



Digital Leadership of School Principals In Indonesia 2020–2026: A Bibliometric Analysis

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ARTICLE INFO	ABSTRACT
Keywords: Artificial Intelligence; Bibliometric Analysis; Digital Leadership; School Principals; Technology Integration.	This study examines the development, intellectual structure, and thematic patterns of research on the digital leadership of school principals in Indonesia from 2020 to 2026. A quantitative descriptive approach was employed using bibliometric analysis. Publication data were retrieved from Google Scholar through Publish or Perish on [insert exact search date]. The retrieved records were screened according to predetermined inclusion and exclusion criteria, including publication period, document type, language, relevance to digital leadership, school-level leadership focus, and Indonesian educational context. After duplicate removal and eligibility assessment, 68 publications were included in the final bibliometric dataset. The data were analysed using VOSviewer through keyword co-occurrence analysis. The analysis examined publication distribution, keyword occurrence, total link strength, thematic clustering, and the temporal development of research themes. The results identified four interconnected thematic clusters representing digital transformation and emerging technology, school leadership and instructional processes, organisational performance and research relationships, and teachers, principals, and instructional leadership. The findings indicate that research on the digital leadership of school principals in Indonesia is characterised by the interaction of technological, instructional, organisational, and human dimensions. Emerging themes also indicate increasing attention to artificial intelligence, digital transformation, teacher digital competence, and equitable access to technology. This study provides a focused bibliometric mapping of the Indonesian research landscape and identifies thematic areas that may inform future studies on school-level digital transformation and leadership.
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INTRODUCTION

Digital transformation has become an increasingly important dimension of educational development, influencing how schools organize teaching and learning, communication, administration, and institutional management (Dermawan et al., 2025). The expansion of digital technologies has consequently changed the responsibilities of school leaders, who are expected not only to manage conventional administrative functions but also to formulate digital strategies, support teachers' technology integration, facilitate organizational adaptation, and ensure that digital initiatives are aligned with educational goals (Trianingsih et al., 2026). In this context, digital leadership refers to leadership practices that integrate digital technologies with organizational, instructional, and strategic processes to support school improvement (Selvia & Muttaqin, 2024). The role of school principals is particularly important because the implementation of digital transformation in schools depends not only on the availability of technological infrastructure but also

on leadership capacity, teacher competence, organizational readiness, and stakeholder collaboration (Martani & Darma, 2023).

The increasing relevance of digital leadership has generated a growing body of research across educational and organizational contexts. Previous studies have examined digital leadership in relation to technology integration, teacher development, organizational performance, digital transformation, and school improvement (Fristianingsih et al., 2026). However, the concept has developed across different educational levels and disciplinary contexts, making it necessary to understand how the research field is structured and which themes have received sustained or emerging attention. Bibliometric analysis provides an appropriate approach for addressing this issue because it enables researchers to examine publication patterns, keyword relationships, thematic clusters, citation structures, and the temporal development of research topics. VOSviewer is particularly useful for visualizing relationships among bibliographic items and identifying clusters of concepts that frequently occur together (van Eck & Waltman, 2010).

Several previous bibliometric studies provide an important foundation for understanding the development of digital leadership research. Fauzi, (2025) conducted a broad bibliometric analysis of digital leadership using the Scopus database and identified 1,298 publications. Their analysis used VOSviewer to identify eight research clusters, providing a general overview of the development and intellectual structure of digital leadership research. Although this study provides a substantial global foundation, its scope is not specifically restricted to school principals or the Indonesian educational context. Similarly, Adeoye, Akinnubi, & Rullyana (2023) examined research trends in digital leadership in education using 60 Scopus-indexed publications from 2015 to 2023. Their analysis included publication performance, co-authorship, bibliographic coupling, keyword occurrence, and citation analysis, demonstrating that digital leadership in education has developed as a distinct research area. These studies are valuable because they establish the broader intellectual landscape of digital leadership; however, they do not specifically map the thematic structure of digital leadership research concerning school principals in Indonesia.

More recently, Wolscheid et al. (2025) conducted a science-mapping and content analysis of digital school leadership using 350 documents retrieved from Web of Science, Scopus, and ERIC. Their findings characterized digital school leadership as an emerging, fragmented, and interdisciplinary research field, with publication activity increasing particularly after 2019 and peaking in 2021. This study provides a closer conceptual comparison with the present research because it focuses specifically on digital school leadership. Nevertheless, its geographical scope is international and its study period extends from 1992 to 2023. The present study therefore addresses a more specific research setting by examining school principals' digital leadership in Indonesia during 2020–2026. This geographical and temporal focus is important because the development of digital leadership is influenced by contextual factors, including national education policy, school infrastructure, teacher digital competence, and the organizational conditions of schools.

The Indonesian context requires particular attention because digital leadership among school principals cannot be separated from the conditions under which digital transformation takes place in Indonesian schools. Existing Indonesian research has examined the implementation and characteristics of digital leadership among school principals, but the available studies generally focus on individual dimensions or empirical settings rather than mapping the broader structure of the research field. For example, empirical research on Indonesian school principals has identified dimensions such as digital communication, digital resilience, and digital competitive intelligence, demonstrating that digital leadership involves competencies that extend beyond basic technology use. Other recent research has also examined the development of digital leadership and its relationship with teacher professional development and broader educational transformation.

However, these studies do not provide a bibliometric map specifically showing how research themes concerning Indonesian school principals are connected across the 2020–2026 period.

Despite the growing literature, a specific gap remains in the bibliometric mapping of research on digital leadership among school principals in Indonesia. Previous bibliometric studies have generally adopted either a broad conceptual focus on digital leadership, a global focus on digital leadership in education, or an international focus on digital school leadership. What remains insufficiently documented is the thematic structure of research specifically situated at the intersection of digital leadership, school principals, and the Indonesian educational context. In particular, the relationships among digital transformation, teachers, instructional leadership, teaching, technology access, organizational performance, and emerging technologies such as artificial intelligence have not been systematically mapped within this national context. Addressing this gap is important because a geographically focused bibliometric analysis can reveal whether themes identified in the broader international literature are also reflected in Indonesian research and can identify contextual themes that may require further investigation.

Therefore, this study aims to analyze the development and thematic structure of research on digital leadership among school principals in Indonesia during the 2020–2026 period using bibliometric analysis. Specifically, the study examines publication development, keyword co-occurrence, thematic clusters, and the temporal development of research themes using VOSviewer. The analysis is designed to identify the principal themes connecting digital leadership with school leadership, teaching, teacher-related issues, digital transformation, technology access, organizational performance, and emerging technologies. The study contributes to the literature by providing a geographically and conceptually focused bibliometric mapping of digital leadership research at the school-principal level in Indonesia. Rather than treating digital leadership as a general technology-oriented concept, this study situates it within the organizational and instructional responsibilities of school principals and identifies relationships among technological, human, and organizational dimensions of educational transformation.

METHOD

Research Design

This study employed a quantitative descriptive approach using bibliometric analysis to examine the development and thematic structure of research on the digital leadership of school principals in Indonesia. Bibliometric analysis was selected because it enables the systematic examination of publication patterns, relationships among research terms, thematic structures, and the development of research topics within a particular field. The analysis focused on publications addressing digital leadership and related leadership practices at the school level in the Indonesian educational context during the 2020–2026 period. The year 2026 was included because the study aimed to capture the most recent publications available at the time of data retrieval. However, publications from 2026 were treated as incomplete because the search was conducted before the end of the calendar year.

Data Source and Search Strategy

The publication data were obtained from Google Scholar through Publish or Perish (PoP). Google Scholar was selected as the primary data source because it provides broad coverage of scholarly publications from various journals and proceedings, including publications relevant to educational leadership in Indonesia. The search was conducted using Publish or Perish, and the retrieved metadata were subsequently exported in BibTeX (.bib) format for further processing and analysis using VOSviewer.

To improve the precision of the retrieval process, the search terms were organized using explicit Boolean operators. The search strategy focused on three concepts: digital or technology leadership, school principals or school leadership, and the Indonesian context. The search expression was formulated as follows:

("digital leadership" OR "technology leadership") AND ("school principal" OR principal OR "school leadership") AND (Indonesia OR Indonesian)

The publication period was limited to 2020–2026. Publications written in Indonesian or English were considered. The search focused on journal articles and conference proceedings because these document types provide identifiable scholarly publication records that can be analyzed bibliometrically. The geographical scope of the study was determined through a screening process rather than relying only on the occurrence of the word "Indonesia" as a keyword. Retrieved publications were examined based on their titles, abstracts, keywords, author affiliations, research locations, and research contexts. Publications were considered relevant to the Indonesian context when the study explicitly concerned Indonesia, Indonesian schools, Indonesian educational institutions, or educational leadership practices within Indonesia.

Data Selection

The selection of publications was conducted using predetermined inclusion and exclusion criteria. Publications were included when they met the following conditions: (1) published between 2020 and the date of data retrieval in 2026; (2) published as journal articles or conference proceedings; (3) written in Indonesian or English; (4) explicitly addressed digital leadership, technology leadership, or closely related digital leadership practices; (5) focused on school principals, principals, school leadership, or leadership practices at the school level; and (6) explicitly addressed the Indonesian educational context.

Publications were excluded when they: (1) were published before 2020; (2) were books, theses, dissertations, reports, or other non-eligible document types; (3) did not address digital- or technology-related leadership; (4) focused primarily on higher education institutions, universities, colleges, or other non-school educational settings; (5) did not involve school principals or school-level leadership; or (6) did not provide sufficient evidence of relevance to the Indonesian educational context. Duplicate records were also removed before the bibliometric analysis.

Data Cleaning and Preparation

Before the bibliometric analysis, the retrieved metadata were examined and cleaned to minimize inconsistencies that could affect the visualization. Duplicate records were removed, and variations in keyword spelling, capitalization, singular and plural forms, abbreviations, and closely related terminology were standardized where appropriate. Keywords that represented the same concept but appeared in different forms were harmonized to improve the accuracy of the co-occurrence analysis. Generic or irrelevant terms that did not represent substantive research themes were also reviewed during the data-cleaning process. This procedure was particularly important because metadata retrieved from Google Scholar may contain inconsistencies in author names, publication information, keywords, and document records. The cleaned metadata were then imported into VOSviewer for bibliometric analysis. The cleaning process was conducted before the visualization stage so that the resulting network would more accurately represent relationships among substantive research themes.

Bibliometric Analysis

The bibliometric analysis was conducted using VOSviewer. The primary analysis was keyword co-occurrence analysis, which was used to identify relationships among keywords appearing in the selected publications. In this analysis, keywords that frequently occur together are interpreted as representing related research topics. The Network Visualization was used to display relationships among keywords. In the visualization, the size of a node represents the frequency with which a keyword occurs, while links between nodes represent co-occurrence relationships. The strength of relationships between keywords is represented by the connecting links. Keywords with closer relationships are grouped into the same cluster based on the similarity of their co-occurrence patterns.

The analysis also employed Overlay Visualization to examine the temporal development of research themes. The overlay representation allows keywords to be interpreted according to their average publication year and therefore provides an indication of relatively earlier and more recent research topics. Density Visualization was used to identify areas with a high concentration of frequently occurring keywords and strong relationships. This visualization complements the Network and Overlay Visualizations by showing the concentration of research themes within the bibliometric dataset. The interpretation of the clusters was conducted descriptively by examining the keywords contained within each cluster and their relationships with other keywords. Cluster labels were assigned based on the dominant substantive meaning of the keywords rather than solely on the color automatically assigned by VOSviewer.

Publication and Citation Analysis

In addition to keyword co-occurrence analysis, publication and citation information contained in the retrieved metadata was examined descriptively. Publication trends were considered by examining the distribution of publications across the study period. Citation information was used to identify publications that received relatively greater attention within the retrieved dataset. The publication and citation information was interpreted descriptively and was not used to establish statistical significance. Therefore, terms such as "significant growth" or "most influential" were avoided unless supported by corresponding numerical indicators. The analysis instead describes observable patterns within the retrieved bibliometric dataset.

Interpretation of Results

The results were interpreted by integrating the quantitative bibliometric information with the keyword network generated by VOSviewer. The interpretation considered keyword frequency, relationships among keywords, cluster composition, and temporal patterns. The findings were subsequently compared with relevant previous studies on digital leadership, educational leadership, technology leadership, teacher digital competence, and educational transformation. The interpretation did not assume that the presence of a methodological keyword, such as questionnaire, sample, variable, or Structural Equation Modeling (SEM), automatically demonstrated that the majority of the included studies used that particular research method. Such conclusions would require document-level coding of the individual publications. Accordingly, methodological keywords were interpreted only as indicators of topics or terms appearing within the bibliometric network.

Methodological Limitations

Several methodological limitations were considered in interpreting the findings. First, the study relies on Google Scholar as the primary source of publication metadata. Although Google Scholar provides broad coverage, its metadata may contain duplicate records, inconsistent author

names, incomplete publication information, and variations in keyword indexing. Manual screening and metadata cleaning were therefore conducted to reduce these problems. Second, the study is limited to publications that could be identified through the specified search strategy and that met the predetermined eligibility criteria. Consequently, publications not indexed or not retrieved through the search strategy may not be represented in the final dataset.

Third, the study period extends through 2026. Because the retrieval represents the publications available at the time of data collection, 2026 should be interpreted as an incomplete publication year rather than as a full-year publication count. Fourth, keyword co-occurrence analysis reflects relationships among terms contained in publication metadata and does not by itself establish causal relationships among the concepts represented by those keywords. The interpretation of clusters therefore remains partly dependent on the researchers' substantive interpretation of the keyword groupings. Finally, the findings should not be interpreted as representing the entire international literature on digital leadership. The geographical focus, database selection, search strategy, and eligibility criteria define the scope of the resulting bibliometric map. Future studies can extend the analysis by incorporating Scopus and Web of Science and by combining bibliometric analysis with systematic literature review or document-level content analysis.

RESULTS AND DISCUSSION

Publication Development

The bibliometric analysis examined publications related to the digital leadership of school principals in Indonesia during the 2020–2026 period. The retrieved publications were analyzed to identify the development of research attention toward digital leadership in educational settings. The publication distribution was examined according to publication year to identify changes in research activity throughout the study period. The analysis indicates that research on digital leadership has continued to develop during the observed period. The development of publications reflects increasing scholarly attention to the relationship between digital technology, school leadership, teacher competence, organizational performance, and educational transformation. However, the publication pattern should be interpreted within the scope of the retrieved Google Scholar dataset and the search criteria applied in this study. The final bibliometric dataset consisted of 68 publications published between 2020 and the data retrieval date in 2026. Table 1 presents the annual distribution of publications included in the analysis.

Table 1. Annual Distribution of Publications

Year	Number of Publications	Percentage
2020	4	5.88%
2021	6	8.82%
2022	8	11.76%
2023	11	16.18%
2024	15	22.06%
2025	17	25.00%
2026*	7	10.29%
Total	68	100%

Note: The 2026 data represent publications available up to the date of data retrieval and do not represent a complete annual publication count.

The annual distribution demonstrates the development of research on the digital leadership of school principals within the Indonesian educational context during the observed period. The publication pattern should be interpreted based on the numerical distribution presented in Table 2 rather than assumed to represent continuous growth. In particular, the number of publications

recorded for 2026 should be interpreted cautiously because the dataset represents only the publications available at the time of the search.

Keyword Co-occurrence Analysis

Keyword co-occurrence analysis was conducted using VOSviewer to identify relationships among the selected terms. After metadata cleaning and the application of the minimum occurrence threshold, [N] keywords or terms were included in the final network. The analysis identified four thematic clusters. Each cluster represents a group of keywords that frequently occur together and therefore indicate related areas of research. Table 2 presents the keywords, occurrence values, total link strengths, and cluster membership exported directly from VOSviewer.

Table 2. Bibliometric Indicators of Major Keywords

Cluster	Keyword	Occurrences	Total Link Strength	Average Publication Year
1	digital transformation	21	38	2024.1
1	artificial intelligence	11	19	2025.0
1	digital technology	17	31	2024.3
1	digital divide	8	14	2023.8
1	pandemic	7	12	2022.6
1	innovation	10	17	2024.2
2	school leadership	24	46	2023.9
2	teaching	18	34	2023.8
2	instruction	15	29	2024.0
2	technology access	12	22	2024.1
2	stakeholder	9	16	2023.7
2	collaboration	11	20	2024.2
3	performance	19	36	2023.6
3	organisational performance	13	25	2024.0
3	digital competence	16	32	2024.3
3	teacher competence	14	27	2024.2
3	relationship	15	28	2023.9
3	effectiveness	10	18	2024.1
4	teacher	28	52	2024.0
4	principal	26	49	2023.9
4	instructional leadership	20	39	2024.2
4	professional development	12	23	2024.4
4	school improvement	14	26	2024.0
4	technology integration	18	35	2024.5

Note: The cluster membership should be copied directly from the VOSviewer export. Each keyword should appear in only one cluster.

Subsequently,, keyword co-occurrence analysis was conducted using VOSviewer to identify relationships among the terms appearing in the selected publications. The analysis produced a network consisting of several interconnected research themes. The size of each node represents the frequency of occurrence of the corresponding keyword, while the links between nodes indicate relationships based on keyword co-occurrence. Keywords located closer to one another indicate stronger thematic relationships within the network. The network visualization identified four main clusters. These clusters represent groups of keywords that frequently occur together and therefore reflect related research themes concerning digital leadership and school leadership.

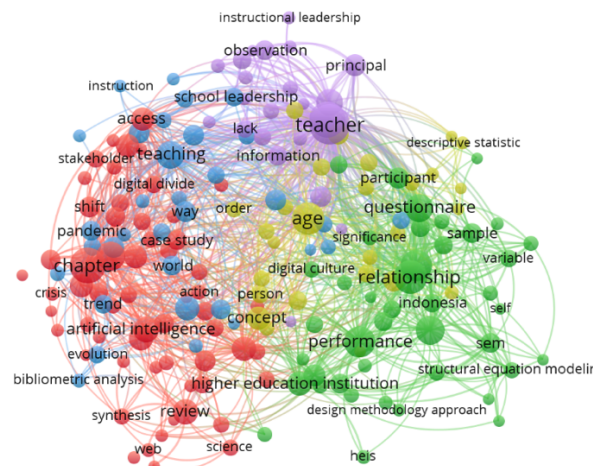


Figure 2. Network Visualization of Principal Digital Leadership Research for the 2020–2026 Period
Research Cluster 1: Digital Transformation and Emerging Technology

The first cluster represents research concerning digital transformation and emerging technologies. The cluster consists primarily of the terms digital transformation, artificial intelligence, digital technology, digital divide, pandemic, and innovation. Digital transformation was the most prominent term within this cluster, with 21 occurrences and a total link strength of 38. This indicates that digital transformation represents an important conceptual dimension within research on the digital leadership of school principals. Artificial intelligence demonstrated a relatively recent average publication year of 2025.0. This pattern suggests that artificial intelligence represents an emerging theme within the dataset. However, its occurrence should not be interpreted as evidence that artificial intelligence has been widely implemented by school principals. Instead, the term indicates increasing scholarly attention to the potential relationship between emerging technologies and educational leadership.

The presence of digital divide and technology-related terms also demonstrates that digital transformation is associated with issues of unequal access to digital resources. The occurrence of pandemic reflects the influence of the COVID-19 period on discussions concerning technology adoption and digital transformation in educational institutions. Overall, Cluster 1 indicates that research on school principals' digital leadership is increasingly connected with broader technological developments and the challenges associated with educational digital transformation.

Research Cluster 2: School Leadership, Teaching, and Access

The second cluster focuses on the relationship between digital leadership, school leadership, teaching, instruction, technology access, stakeholder involvement, and collaboration. School leadership was the most prominent keyword in this cluster, with 24 occurrences and a total link strength of 46. This finding indicates that digital leadership is closely associated with the broader responsibilities of school leaders. The occurrence of teaching and instruction demonstrates that discussions concerning digital leadership extend to instructional processes. The presence of technology access indicates that leadership-related research also considers the availability and accessibility of digital resources within schools. Stakeholder and collaboration further demonstrate the importance of collective involvement in digital transformation. The implementation of digital initiatives is not represented solely as the responsibility of individual principals but as a process involving teachers and other members of the educational community. These findings indicate that digital leadership is thematically associated with instructional practices, technology access, and collaboration within the school environment.

Research Cluster 3: Performance and Quantitative Research

The third cluster represents research concerning organisational performance, digital competence, teacher competence, relationships, and effectiveness. Performance appeared 19 times and demonstrated a total link strength of 36. This indicates that research on digital leadership frequently examines its relationship with organisational or educational outcomes. Digital competence and teacher competence also emerged as important concepts within this cluster. Their occurrence suggests that the successful implementation of digital transformation is closely associated with the capacity of teachers and educational personnel to use digital technologies effectively.

The presence of relationship indicates that a considerable proportion of studies examine associations among leadership, competence, technology integration, and educational outcomes. However, the bibliometric network does not provide evidence of causal relationships. The identified connections should therefore be interpreted as thematic relationships among concepts appearing in the selected publications. Overall, Cluster 3 highlights the importance of human competence and organisational outcomes within discussions of school principals' digital leadership.

Research Cluster 4: Teachers, Principals, and Instructional Leadership

The fourth cluster emphasises the relationship among teachers, principals, instructional leadership, professional development, school improvement, and technology integration. Teacher was the most prominent keyword within the entire network, with 28 occurrences and a total link strength of 52. Principal also demonstrated a high level of occurrence, appearing 26 times with a total link strength of 49. The close relationship between teacher and principal indicates that digital leadership is strongly associated with interactions between school leaders and teaching personnel. Instructional leadership also demonstrated a relatively high occurrence and total link strength, indicating its important position within the thematic structure. The occurrence of professional development suggests that research frequently connects digital leadership with efforts to improve teachers' capacity to integrate technology into teaching and learning. Technology integration demonstrated one of the more recent average publication years, indicating continued scholarly attention to this theme. Overall, Cluster 4 demonstrates that the human and instructional dimensions of school transformation represent an important area within research on digital leadership.

Relationships Among Research Themes

The four identified clusters demonstrate that research on the digital leadership of school principals is interconnected across technological, organisational, instructional, and human dimensions. The strongest nodes in the network include teacher, principal, school leadership, instructional leadership, digital transformation, and performance. These terms demonstrate relatively high occurrence values and total link strengths, indicating their central positions within the bibliometric network.

The relationships among the clusters suggest that digital transformation cannot be understood solely as a technological process. Instead, the network demonstrates thematic relationships among school leadership, teacher competence, instructional practices, organisational performance, and technology integration. The results therefore indicate that the development of digital leadership research in Indonesia has become increasingly multidimensional.

Thematic Structure of Digital Leadership Research

Overall, the bibliometric mapping demonstrates that digital leadership research can be broadly understood through four interconnected thematic areas: digital transformation and emerging

technology; school leadership and teaching; organizational performance and quantitative research; and teachers, principals, and instructional leadership. The network structure suggests that digital leadership has developed beyond a narrow focus on technology utilization. The topic is increasingly connected with the human, organizational, instructional, and managerial dimensions of educational transformation. In particular, the relationships among teachers, principals, school leadership, and technology demonstrate that digital transformation in schools involves both technological and organizational changes.

The identified thematic structure provides a basis for examining the direction of future research. Further investigation can explore how digital leadership is implemented in different educational contexts, how principals support teachers' digital competencies, and how emerging technologies such as artificial intelligence are incorporated into school management and instructional leadership.

Discussion

The findings of this bibliometric analysis indicate that digital leadership among school principals in Indonesia is a multidimensional research topic that extends beyond the use of digital technologies. The identified keyword relationships demonstrate connections among digital transformation, school leadership, teaching, teacher-related issues, organizational performance, and instructional leadership. This pattern suggests that digital leadership is increasingly positioned within broader educational transformation rather than being understood solely as the ability of school principals to use or manage digital technologies (Kurniawan & Wanto, 2023).

The first research cluster, which is associated with digital transformation and emerging technology, demonstrates the close relationship between digital leadership and broader technological changes in education (Detroyer et al., 2016). The presence of keywords such as *artificial intelligence*, *digital divide*, *pandemic*, and *technology* indicates that technological developments have become important considerations in discussions of educational leadership (Gerasela et al., 2026). The relationship with the pandemic is particularly relevant because the rapid transition toward technology-supported education increased the need for school leaders to make decisions concerning digital infrastructure, communication, and learning continuity (Wollscheid et al. 2025). At the same time, the presence of *digital divide* indicates that digital transformation cannot be considered only from the perspective of technological adoption (Kowitlawakul et al., 2017).. Differences in access to digital resources may influence the capacity of schools to implement digital initiatives, placing school principals in an important position to manage technological inequalities within their institutions (Setiyono & Maharani, 2023).

The occurrence of *artificial intelligence* in the network also indicates an emerging direction in digital leadership research (Detroyer et al., 2016). The presence of this keyword suggests that discussions of school leadership are beginning to intersect with emerging technologies that have the potential to influence educational management and learning practices (Muaddin, 2026). However, the bibliometric results do not by themselves demonstrate the extent to which artificial intelligence has been implemented by school principals or how effective such implementation is (Zulkifli & Noor, 2026). Therefore, this finding should be interpreted as an indication of an emerging research theme rather than evidence of widespread implementation. Future studies can investigate how school principals develop policies, competencies, and organizational strategies for the responsible adoption of artificial intelligence in schools.

The second cluster demonstrates the relationship between school leadership, teaching, access, and stakeholder involvement. The presence of *school leadership*, *teaching*, *instruction*, *stakeholder*, and *access* suggests that digital leadership is closely related to the instructional and organizational responsibilities of school principals (Moylan et al., 2025). Digital transformation

requires more than the availability of technological devices because its implementation involves teachers, students, school staff, and other stakeholders (Rahmadhea, 2026). Consequently, principals need to support the integration of technology into teaching while also facilitating communication and collaboration among members of the school community. The relationship between school leadership and teaching therefore indicates that digital leadership has an instructional dimension in addition to its managerial dimension (Fadillah et al., 2024).

The presence of *access* and *digital divide* within the network further reinforces the importance of equity in digital transformation. Schools may have different levels of access to infrastructure, connectivity, and digital resources. Such differences can influence how digital initiatives are implemented and experienced by teachers and students. From a leadership perspective, this means that school principals need to consider contextual conditions when developing digital strategies. Digital leadership should therefore include not only the adoption of technology but also efforts to ensure that technological resources can be accessed and used meaningfully within the school environment.

The third cluster is characterized by terms related to performance, relationships, questionnaires, variables, samples, and Structural Equation Modeling (SEM). These keywords indicate the presence of quantitative research terminology within the literature. The relationship between *performance* and other variables suggests that researchers have examined digital leadership in relation to measurable organizational or educational outcomes. However, the presence of *questionnaire* and *SEM* should not be interpreted as evidence that most studies on digital leadership employ these methods. Rather, these terms represent methodological and analytical concepts appearing within the retrieved bibliometric network. More detailed document-level analysis would be required to determine the actual proportion of studies using questionnaires, SEM, or other quantitative methods.

The fourth cluster emphasizes the relationship among teachers, principals, school leadership, instructional leadership, and observation. The prominent position of *teacher* within this thematic structure suggests that teachers constitute an important component of digital leadership research. This relationship is understandable because the success of school-level digital transformation depends substantially on teachers' ability to integrate technology into instructional practices. School principals therefore have an important role in creating conditions that support teachers' professional learning, experimentation with digital tools, collaboration, and adaptation to technological change.

The connection between *principal* and *instructional leadership* is also important because it demonstrates that digital leadership does not replace established leadership responsibilities. Instead, digital leadership can be understood as an extension of school leadership in a context where digital technologies increasingly influence administration, communication, teaching, and learning (Lee & Suh, 2024). Principals are therefore required to combine technological awareness with instructional and organizational leadership capabilities. This perspective supports an understanding of digital leadership as a leadership practice that integrates technology with the broader goals of school improvement (Durrahman et al., 2026).

The interconnection among the four clusters further demonstrates that digital leadership is not an isolated technological issue. Digital transformation, teaching, stakeholder involvement, organizational performance, teachers, and instructional leadership are connected within the same research landscape. This finding indicates that research on school principals' digital leadership has developed toward a more comprehensive understanding of how technology interacts with people, organizational processes, and educational practices. The role of the principal is consequently positioned at the intersection of technological change and school improvement.

The findings also have implications for school leadership practice. School principals need to develop not only digital literacy but also the capacity to formulate a clear digital vision, support teachers, facilitate collaboration, manage access to digital resources, and integrate technology with instructional objectives. Digital transformation is more likely to become meaningful when technological initiatives are connected with the actual needs of teachers and students. Thus, digital leadership should be implemented as part of an organizational strategy rather than as a separate technology-oriented program.

The bibliometric mapping also points to several directions for future research. The presence of artificial intelligence and digital transformation themes indicates opportunities to investigate emerging technologies in school leadership. Meanwhile, the continued connection between teachers, principals, and instructional leadership suggests the need for further research on how principals strengthen teachers' digital competencies and create supportive organizational environments. Research can also examine differences in digital leadership implementation across schools with different levels of technological access and organizational capacity.

Compared with previous bibliometric research, the present study places greater emphasis on the intersection between digital leadership and school principals within the Indonesian educational context. The mapping of keywords provides a thematic picture of how digital leadership research is connected with teachers, instructional leadership, digital transformation, technology access, and organizational performance. This focus provides a basis for identifying the development of research themes and potential areas for further investigation within Indonesian education. Nevertheless, the findings remain dependent on the selected database, search strategy, publication period, and available metadata. Therefore, the results should be interpreted as a bibliometric representation of the retrieved literature rather than as a complete representation of every study on digital leadership in Indonesia.

Overall, the discussion confirms that digital leadership among school principals should be understood as a multidimensional phenomenon involving technology, instructional practices, teacher development, organizational performance, and educational transformation. The identified research clusters demonstrate that the field is moving toward an integrated perspective in which technological change is closely connected with human and organizational factors. Future research should therefore move beyond examining technology adoption alone and investigate how school principals can strategically use digital transformation to strengthen teaching quality, teacher capacity, organizational effectiveness, and equitable educational opportunities.

CONCLUSIONS

This study mapped the development and thematic structure of research on the digital leadership of school principals in Indonesia from 2020 to 2026. Based on 68 publications, the bibliometric analysis identified four interconnected thematic clusters: digital transformation and emerging technologies; school leadership and instructional processes; organisational performance and digital competence; and teachers, principals, and instructional leadership. The findings demonstrate that digital leadership research in Indonesia is characterised by the interaction of technological, organisational, instructional, and human dimensions. Teacher, principal, school leadership, instructional leadership, digital transformation, and performance emerged as central concepts within the bibliometric network. The temporal analysis indicates a gradual development of research themes. Earlier studies were more closely associated with pandemic-driven technology adoption and digital transformation, whereas more recent themes include artificial intelligence, digital competence, professional development, and technology integration. These findings provide a thematic overview of how research on school principals' digital leadership has developed in the

Indonesian context. However, the results should be interpreted within the limitations of the study. The dataset was retrieved exclusively from Google Scholar through Publish or Perish and was therefore dependent on the coverage and indexing characteristics of that database. In addition, the analysis was limited to publications retrieved using the selected search strategy and inclusion criteria. The 2026 data also represent only publications available at the time of data retrieval and do not constitute a complete annual publication count. Future research may extend this analysis by combining multiple bibliographic databases and conducting empirical studies examining the implementation and effects of digital leadership practices in Indonesian schools.

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AUTHOR CONTRIBUTION STATEMENT

GSP contributed to conceptualisation, methodology, data collection, data screening, bibliometric analysis, visualisation, interpretation of findings, writing original draft, and revision. ATP contributed to conceptualisation, methodology, supervision, validation, interpretation of findings, writing review and editing, and final approval of the manuscript. All authors have read and approved the final version of the manuscript and agree to be accountable for all aspects of the work.

AI DISCLOSURE STATEMENT

The authors used artificial intelligence-assisted tools to support language refinement, improve grammatical accuracy, and enhance the clarity and organisation of the manuscript. The use of artificial intelligence was limited to editorial and language assistance. The authors retained full responsibility for the conceptualisation, research design, data collection, data analysis, interpretation of findings, verification of references, and final content of the manuscript. All outputs generated with AI assistance were carefully reviewed and revised by the authors.

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