensive dynamics of pedagogical competence in the digital era (Dahal & Khadka, n.d.; Kardiwan et al., n.d.). Specifically, there is a distinct lack of bibliometric mapping to uncover the collaboration networks, thematic trends, and conceptual evolution of this field over the last decade. Consequently, a thorough analysis is necessary to integrate these varied findings into a systematic and coherent framework.

Bibliometric analysis serves as a strategic approach to understanding the developmental patterns of research on teacher pedagogical competence, spanning publication trends, scientific collaborations, and global thematic maps (Herut, 2024; Utomo, & Anindyarini, 2023). Bibliometrics also helps researchers find knowledge structures and show how concepts have changed over time by using keyword network visualizations and interdisciplinary relationships. In the context of literature indexed by Scopus, this method is essential for monitoring the increase in research activity after the pandemic and the rising importance of digital pedagogy in global research (Widyastuti et al., 2024). Additionally, this method effectively maps the most productive countries and institutions (Dahal & Khadka, n.d.). Consequently, bibliometrics functions as a strong scientific tool for a comprehensive analysis of the ongoing transformation in teacher pedagogical competence.

Pedagogical competence is defined as a teacher's ability to understand learner characteristics and to effectively design, implement, and evaluate instruction, as reflected in various professional competence frameworks. Research indicates that this competence encompasses a broad scope, ranging from subject matter mastery to sensitivity toward learning contexts, educational interaction, and student-oriented classroom management (Hartini et al., 2018; Trianto, 2019). Shulman, (1987) introduced the concept of Pedagogical Content Knowledge (PCK) as an epistemological foundation, highlighting the critical integration of content knowledge and effective instructional strategies. This concept was subsequently expanded by Mishra & Koehler (2006) into Technological Pedagogical Content Knowledge (TPACK), which incorporates technology as an inherent

dimension of modern teaching competence. Findings from the analyzed literature show that terms such as "teacher competence," "pedagogical skills," "teacher readiness," and "professional growth" are frequently used as derivatives or extensions of pedagogical competence within digital contexts (Kausar & Ajmal, 2024; Liesa-Orus et al., 2023). Consequently, pedagogical competence is no longer understood merely as a traditional teaching ability; it has evolved into the capacity to reflectively and continuously integrate pedagogical, content, and technological knowledge (Shulman, 1987; Mishra & Koehler, 2006).

Digital Transformation in Education

The digital transformation sweeping through global education systems has fundamentally shifted the teacher's role from a mere transmitter of knowledge to a designer of technology-based learning experiences (Lindfors et al., 2021; Zhao et al., 2021). In this context, educators are required to utilize digital resources effectively, manage online and blended classrooms, and integrate digital tools and platforms into daily pedagogical practice (Raymond & Gabriel, 2023; fathoni, et al., 2021). Based on the analyzed Scopus-indexed literature, issues such as ICT integration, blended learning, teacher digital readiness, and AI-based instruction consistently emerge as central themes in professional development (Goncharova et al., 2021; Lindfors et al., 2021). Furthermore, ecological and activity-based approaches to teacher training emphasize that digital transformation extends beyond technical skills; it reshapes role structures, school cultures, and social interactions within the learning process (Isaev, 2020; Lindfors et al., 2021). Consequently, digital transformation drives the expansion of pedagogical competence into the realms of technological adaptability and innovation capability, which serve as the foundations for theoretical models such as TPACK and DigCompEdu (Díaz-Suárez et al., 2025; Mishra & Koehler, 2006).

The Role of Bibliometrics in Educational Research Mapping

Bibliometric analysis is a quantitative method used to chart the structure and dynamics of knowledge in a particular research area by looking at publication patterns, citations, and how documents are related to each other (Zupic & Čater, 2015). In this context, two primary approaches are commonly employed: performance analysis, which focuses on the productivity of publications, authors, institutions, and countries; and science mapping, which reveals the intellectual structure and thematic evolution through techniques such as co-word analysis and network analysis (Aria & Cuccurullo, 2017; Zupic & Čater, 2015). Many studies show that bibliometrics has been widely utilized to map research trends in education, including investigations into teacher competence, open learning, and the integration of digital technology in the learning process (Das, 2021; López-Martín et al., 2023). In this study, bibliometrics is applied to understand how research on pedagogical competence has evolved toward digital pedagogical competence by analyzing Scopus-indexed publications based on temporal trends, geographical distribution, and keyword mapping (Aria & Cuccurullo, 2017; López-Martín et al., 2023). Furthermore, the utilization of software tools such as Bibliometrix (R-package) enables a more comprehensive visualization of thematic networks and knowledge structures, thereby supporting the formulation of future research agendas in the field of education (Aria & Cuccurullo, 2017; Zupic & Čater, 2015). Building upon this foundation, the following section will detail the specific bibliometric methodology employed in this study.

Research Questions

The primary research questions addressed in this study are as follows:

- 1) What are the publication trends and productivity levels of research related to teacher pedagogical competence indexed in Scopus for the period 2016–2025?
- 2) Which countries have made the most significant contributions to the development of research in teacher pedagogical competence?
- 3) What are the predominant keywords and thematic clusters within publications concerning teacher competence in the context of digital transformation?
- 4) What is the trajectory of the conceptual transformation in teacher pedagogical competence research based on bibliometric mapping over the last decade?
- 5) How do the scientific collaboration structures among authors and institutions shape the intellectual landscape of research in this field?

The answers to these questions are expected to provide an in-depth look at the knowledge landscape, developmental dynamics, and transformational direction of teacher competence studies in the digital era.

2. MATERIALS AND METHODS

2.1 Subtopic Data Source: Scopus Database

This section outlines the data sources utilized in the study through a bibliometric approach. Research data were retrieved directly from Scopus, which serves as one of the most comprehensive and credible international scientific databases for indexing reputable journals, conference proceedings, and book chapters (Aria & Cuccurullo, 2017; Schotten et al., 2017). The choice of Scopus was based on how complete its metadata was. This included titles, abstracts, keywords, author affiliations, and citation counts, all of which are important for the bibliometric mapping process (Zupic & Čater, 2015). The .csv format features made it easier to analyze the data with VOSviewer and R Bibliometrix software (Van Eck & Waltman, 2022). Following the extraction and screening process, a total of 404 documents met the criteria and were utilized for the full analysis.

2.2 Search Strategy and Keywords

LoRem The literature search strategy was executed using a combination of the primary keywords "Pedagogical Competence" AND "Teacher," applied across the title, abstract, and keyword fields to ensure the retrieval of relevant results. Boolean operators and quotation marks were utilized to maintain terminological precision during the document identification process (Kumar et al., 2022; Page et al., 2021). Variations and related keywords such as digital competence, TPACK, teacher professional development, and digital pedagogy were identified as secondary keywords. These were further examined through keyword mapping using co-occurrence analysis (Hincapie et al., 2021; Syamsuri et al., 2020). This approach aligns with international bibliometric standards to ensure adequate terminological representation within the dataset (Sagarra & Mar-Molinero, 2023).

2.3 Temporal Scope

The research timeframe was established from 2016 to 2025, covering a decade of significant shifts in the digital transformation of education, including the accelerated adoption of technology triggered by the COVID-19 pandemic (OECD, 2021; UNESCO, 2022). This period was selected to capture the thematic evolution and publication patterns within a highly dynamic global context, particularly concerning teacher competence and digital pedagogy.

2.4 Document Types

The analyzed dataset comprises a diverse range of publication types. Utilizing various document types facilitates a comprehensive analysis of progress in educational research and teacher competence (Aria & Cuccurullo, 2017; Zupic & Čater, 2015). Each document was screened for metadata completeness; those lacking abstracts, keywords, or sufficient affiliation information were excluded from the dataset to maintain analytical accuracy (Page et al., 2021).

2.5 Inclusion Criteria

Inclusion criteria were established to ensure that all analyzed documents were strictly relevant to the research topic. Documents were retained if they met three primary requirements: (1) addressed topics related to pedagogical competence, teachers, education, or digital pedagogy; (2) were written in English; and (3) contained complete metadata in Scopus (title, abstract, keywords, affiliation, and citations). Duplicate records, irrelevant entries, or documents categorized as non-academic were excluded from the analysis (Page et al., 2021; Zupic & Čater, 2015).

2.6 Analysis Procedures: PRISMA Flow Diagram

The analysis process started by using PRISMA 2020 as the guideline for reviewing documents, which included four main steps: Identification, Screening, Eligibility, and Inclusion (Page et al., 2021). This systematic process resulted in a final dataset of 404 documents after eliminating duplicates, irrelevant records, and publications that failed to meet the specified inclusion criteria (Kumar et al., 2022; Van Eck & Waltman, 2022).

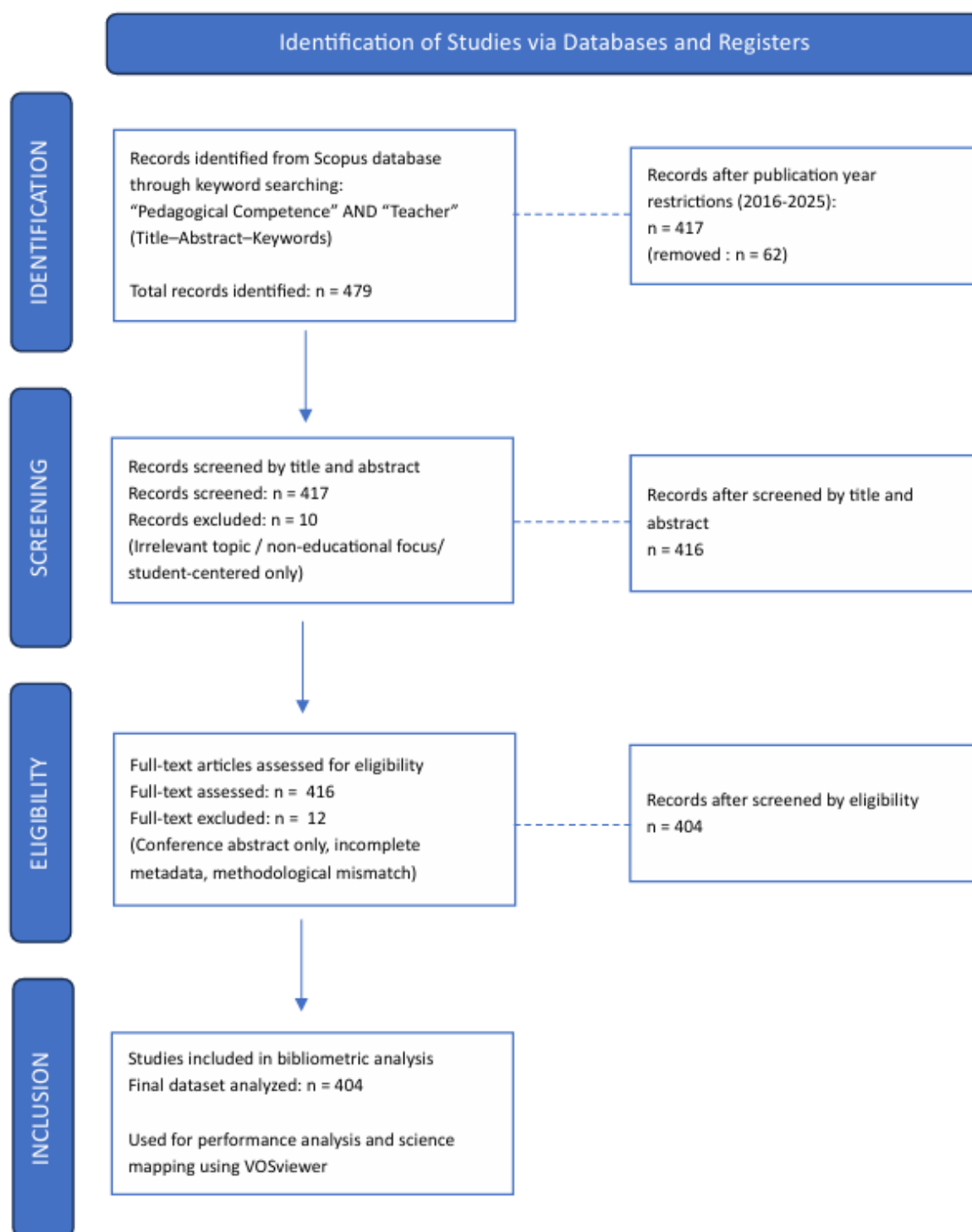


Figure 1 PRISMA Flow Diagram of The Study Selection Process

3. RESULTS AND DISCUSSION

3.1 Annual Publication Analysis

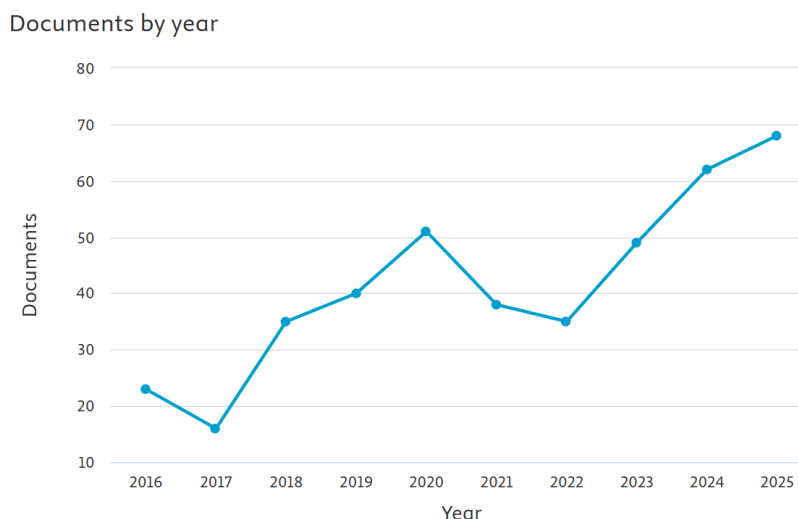


Figure 2 Annual Publication Volume

Table 1 Top Keywords

Keyword	Occurrences	Total link strength
pedagogical competence	68	69
students	30	113
teaching	28	115
competence	26	51
personal training	24	101
teacher training	23	72
professional development	23	61
higher education	22	38
teacher	21	78
curricula	19	74

This section presents the dynamics of publication volume regarding the transformation of teacher pedagogical competence in the digital era during the 2016–2025 period, as illustrated in Figure 2: Annual Publication Volume. The analysis shows that the number of publications grew steadily from 2018 to 2020, with a stable trend. Most of these were conceptual studies on teacher competence and how to use ICT in the classroom. During this time, research mainly looked at identifying basic teacher skills, analyzing school culture, and developing models for improving these skills in traditional and early blended learning settings. These findings suggest that prior to 2020, the issue of pedagogical competence was primarily positioned within a framework of teacher professional strengthening, without the intense pressure of technological disruption or global crises. Therefore, we can understand this initial phase as the conceptual foundation that initiated further transformation in the digital era.

During the 2023–2025 period, Figure 2 illustrates a sharp surge in the number of publications related to pedagogical competence, digital pedagogy, and the widespread adoption of online learning. The analysis confirms that topics such as post-

pandemic digital pedagogy, teacher readiness for virtual instruction, and technology integration in teaching have become the dominant themes.

Moving into 2024–2025, publication trends indicate a sustained volume that remains significantly higher than the pre-2020 period. In this phase, research focus has shifted from short-term pandemic responses toward a long-term restructuring of teacher competence frameworks to navigate the era of Artificial Intelligence (AI) and Big Data.

3.2 Geographical Distribution of Publications

Documents by country or territory

Compare the document counts for up to 15 countries/territories.

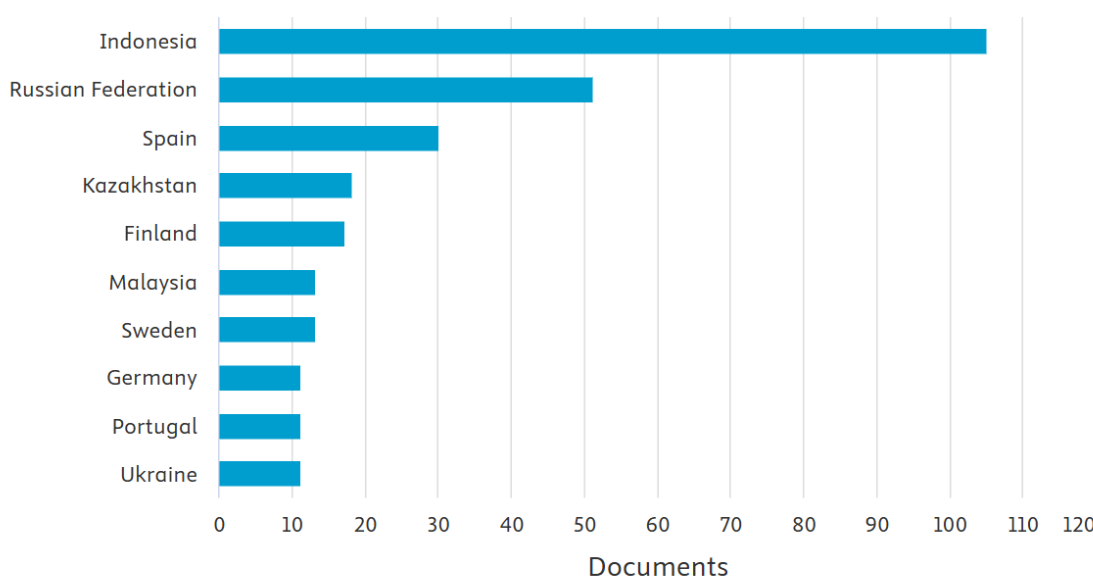


Figure 3 Documents by Country

This section presents the geographical distribution of publications and institutional affiliations contributing to the study of teacher pedagogical competence in the digital era. As illustrated in Figure 3: Documents by Country, the five most productive countries in this research domain are Indonesia, Russia, Spain, Kazakhstan, and Finland. Indonesia is the top contributor because of its strong national policies that focus on improving teacher skills and using digital tools in education, including various digital literacy programs and the Merdeka Belajar (Freedom to Learn) initiative (Hartini et al., 2020). Russia provides a significant contribution through studies on developing teacher training systems and technological adaptation within the contexts of higher education and general schooling (Isaev, 2020; Gafurova et al., 2019). Meanwhile, Spain plays a pivotal role in developing digital competence models and global mapping within teacher education (Almerich et al., 2021; Getahun, 2025; Zhou & Zhao, 2023).

Furthermore, several nations have established themselves as hubs for knowledge production in the field of digital pedagogical competence. In Indonesia, research has been instrumental in formulating competence models and teacher development ecologies that emphasize socio-cultural contexts (Hartini et al., 2020). In the European region, researchers studying digital competence have extensively published on the measurement of teacher digital proficiency and the integration of the TPACK (Technological Pedagogical Content Knowledge) framework into classroom practice (Almerich et al., 2021; Suarez-Rodriguez et al., 2018). Meanwhile, other regions in Asia have contributed significantly to the discourse on growth mindsets and digital pedagogical readiness within the context of smart learning environments (Chien & Sun, 2025; Mesquita & Moreira, 2020). This institutional mapping demonstrates that the transformation of teacher competence in the digital era is not centralized in a single region but is globally dispersed with high concentrations in both Asia and Europe.

3.3 Keyword Co-occurrence Analysis

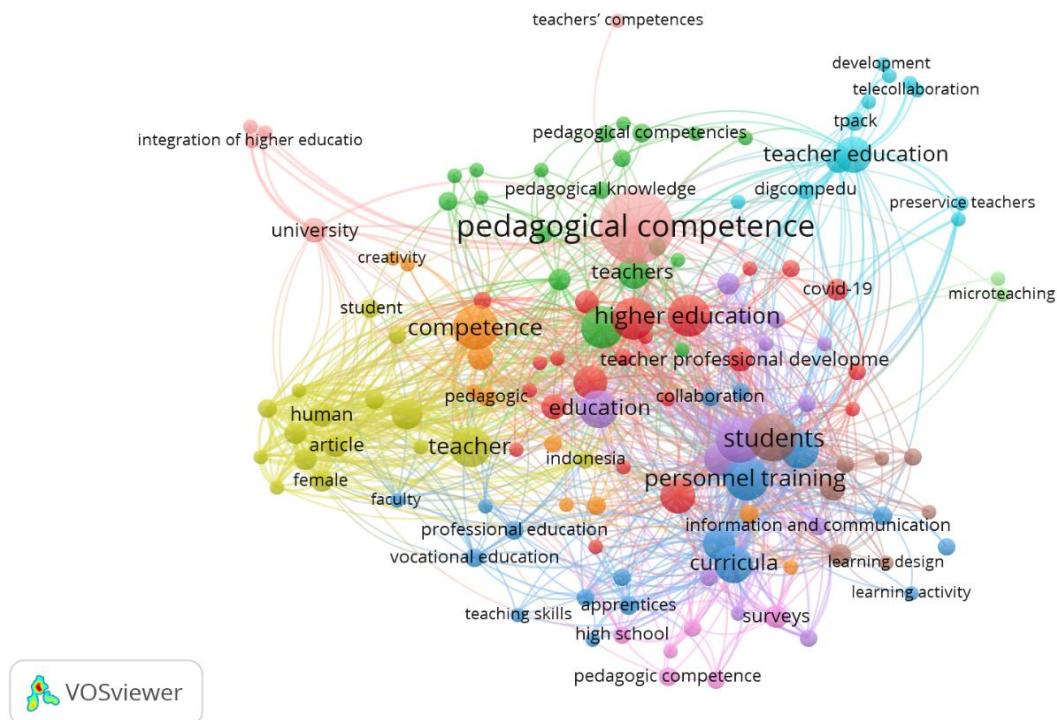


Figure 4 Keyword Co-occurrence Network Map

VOSviewer's keyword cluster analysis reveals the relationships between various keywords in the field. Of the approximately 1,618 identified keywords, a minimum threshold of three occurrences was applied to generate a more focused and representative network (Figure 4: Keyword Co-occurrence Network Map). The clustering results reveal six primary clusters that represent the core research focuses regarding teacher pedagogical competence in the digital era.

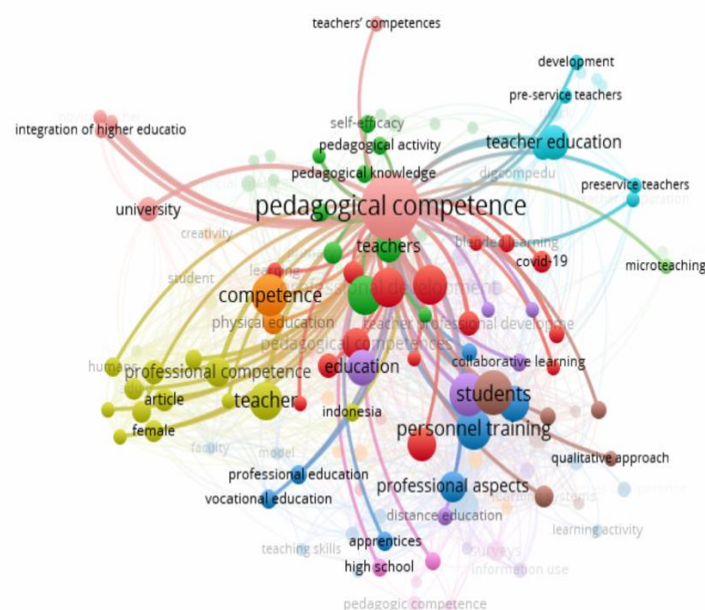
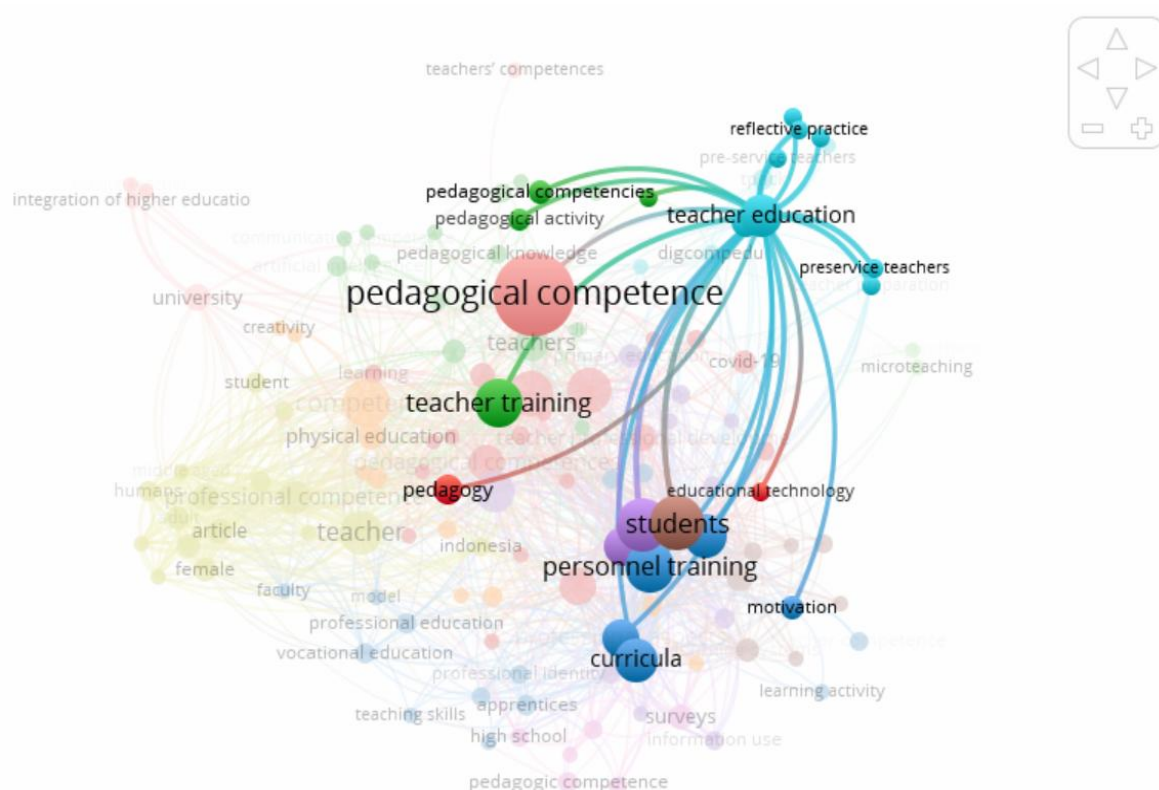


Figure 5. Pedagogical Competence Cluster



Cluster 2 (light blue) groups keywords related to teacher education. This cluster is intrinsically linked to terms such as "teacher training," "professional training," and "pre-service teachers," while also extending into concepts like "reflective practice" and "curricula." The analysis identified a substantial body of 3,746 documents associated with teacher education and teacher training. A representative study by Ruiz-Requies et al. (2025) explores the satisfaction of student teachers with their practical training programs. Their findings underscore that the education and training undergone by teachers significantly influence their pedagogical efficacy. Another notable example is the work of Andersson Hult & Persson (2025), which provides a historical perspective by examining how modern societal shifts and civic issues were reflected in final examination papers across four teacher education institutions during the 1914–1937 period.

Figure 7 Competence Cluster

The third cluster (orange) centers on the keyword "competence." This keyword is primarily associated with research exploring specialized themes within the field of pedagogical competence. Furthermore, this cluster encompasses keywords like "creativity," "article," and "model," all closely associated with the development and implementation of digital dimensions in education. The analysis also shows that there is a strong link between a teacher's pedagogical competence and the words "students" or "student." For instance, a study by Maryani et al. (2025) examines the correlation between a teacher's professional competence and its influence on students' learning interest. In addition to this study, the Scopus database identifies 158 documents that simultaneously integrate the keywords "competence" and "professional teacher," highlighting a robust sub-field dedicated to the professional standards of modern educators.

Figure 8 Teacher Cluster

The fourth cluster (yellow) focuses on the keyword "teacher" as the primary subject of investigation concerning teaching proficiency across various educational stages. Strong interconnections between keywords such as "professional competence," "personnel training," and "pedagogical competence" underscore this focus. Furthermore, the specific educational environments where teachers apply their pedagogical expertise are highlighted by the emergence of keywords such as "primary school," "primary education," and "high school," as well as specialized subjects like "physical education." A representative study within this cluster is the work of Mustaqimah et al. (2025), which explores how these competencies are operationalized within specific school settings.

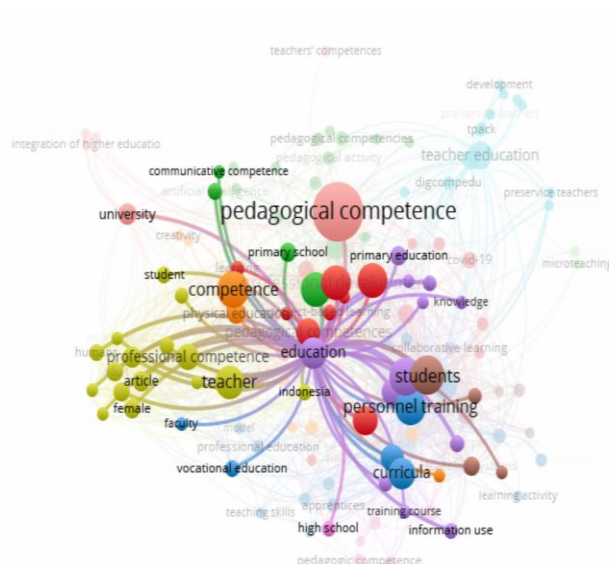


Figure 9 Education Cluster

The fifth cluster (purple) represents research focusing on students and human resource development within education. This cluster is characterized by the co-occurrence of keywords such as "students," "personnel training," "curricula," and "collaborative learning." The strong link between educator training and student learning experiences reinforces the necessity of personnel training programs in elevating the quality of instruction tailored to learner needs. Furthermore, the emergence of "collaborative learning" as a key term indicates a pedagogical paradigm shift toward more participatory and student-centered approaches. In this context, the curriculum serves as the primary framework for integrating pedagogical competencies into active classroom practices.

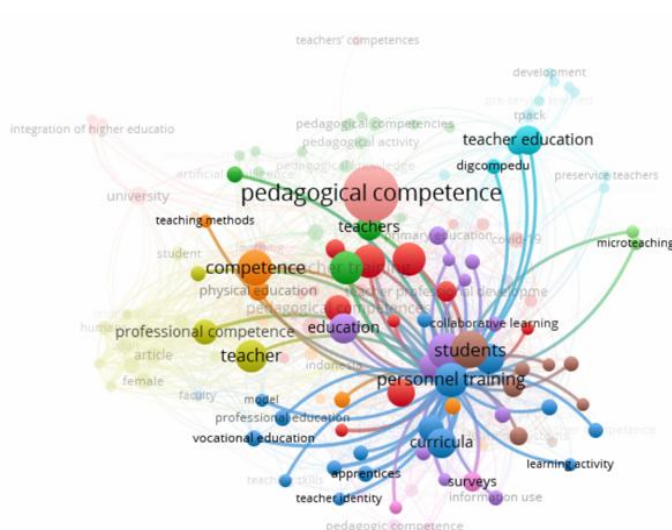


Figure 10 Personal Training Cluster

Cluster 6 (dark blue) represents a research focus on personnel training as a central node connecting students, curricula, and learning activities. This cluster emphasizes that pedagogical competence is cultivated through structured training programs that are integrated with the curriculum, thereby improving student learning experiences. Within this cluster, keywords such as DigCompEdu (the Digital Competence Framework for Educators) emerge, representing the integration of digital and communication competencies in teacher education as a response to the spread of technology-based learning. Its close association with teacher education, pre-service teachers, and TPACK indicates that pedagogical competence is increasingly centered on mastering instructional technology in alignment with curricular goals. Research concerning pre-service teacher training and TPACK, such as studies by Aldemir et al. (2025) and Güner et al. (2025), discusses the preparation of future educators to develop a comprehensive TPACK framework encompassing content knowledge, instructional methods, and the capacity to effectively integrate technology into the learning process.

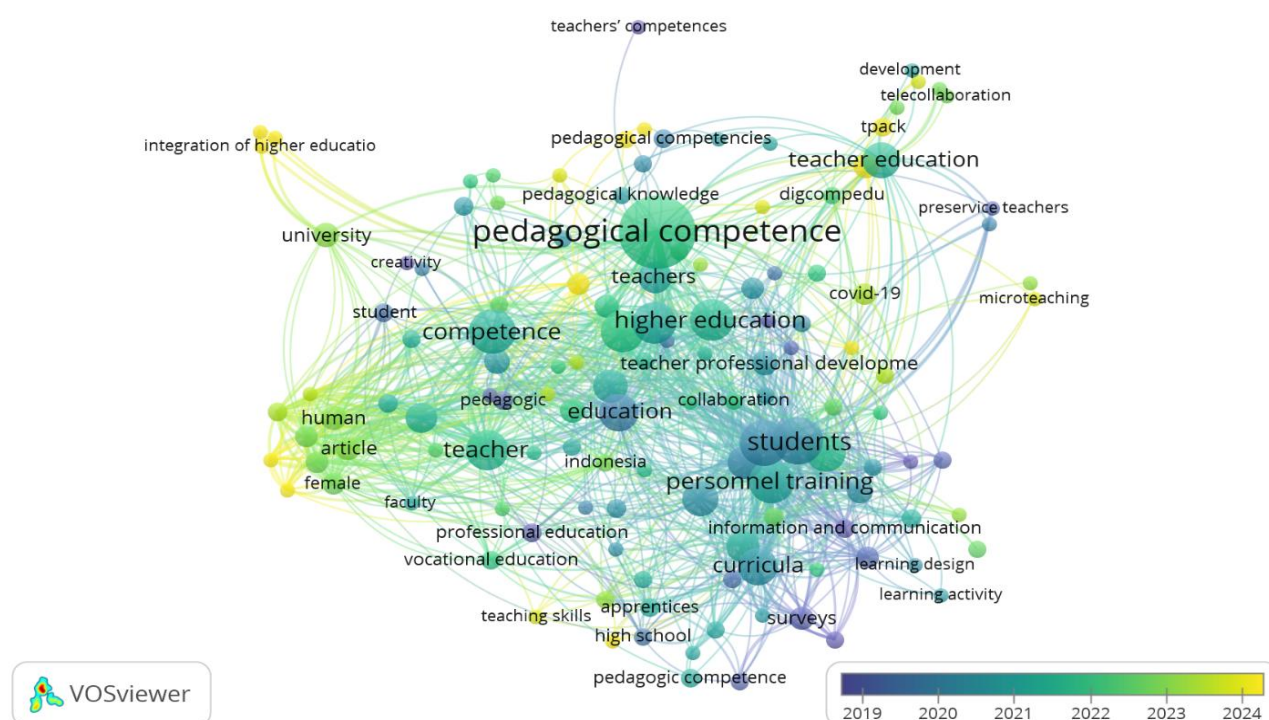


Figure 11 Keyword Overlay Visualization

The overlay visualization in Figure 11: Keyword Overlay Visualization illustrates the temporal dimensions of keyword evolution within the field. In the initial period of the study, terms such as "pedagogical competence" and "teacher competence" were more dominant. This pattern reflects an early scholarly focus on foundational definitions and the basic evaluation of teacher capabilities (Sun & Sihes, 2020; Nemet, 2018). After 2020, the overlay colors change to more recent and relevant terms, such as digital competence, teacher readiness, AI-based education, and smart learning environments (Estrada-Molina et al., 2024; Sumakul & Hamied, 2023; Chien & Sun, 2025). This shift aligns with the TPACK and DigCompEdu frameworks, which position technology as a primary dimension of teacher competence. It further affirms that digital pedagogy has emerged as a new paradigm in educational practice (Mishra & Koehler, 2006; Redecker, 2022). Overall, the keyword analysis demonstrates a clear transition from conventional pedagogical approaches toward an integrative, future-oriented, and technology-based learning paradigm.



Future research in this domain could further explore the complex interactions between knowledge frameworks, professional competencies, and digitalization in the teaching profession.





3.4 Conceptual Transformation

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Time-based mapping shows that although "pedagogical competence" was the most common term at the start of the study, terms related to digital learning have become much more common after 2020. This trend is especially clear in the areas of online learning and AI-based education (Estrada-Molina et al., 2024; Sumakul & Hamied, 2023). This shift is consistent with the OECD (2021) report, which emphasizes the necessity of technological literacy and teacher adaptability in the face of digital disruption. It also aligns with the UNESCO (2022) framework, which conceptualizes ICT-based competencies as a core element of educator professionalism. Consequently, the evolution of these terms reflects more than just a linguistic shift; it signifies a fundamental change in the professional reality and responsibilities of teachers within increasingly digitized classroom environments.

Furthermore, the DigCompEdu framework, developed by Redecker (2022) and colleagues, complements this conceptual transformation by providing more operational dimensions of competence. These include professional engagement, digital resources, teaching and learning, assessment, and empowering learners. This framework operationalizes digital pedagogical competence as a set of measurable practices that can be systematically developed through targeted training and institutional policies (Redecker, 2022; Hanifah et al., 2024). Recent studies show that teachers who successfully combine TPACK principles, DigCompEdu standards, and hands-on or ecological methods in education are more effective at creating thoughtful and adaptable digital learning experiences (Isaev, 2020; Hartini et al., 2020; Getahun, 2025). Consequently, the transformation of pedagogical competence is best understood as an epistemological shift that reshapes how teachers conceptualize, deliver instruction, and engage with students within complex digital environments.

3.5 Critical Discussion

This section integrates the empirical findings with theoretical frameworks and policy implications for the development of teacher pedagogical competence in the digital era. The increase in publications after 2020, the focus on digital teaching topics, and the strong connections between TPACK and teacher professional development highlight an important fact: using technology in teaching is now a central part of teacher training (Mishra & Koehler, 2006; Mesquita & Moreira, 2020; Hanifah et al., 2024). The TPACK and DigCompEdu frameworks provide the conceptual foundation for understanding how technological, pedagogical, and content knowledge interact in practice. The bibliometric data confirms that global research is moving in a direction consistent with these two frameworks (Redecker, 2022; Zhou & Zhao, 2023; Getahun, 2025). Therefore, the results of this study strengthen the argument that reinforcing pedagogical competence in the digital era must be executed through a systemic, evidence-based, and coordinated approach, both at the policy level and in classroom practice.

Another prominent finding is the dominance of themes such as digital readiness, teacher adaptability, and AI-based pedagogy. These trends highlight an urgent need for continuous upskilling and reskilling programs. Research regarding teacher adaptation to AI-driven education and open learning environments suggests that successful transformation is not merely determined by the availability of hardware. Instead, it relies on psychological, pedagogical, and organizational readiness (Sumakul & Hamied, 2023; Estrada-Molina et al., 2024; Gafurova et al., 2019). Across numerous contexts, educators continue to confront significant barriers related to infrastructure, school culture, and heavy workloads, all of which hinder their capacity for instructional innovation (Nemet, 2018; Hartini et al., 2020). Consequently, educational policies must provide comprehensive support mechanisms, including the provision of high-quality training, the cultivation of professional learning communities (PLCs), and the implementation of incentive structures that foster technology-based pedagogical experimentation (OECD, 2021; UNESCO, 2022).

Furthermore, the growing emphasis on digital pedagogical competence indicates that teachers' role have become increasingly multifaceted in contemporary education (Kiryakova & Kozhuharova, 2024). Teachers are no longer viewed solely as knowledge transmitters. They are expected to act as learning facilitators, digital content curators, and mediators of interaction within technology-enhanced learning environments (Dochia, 2025). This transformation requires educators to effectively integrate innovative pedagogical approaches with appropriate technological tools to ensure meaningful, inclusive, and student-centered learning experiences. Previous studies also suggest that integration of technology in education depends significantly on teachers' ability to design collaborative, reflective, and adaptive learning experiences that respond to the evolving demands of modern education.

The findings of this study suggest that future research on teachers' teaching skills in the digital age will be mainly influenced by three key trends: the global nature of education, the rise of AI and learning analytics, and the need for skills relevant to the 21st century. To fully capture this complexity, future research must move beyond bibliometric mapping by combining content analysis, detailed studies, and data from different platforms that show what is really happening in schools and higher education.

institutions (Getahun, 2025; Zhou & Zhao, 2023). Moreover, the international collaboration evident in contemporary publication networks should be enhanced through collaborative research initiatives, exchange programs, and the development of skill frameworks that address local requirements while aligning with a global context (Hanifah et al., 2024; Mesquita & Moreira, 2020). In conclusion, the findings of this research offer more than just a map of the current knowledge landscape; they provide a foundation for formulating a strategic research agenda and policy framework. The ultimate goal is to give teachers the tools they need to become digital learning designers, professionals who can lead and adapt in a time of constant change in education.

4. CONCLUSION

The bibliometric analysis of 404 Scopus-indexed publications from the 2016–2025 period reveals a significant upward trajectory in research concerning teacher pedagogical competence. This growth is particularly pronounced after 2020, aligning with the accelerated digital transformation within the education sector. The mapping results highlight a post-pandemic surge in publications centered on digital pedagogy, TPACK integration, teacher readiness, and AI-based education. Furthermore, the publication structure underscores substantial contributions from nations such as Indonesia, China, Spain, Russia, and Ethiopia, positioning several key institutions and authors as vital nodes within the global scientific collaboration network. The keyword analysis revealed five main groups: digital pedagogy and the TPACK framework, teacher professional development, pre-service teacher education, curriculum and policy reform, and 21st-century skills. Overall, these findings highlight that pedagogical competencies are no longer just about traditional methods; instead, they have become a complex area that keeps changing to fit the digital learning environment.

Conceptually, this study illustrates a significant paradigm shift in the teacher's role, transitioning from a traditional knowledge transmitter to a digital learning designer responsible for crafting innovative, collaborative, and student-centered learning experiences. The bibliometric findings highlight that TPACK, teacher professional development, and digital readiness are key elements in updating pedagogical competency for the digital age. Furthermore, educators are now required to demonstrate high teacher adaptability, embody the ethos of lifelong learning, and proactively engage in continuous professional development to ensure their competencies remain aligned with rapid technological advancements and evolving student needs. The change in terms from "pedagogical competence" to "digital pedagogical skills" and "technological pedagogical competence" reflects a major shift in the knowledge, skills, and attitudes needed for today's Society 5.0 and data-focused learning environments. Ultimately, this research affirms that the transformation of pedagogical competence is a multifaceted process that is simultaneously technical, pedagogical, and epistemological in nature.

From a policy viewpoint, the results of this study support global goals like Sustainable Development Goal (SDG) 4 (Quality Education), the Society 5.0 vision, and various national education reforms, including the Merdeka Belajar (Freedom to Learn) policy, which focus on combining digital skills with teaching innovation. The importance of improving teachers' digital skills, using AI in teaching methods, and applying digital competency frameworks like TPACK and DigCompEdu creates a strong basis for developing more focused and evidence-based teacher training programs. Furthermore, this study highlights the necessity of international collaboration, cross-platform data integration, and mixed-methods research approaches (combining bibliometrics with content analysis) to deepen the understanding of how pedagogical transformation manifests in practical, real-world contexts. Ultimately, this research offers significant conceptual and methodological contributions to the global mapping of teacher pedagogical competence. It serves as a vital reference for policymakers, educational administrators, and researchers in designing strategic digital transformation frameworks for the future of education.

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The authors declare that there are no conflicts of interest or potential biases that could compromise the integrity of the findings presented in this study. All data analyzed in this research was retrieved from publicly available records in the Scopus database.

AUTHOR CONTRIBUTIONS

Asep Purwo Yudi Utomo: Conceptualization, Investigation.

Ngabiyanto, Tutik Wijayanti: Methodology, Laboratory Analysis.

Rossi Galih Kesuma, Muhammad Feriady: Data Curation, Formal Analysis.

Dyah Prabaningrum, Amilia Buana Dewi Islamy: Supervision, Writing, Review & Editing.

CONFLICT OF INTEREST

The authors declare that there is no conflict of interest.

ETHICS STATEMENT

Ethical approval was not required for this study.

DATA AVAILABILITY STATEMENT

Lorem ipsum Data supporting the findings of this study are available from the corresponding author upon reasonable request.

REFERENCES

- [1] Lorem, Aldemir, T., Kilinc, S., Bicer, A., Grant, P., Davis, T., & Sweany, N. W. (2025). Intelligent-TPACK in practice: Design and evidence from a three-week teacher preparation module. *Computers and Education Open*, 9, Article 100306. <https://doi.org/10.1016/j.caeo.2025.100306>
- [2] Almerich, G., Orellana, N., Suárez-Rodríguez, J., & Díaz-García, I. (2016). Teachers' information and communication technology competences: A structural approach. *Computers & Education*, 100, 110–125.
- [3] Almerich, G., Suárez-Rodríguez, J., Díaz-García, I., & Orellana, N. (2021). The influence of using ICT in high-skills competences and ICT competences. A structural model. *Education and Information Technologies*, 26(4), 3845–3869. <https://doi.org/10.1007/s10639-021-10437-y>
- [4] Al-Qashouti, N. M. H. A. (2024). Educational System Management Under Crisis Events: Remote Education Framework During and Post the Pandemic. *Hamad Bin Khalifa University (Qatar)*.
- [5] Andersson Hult, L., & Persson, A. (2025). Exploring civics in early 20th century Sweden: A study of final exam questions at four teacher training colleges between 1915 and 1937. *Journal of Social Science Education*, 24(1), 1–23. <https://doi.org/10.11576/jsse-7454>
- [6] Aria, M., & Cuccurullo, C. (2017). bibliometrix: An R-tool for comprehensive science mapping analysis. *Journal of Informetrics*, 11(4), 959–975.
- [7] Asad, M. M., Aftab, K., Sherwani, F., Churi, P., Moreno-Guerrero, A.-J., & Pourshahian, B. (2021). Techno-pedagogical skills for 21st century digital classrooms: An extensive literature review. *Education Research International*, 2021(1), 8160084.
- [8] Asikainen, E., Uusimäki, L., Ruhalhti, S., Davis, H., & Brauer, S. (2025). Collaborative meaning-making: Teacher educators' experiences in developing sustainability competence badges. *Acta Didactica Norden*, 19(2). <https://doi.org/10.5617/adno.11385>
- [9] Chien, C., & Sun, L. (2025). Growth mindset and digital pedagogical readiness among teachers in smart learning environments. *Educational Technology Research and Development*, 73(2), 455–472. <https://doi.org/10.1007/s11423-025-10118-9>
- [10] D'mello, S. (2021). OECD digital education outlook 2021: pushing the frontiers with artificial intelligence, blockchain robots. *OECD*.
- [11] Dahal, R. K., & Khadka, S. (n.d.). An Empirical Study on the Determinants of ICT Integration in Nepalese Higher Education: The Perspectives of University Teachers on Infrastructure, Support, and Readiness.
- [12] Das, S. (2021). Research trends of e-learning: A bibliometric and visualisation analysis. *Library Philosophy and Practice*, 1–27.
- [13] Díaz-Suárez, V., Martín-Paciente, M., & Travieso-González, C. M. (2025). Exploring the Impact of Digital Platforms on Teaching Practices: Insights into Competence Development and Openness to Active Methodologies. *Applied System Innovation*, 8(3), 64.

- [14] Dochia, I. (2025). The changing role of teachers in the digital age: From knowledge transmitter to learning facilitator. *International Journal of Social and Educational Innovation (IJSEIro)*, 12(23), 109-118.
- [15] Estrada-Molina, O., Mena, J., & López-Padrón, A. (2024). The use of deep learning in open learning: A systematic review (2019–2023). *The International Review of Research in Open and Distributed Learning*, 25(3), 55–73. <https://doi.org/10.19173/irrodl.v25i3.7571>
- [16] Fathoni, K., Utomo, A. P. Y., Prasetyo, B., & Retnoningsih, A. (2021). Integrated waste management system in Universitas Negeri Semarang, Indonesia. *Journal of Physics: Conference Series*, 1918(5). <https://doi.org/10.1088/1742-6596/1918/5/052087>
- [17] Fernández-Batanero, J. M., Montenegro-Rueda, M., Fernández-Cerero, J., & García-Martínez, I. (2022). Digital competences for teacher professional development. Systematic review. *European Journal of Teacher Education*, 45(4), 513–531.
- [18] Gafurova, N., Khusainova, A., & Sharipova, S. (2019). Adaptive systems for teacher training in digital contexts. *International Journal of Instruction*, 12(4), 333–348. <https://doi.org/10.29333/iji.2019.12421a>
- [19] Getahun, A. M. (2025). Trends and transformations in pedagogical competence. *Teaching and Teacher Education*, 137, 104352. <https://doi.org/10.1016/j.tate.2024.104352>
- [20] Güner, P., Kiliç, Ç., Sevimli, E., & Gökçe, S. (2025). Mapping routes from teacher identity to TPACK: Mediating roles of technostress, belief, and competency. *Social Psychology of Education*, 28(1). <https://doi.org/10.1007/s11218-024-09996-y>
- [21] Goncharova, N., Daineko, L., & Larionova, V. (2021). Development of an adaptive learning model based on digital technologies and the work of the teacher. *INTED2021 Proceedings*, 6549–6558.
- [22] Hanifah, D. N. R., Saputri, N. D., Yulisetiani, S., & Suwandi, S. (2024). Inovasi Pembelajaran Bahasa Indonesia Berbasis Digital dalam Implementasi Kurikulum Merdeka di SMP Tiga Bahasa Bina Widya Surakarta: Inovasi Pembelajaran Bahasa Indonesia Berbasis Digital. *Jurnal Onoma: Pendidikan, Bahasa, dan Sastra*, 10(2), 1305-1319.
- [23] Hartini, S., Bhakti, C. P., Hartanto, D., & Ghiffari, M. A. N. (2018). Teacher pedagogic competency development model: a literature review. *5th Asia Pasific Education Conference (AECON 2018)*, 211–215.
- [24] Hartini, S., Bhakti, C. P., Kurniawan, S. J., & Fitri, P. N. (2021, March). Teacher Training Design Blended Learning of Pedagogical Competence School Counseling. In *BICED 2020: Proceedings of the 2nd EAI Bukittinggi International Conference on Education, BICED 2020, 14 September, 2020, Bukittinggi, West Sumatera, Indonesia* (p. 234). European Alliance for Innovation.
- [25] Herut, A. H. (2024). Global trends of research on advancing the pedagogical competence of preschool teachers: A bibliometric analysis. *Social Sciences & Humanities Open*, 10, 100947.
- [26] Hincapie, M., Diaz, C., Valencia, A., Contero, M., & Güemes-Castorena, D. (2021). Educational applications of augmented reality: A bibliometric study. *Computers & Electrical Engineering*, 93, 107289.
- [27] Hooker, M., Mwiyeri, E., & Verma, A. (2011). ICT competency framework for Teachers (ICT-CFT): Contextualization and piloting in Nigeria and Tanzania: synthesis report. UNESCO.
- [28] Isaev, E. I. (2020). Activity approach in teacher training: Formation and implementation. *PSYCHOLOGICAL SCIENCE AND EDUCATION*, 25(5), 110.
- [29] Kardiwan, D. D., Hartono, C. R., Yahya, C. R. F., Fatmawati, F., Hidayat, R., & Rahmawati, S. (n.d.). Mapping the Challenges of 21st-Century Pedagogy: A Bibliometric Study. *Jurnal Tata Kelola Pendidikan*, 7(2), 91–104.
- [30] Kausar, H., & Ajmal, F. (2024). Meta-Analysis Study: Expectations of 21st Century Teaching from Pre-Service Teacher Education Programs. *Journal of Research in Social Sciences*, 12(2), 1–14.
- [31] Kiryakova, G., & Kozhuharova, D. (2024). The digital competences necessary for the successful pedagogical practice of teachers in the digital age. *Education Sciences*, 14(5), 507.
- [32] Kumar, S., Maggino, F., Mahto, R. V., Sureka, R., Alaimo, L. S., & Lim, W. M. (2022). Social indicators research: a retrospective using bibliometric analysis. *Social Indicators Research*, 162(1), 413–448.
- [33] Liesa-Orus, M., Lozano Blasco, R., & Arce-Romeral, L. (2023). Digital competence in university lecturers: A meta-analysis of teaching challenges. *Education Sciences*, 13(5), 508.
- [34] Lindfors, M., Pettersson, F., & Olofsson, A. D. (2021). Conditions for professional digital competence: The teacher educators' view. *Education Inquiry*, 12(4), 390–409.

- [35] López-Martín, E., Gutiérrez-de-Rozas, B., González-Benito, A. M., & Expósito-Casas, E. (2023). Why do teachers matter? A meta-analytic review of how teacher characteristics and competencies affect students' academic achievement. *International Journal of Educational Research*, 120, 102199.
- [36] Masoumi, D., & Noroozi, O. (2025). Developing early career teachers' professional digital competence: A systematic literature review. *European Journal of Teacher Education*, 48(3), 644–666.
- [37] Maryani, I., Irsalinda, N., Jaya, P. H., Sukma, H. H., & Raman, A. (2025). Understanding student engagement: An examination of the moderation effect of professional teachers' competence. *Journal of Education and Learning*, 19(1), 14–23. <https://doi.org/10.11591/edulearn.v19i1.21455>
- [38] Mishra, P., & Koehler, M. J. (2006). Technological pedagogical content knowledge: A framework for teacher knowledge. *Teachers College Record*, 108(6), 1017–1054.
- [39] Mustaqimah, U., Dollah, S., Basri, M., Asiza, N., & Akib, M. (2025). Teachers' pedagogical competencies in implementing contextual teaching and learning in vocational high schools in South Sulawesi. *International Journal of Language Education*, 9(1), 180–194. <https://doi.org/10.26858/ijole.v1i1.74766>
- [40] Narmaditya, B. S., Sahid, S., & Hussin, M. (2025). From classroom to entrepreneurship: The link between educator competencies, entrepreneurial literacy, and entrepreneurial behaviour in higher education. *Journal of Applied Research in Higher Education*, 17(3), 1066–1080. <https://doi.org/10.1108/JARHE-11-2023-0521>
- [41] Nemet, M. B. (2018). A Correlation between Teachers' Social and Pedagogical Competences and School Culture. *Journal of Contemporary Educational Studies/Sodobna Pedagogika*, 69(3).
- [42] Nurkhin, A., Mulyono, K. B., Saputro, I. H., Pramono, D., & Utomo, A. P. Y. (2023). Teachers' Performance During the COVID-19 Pandemic in Indonesia: Causality and Comparison. *European Journal of Educational Research*, 12(2), 605–621. <https://doi.org/10.12973/eu-jer.12.2.605>
- [43] OECD. (2021). AI and data in education. OECD Publishing.
- [44] Page, M. J., McKenzie, J. E., Bossuyt, P. M., Boutron, I., Hoffmann, T. C., Mulrow, C. D., Shamseer, L., Tetzlaff, J. M., Akl, E. A., & Brennan, S. E. (2021). The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. *Bmj*, 372.
- [45] Redecker, C. (2022). DigCompEdu framework: The European model for educator digital competence. Luxembourg: Publications Office of the EU.
- [46] Raymond, S., & Gabriel, F. (2023). An ecological framework for early years teacher self-efficacy development. *Teaching and Teacher Education*, 132, 104252.
- [47] Ruiz-Requies, I., Rodríguez-Medina, J., Herguedas-Esteban, M. C., & Ayuso-Lanchares, A. (2025). University and educational centre in the practicum: analysis of student satisfaction in Early Childhood and Primary Education Degrees. *Revista Interuniversitaria de Formacion del Profesorado*, 39(3), 29–41. <https://doi.org/10.47553/rifop.v39i3.116884>
- [48] Schotten, M., Meester, W. J. N., Steinginga, S., & Ross, C. A. (2017). A brief history of Scopus: The world's largest abstract and citation database of scientific literature. In *Research analytics* (pp. 31–58). Auerbach Publications.
- [49] Shulman, L. (1987). Knowledge and teaching: Foundations of the new reform. *Harvard Educational Review*, 57(1), 1–23.
- [50] Suárez-Rodríguez, J., Almerich, G., Orellana, N., & Díaz-García, I. (2018). A basic model of integration of ICT by teachers: competence and use. *Educational Technology Research and Development*, 66(5), 1165–1187.
- [51] Sumakul, D. T. Y., Hamied, F. A., & Sukyadi, D. (2022). Artificial intelligence in EFL classrooms: Friend or foe?. *LEARN Journal: Language Education and Acquisition Research Network*, 15(1), 232–256.
- [52] Syamsuri, A. S., Ishaq, I., & Muhsin, M. A. (2020). Teacher orientation of post competence mapping in 21st century teaching systems. *International Journal of Innovation, Creativity and Change*, 12(8), 468–484.
- [53] Thyssen, C., Huwer, J., Irion, T., & Schaal, S. (2023). From TPACK to DPACK: The “Digitality-related pedagogical and content knowledge”-model in STEM-education. *Education Sciences*, 13(8), 769.
- [54] Tran-Duong, Q. H., & Nguyen, D.-T. (2025). Enhancing engagement in pre-service primary school teachers: Which teaching style should teacher educators adopt? *European Journal of Education*, 60(3). <https://doi.org/10.1111/ejed.70145>
- [55] Triana, Y. (2025). Improving linguistics skill on EFL students using learning management system: A critical literature review. *Journal of Ethnic and Cultural Studies*, 12(3), 199–223. <https://doi.org/10.29333/ejecs/1864>
- [56] Trianto, A. (2019). Teacher's Competency Assessment (TCA) in Indonesia: a new frame work. Iceap 2019.
- [57] UNESCO. (2022). Reimagining our futures together.

- [58] Utomo, A. P. Y., & Anindyarini, A. (2023). Critical Reading of Cultural Texts: A Bibliometric Content Analysis. *ISVS E-Journal*, 10(9), 31–49. <https://doi.org/10.10627/ISVSej-2023-10-09-03>
- [59] Van Eck, N. J., & Waltman, L. (2022). VOSviewer Manual. Leiden university. *ISSI Newsletter*, 7(3), 50–54.
- [60] Widyastuti, P., Dos Santos, M., & Mwakapemba, J. L. (2024). Mapping digital learning transformation for 21st century skills: A bibliometric analysis. *Journal of Technological Pedagogy and Educational Development*, 1(2), 53–66.
- [61] Zhao, Y., Llorente, A. M. P., & Gómez, M. C. S. (2021). Digital competence in higher education research: A systematic literature review. *Computers & Education*, 168, 104212.
- [62] Zu Zhou, H., & Zhao, Y. (2023). Teacher professional development and digital transformation: A global view. *Frontiers in Education*, 8, 112349. <https://doi.org/10.3389/feduc.2023.112349>
- [63] Zupic, I., & Čater, T. (2015). Bibliometric methods in management and organization. *Organizational Research Methods*, 18(3), 429–472.