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Research Trends in Elementary School Digital Literacy: A Bibliometric Analysis

Silvia Maharani[1], Hisny Fajrussalam[2], Aliya Nauli Hidayat[3], Anggi Srifloria Zefanya Pasaribu[4], Laila Puspita[5], Nadia Haeriska[6], Neneng Sri Wulan[7], Haidir Ali[8]*

[1,2,3,4,5,6,7]Universitas Pendidikan Indonesia, Bandung, Indonesia
[2]Center of Advanced Technologies for Sustainable Development, Purwakarta, Indonesia
[8]Sekolah Indonesia Kuala Lumpur, Kuala Lumpur, Malaysia
*Correspondence: E-mail: hfajrussalam@upi.edu

ABSTRACT

Digital literacy has become an essential competency for primary school teachers in responding to the rapid digital transformation of education. However, studies that comprehensively map the development of research on primary school teachers' digital literacy remain limited. This study aims to analyze the growth of publications, scientific influence, collaboration patterns, and thematic developments in this field. Using a quantitative bibliometric approach, 313 publications indexed in the Scopus database between 2005 and 2025 were analyzed and visualized using VOSviewer and Biblioshiny. The findings indicate that research on primary school teachers' digital literacy has grown significantly and has followed three developmental phases: embryonic, growth, and acceleration, reaching its highest productivity in 2025, with 53 publications. The United States dominated scientific production and citation impact, accounting for 200 publications and 1,140 citations, highlighting the concentration of scientific influence within developed countries. Keyword co-occurrence analysis identified digital literacy as the central theme linked to teacher education, pedagogical competence, digital technologies, and professional development. Furthermore, emerging topics such as artificial intelligence and critical literacy indicate an ongoing shift from technology-oriented research toward broader pedagogical and professional concerns. These findings demonstrate that research on primary school teachers' digital literacy has evolved into a more interdisciplinary field, yet disparities in global scientific influence persist.

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1. INTRODUCTION

The rapid development of information and communication technology has brought significant changes to education, including at the primary school level. Teachers no longer merely act as conveyors of information but also as learning facilitators capable of utilising technology effectively. In this context, digital literacy has become a vital competence for primary school teachers, enabling them to select, use, and evaluate digital learning resources critically, creatively, and responsibly. Digital literacy is not only about the technical skills of using digital devices but also encompasses critical thinking, media ethics, and an understanding of the social impact of technology on the learning process. This is in line with the findings of Tinmaz et al. (2022), who state that digital literacy is a multidimensional concept encompassing technological, cognitive, and social skills for the effective and responsible use of digital media.

In practice, the digital literacy skills of primary school teachers in the field still vary considerably. Some teachers have been able to utilise digital technology to design interactive lessons, access online learning resources, and use digital media creatively. However, a significant number of teachers still face challenges in integrating technology into their teaching. This may be due to limited digital skills, inadequate facilities, or a lack of ongoing training support. This situation has prompted increased attention from researchers towards the issue of primary school teachers' digital literacy. This is reflected in the growing number of scientific publications in recent years. To better understand the development of this research, a bibliometric analysis is required. It can help map publication patterns, research topic trends, author collaboration networks, and the evolving focus of research. Through this approach, the research can provide a comprehensive overview of the dynamics and trends in research on primary school teachers' digital literacy in the digital age. Using bibliometric analysis, the contents of reference lists and articles published in scientific journals and other journals can be examined.

Research on publications using bibliometric analysis has been widely conducted across various fields of science, including bibliometrics in medicine (Kokol P. et al., 2021), bibliometrics in higher education (López-Chila, R. et al., 2023), bibliometrics in tourism and hospitality (Ulker et al., 2023), bibliometrics in green hydrogen (Raman, R. et al., 2022), bibliometrics in nanomaterials for the remediation of environmental pollutants (Asghar, N. et al., 2024), bibliometrics in social sciences (Prieto-Gutierrez, J. J. et al., 2023), bibliometrics in global science and national comparisons (Marginson, S., 2022), bibliometrics in climate change and sustainable development (Baidya & Saha, 2024), bibliometrics on artificial intelligence and multimodal data fusion for smart healthcare (Chen, X. et al., 2024), bibliometrics of Artificial Intelligence Marketing (AIM) (Anayat, S. et al., 2024).

Although research on digital literacy continues to advance and has been widely studied across various educational contexts, most studies still focus on students, higher education, or digital competencies in general. On the other hand, elementary school teachers have distinct characteristics, pedagogical needs, and technology implementation challenges compared with teachers at other levels of education. Therefore, a comprehensive mapping of research on elementary school teachers' digital literacy is crucial for understanding publication trends, intellectual structures, collaboration patterns, and the direction of research in this field. Understanding the intellectual structure and thematic evolution of this field is important for identifying research gaps, guiding future investigations, and supporting evidence-based policies to strengthen teachers' digital competencies in primary education.

However, no research has yet been conducted on the analysis of publications regarding primary school teachers' digital literacy using bibliometric computation, particularly regarding publications on primary school teachers' digital literacy over the last 20 years, namely between 2005 and 2025. This study contributes by comprehensively mapping the development of digital literacy research on elementary school teachers during 2005–2025, based on Scopus data. The analysis not only examines publication trends but also includes source productivity, countries, collaboration networks, intellectual structures, and the development of research themes using Biblioshiny and VOSviewer. Therefore, this study was conducted to analyse Scopus-indexed articles using bibliometric computation with the assistance of the VOSviewer and Biblioshiny software. This study was conducted in the hope that it may serve as a reference for other researchers to identify research themes, particularly those related to digital literacy.

2. METHODS

This study uses a quantitative bibliometric approach to analyze research on elementary school teachers' digital literacy published in Scopus. The data set includes 313 digital literacy articles from Scopus. Scopus was chosen for its wide range of reputable, peer-reviewed scientific articles, ensuring quality and relevance to digital literacy research. Selecting the data source was crucial to ensure the quality and accuracy of the analysis. Sweileh (2018) and Yas et al. (2020) note that Scopus, developed by Elsevier since 2004, contains over 77.8 million documents dating from 1969. It covers thousands of peer-reviewed journals, trade publications, book series, and global scientific activities. This broad scope allows Scopus to represent global research trends. Scopus also features bibliometric tools, such as multi-criteria filters, allowing users to filter data by journal, document type, year, author, affiliation, and citation count.

The research was conducted in several stages, namely:

1. Codification of research data using articles from the Scopus database;
2. Data processing using Microsoft Excel;
3. Computational mapping analysis of bibliometric publication data using the VOSviewer and RStudio Biblioshiny applications (Aria & Cuccurullo, 2017, Aria & Cuccurullo, 2026);
4. Analysis of the results of the computational mapping analysis (al Husaeni & Nandiyanto, 2022).

A search of the Scopus database was conducted to filter publications using the search string TITLE-ABS-KEY ("digital literacy" AND ("elementary teacher" OR "primary teacher"). The articles used were published between 2005 and 2025. Data obtained from the Scopus database were exported as CSV and analyzed using Biblioshiny and VOSviewer. The analysis was conducted to identify publication trends, source productivity, country productivity, network collaboration, keyword co-occurrence, and the intellectual structure of research on elementary school teachers' digital literacy. All data were retrieved in February 2026. The articles collected that met the criteria for this research analysis were then exported into three file types: Research Information System (.ris), Comma Separated Values (*.csv), and Bibliography and TeX (.bib). In addition, VOSviewer was used to visualise and analyse the data with bibliometric maps, producing three types of publication mapping: network visualisation, density visualisation, and overlay visualisation based on co-citation networks among existing items.

3. RESULTS AND DISCUSSION

This section presents the detailed results of the bibliometric analysis. The presentation begins by describing the state of digital literacy among elementary school teachers, followed by a keyword analysis to identify the primary research focus related to elementary school teachers' digital literacy.

Table 3. Type of retrieved documents

Type of document	Frequency	Propotision(%)
Conference paper	53	17
Article	209	66.7
Review	6	2
Book Chapter	45	14.3
Total	313	100.0

Based on the data collection and processing results, the types of documents obtained in this study fall into several categories. Articles were the most dominant document type, comprising 209 publications. This was followed by conference papers (53), book chapters (45), and reviews (6). Overall, the total number of documents analyzed in this study was 313 publications.

Bibliometric analysis in this study was used as a quantitative approach to examine a large volume of scientific data in the form of research publications. This method aims to provide an overview of the main areas of research and to assist in predicting the future direction of a topic's development (Zupic, I., & Čater, T., 2015). Nevertheless, the value of bibliometric analysis lies not only in the results of data analysis but also in its visualisation capabilities, which facilitate the understanding of patterns and relationships between the generated data (Van Eck, N. J., & Waltman, L., 2010).

In this study, the VOSviewer software was used as an analytical tool. VOSviewer is software developed to map and visualise scientific data networks, such as relationships between authors, keywords, and publications (Meng, L., Liu, Y., & Zhou, X., 2019). Through this tool, researchers can identify connections between research elements, such as co-authorship, co-occurrence, citations, and co-citation.

Another advantage of VOSviewer is its ability to process data from various scientific databases, such as Scopus and Web of Science, as well as reference management files such as RIS and EndNote (Van Eck, N. J., & Waltman, L., 2010). This enables analysis to be conducted more comprehensively and accurately.

1.1 Current Status of Digital Literacy Among Primary School Teachers

1.1.1 Annual Publication Trends

An analysis of annual publication trends was conducted to identify changes in the number of publications related to elementary school teachers' digital literacy each year. The results of this analysis show the growth and development of research in this field over time. The annual publication trends are shown in Figure 1 below.

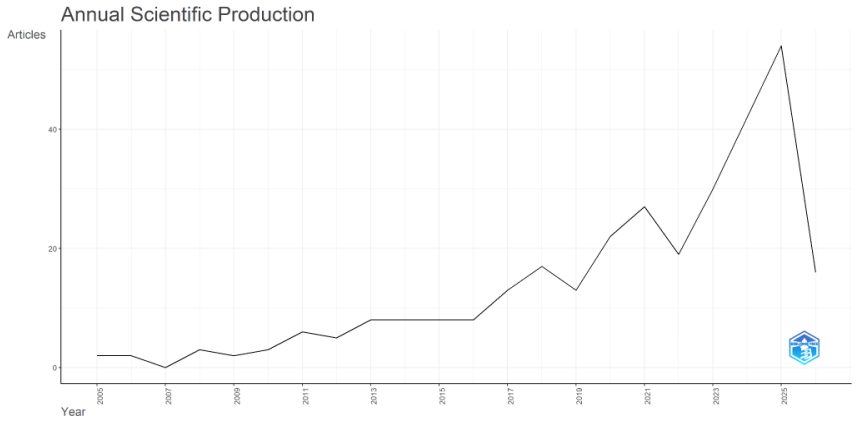

Figure 1. Annual Scientific Production Chart

Based on Fig 1, the Annual Scientific Production graph shows that research on primary school teachers' digital literacy in the digital age has increased year on year. In the early period, from around 2005 to 2010, the number of publications remained relatively low and fluctuated. From 2011 to 2016, the number of studies began to increase more steadily, though not yet significantly.

Since 2017, there has been a fairly sharp increase in the number of publications. This indicates growing attention among researchers to the importance of digital literacy for primary school teachers, in line with the rapid development of information and communication technology in education (Ng, 2012). Furthermore, teachers are required not only to possess technical skills but also pedagogical competence and critical thinking skills to utilise digital technology effectively in teaching (Falloon, 2020).

The peak in publications was observed around 2025, reflecting the high level of interest and urgency of research on this topic in the current digital era. This trend aligns with the growing need for educators to adapt to digital transformation and integrate technology into the learning process (Falloon, 2020). However, in the most recent year, a decline in the number of publications is observed, which is likely due to data limitations or an incomplete publication process for that year.

Table 2. Annual Scientific Production

Year	Articles
2005	2
2006	2
2007	0
2008	3
2009	2
2010	3
2011	6
2012	5
2013	8
2014	8
2015	8
2016	8
2017	13
2018	18
2019	13

Year	Articles
2020	22
2021	27
2022	20
2023	30
2024	43
2025	53
2026	19
Total	**313**
Average	**14,09**

The data in Table 2 present the detailed annual number of publications in numerical form, providing a clearer picture of the dynamics of publication development over time. Based on this data, it is clear that the number of publications fluctuated in the initial period, then increased consistently in subsequent years, although there were still some declines in certain periods. If classified, this development trend can be divided into three phases. First, the embryonic phase (2005–2012) was characterized by a relatively low and unstable number of publications, with figures ranging from 0 to 6 articles per year. Second, the growth phase (2013–2017) showed a more consistent increase, although still at a moderate level, with the number of publications ranging from 8 to 13 articles. Third, the acceleration phase (2018–2025) was characterized by a significant, more rapid increase, as evidenced by a surge in publications, peaking in 2025 at 53 articles. However, in 2026, there was a fairly sharp decline, which could be influenced by data limitations or the publication process not being fully completed in that year.

3.1.2 Distribution of Organizations

The distribution of organizations analysis aims to identify the most productive organizations in producing publications related to elementary school teacher digital literacy. This analysis provides an overview of the distribution of organizational productivity based on the number of publications produced, allowing for the identification of institutions that play a significant role in developing research in this field. The results of the distribution of organizations analysis are presented in Figure 2. and Table 3. below.

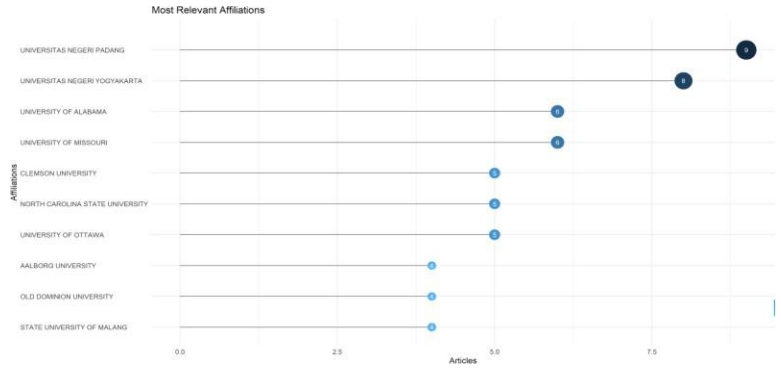

Figure 2. 10 institutions by number of publications.

Table 3. 10 institutions by number of publications.

Affiliation	Articles
Universitas Negeri Padang	9
Universitas Negeri Yogyakarta	8
University of Albama	6
Clemson University	5
North Carolina State University	5
University of Ottawa	5
Aalborg University	4
Old Dominion University	4
State University of Malang	4
Total	56
Average	5,6

Based on the analysis of author affiliations, it was found that several institutions made the most significant contributions to the publications in this study. The data in Figure 2 and Table 3 show that 10 institutions have the highest number of publications. Padang State University ranks first as the institution with the highest number of publications, namely 9 articles, followed by Yogyakarta State University with 8 articles. This indicates that these two institutions play a dominant role in producing research in this field, particularly at the national level. Furthermore, the contribution from international institutions is also quite significant. The University of Alabama and the University of Missouri each produced 6 articles. Furthermore, Clemson University, North Carolina State University, and the University of Ottawa each contributed 5 articles. Meanwhile, Aalborg University and Old Dominion University each contributed 4 articles.

Overall, this distribution indicates that research on the topic under study is not dominated solely by domestic institutions but also includes contributions from various international institutions. This dominance is influenced by growing attention to strengthening elementary school teachers' digital literacy as a necessary competency to meet technological developments and the demands of 21st-century learning. Teacher digital literacy is a crucial factor in supporting the effectiveness of technology-based learning, thus encouraging more institutions to conduct research in this area (Teane, 2024). Furthermore, the acceleration of digital transformation in the education sector has increased the need to develop teachers' digital competencies, which in turn has led to higher publication productivity and greater research collaboration between institutions. With a total of 56 publications and an average of 5.6 articles per affiliation, this distribution reflects that the development of digital learning studies is proceeding fairly evenly, with contributions coming from various national and international institutions.

3.1.3 Distribution of Published Journals and Conference Papers

The analysis of the distribution of published journals and conference papers aims to identify the distribution of research publications on elementary school teachers' digital literacy by publication type. The results of this analysis show the proportion of articles published in journals and conference proceedings, thereby providing an overview of the

characteristics of publications in this field. The results of the analysis are shown in Figure 3 below.

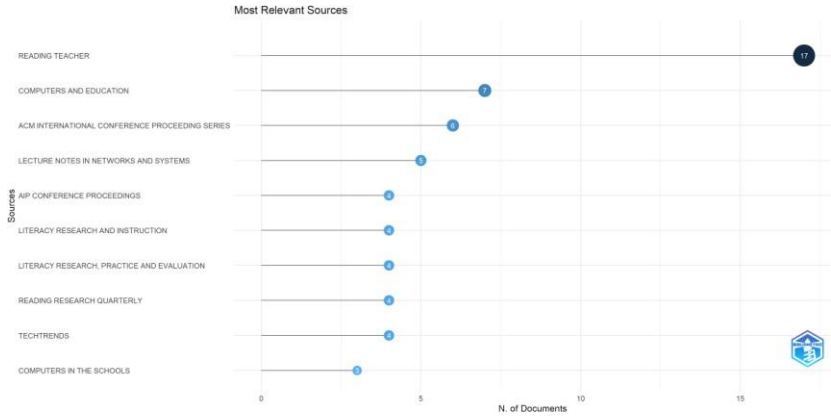

Figure 3. 10 journals by number of publications

Based on the results of the Most Relevant Sources analysis (Figure 3), it is known that publications that discuss research topics are spread across various scientific journals and conference proceedings that focus on the fields of literacy, education, educational technology, and digital learning. Analysis of publication sources is one of the important indicators in bibliometric studies because it can show the most active and influential scientific media in disseminating the development of a research field (Zupic & Čater, 2015). By identifying the dominant source of publication, researchers can understand the direction of scientific development, the academic community involved, and the tendency of research focus to develop within a study theme (Donthu et al., 2021).

The results of the analysis show that Reading Teacher is the most productive source of publications with a total of 17 articles. This number far exceeds other sources, thus showing the central position of the journal in the development of research related to the topic studied. As a journal that focuses on reading literacy and language learning practices, the dominance of Reading Teacher indicates that research in this field is mostly directed at developing students' literacy skills, reading learning strategies, and pedagogical innovations that support the improvement of literacy competence. These findings are in line with the view that literacy is the main foundation in the learning process and is an important focus in various contemporary educational research.

Furthermore, the ACM International Conference Proceeding Series (6 articles) and Lecture Notes in Networks and Systems (5 articles) occupy the next position. The presence of these two sources shows that research is not only developing in the realm of education, but also involves computer science disciplines, information systems, and digital technology. This condition reflects the multidisciplinary character of research that connects pedagogical aspects with technological innovation, as stated by Aria and Cuccurullo (2017).

Other publication sources, such as AIP Conference Proceedings, Literacy Research and Instruction, Literacy Research, Practice and Evaluation, Reading Research Quarterly, and TechTrends each contributed 4 articles, while Computers in the Schools had 3 articles. Overall, the distribution of publication sources shows that primary school teachers' digital literacy research develops through a combination of literacy, education, and technology perspectives. These findings confirm that the development of teachers' digital competencies is increasingly an important focus in supporting effective learning in the digital era.

Table 4. Top 10 journals by number of publications

Sources	Articles
Reading Teacher	17
Computers And Education	7
ACM International Conference Proceeding Series	6
Lecture Notes in Networks and Systems	5
AIP Conference Proceedings	4
Literacy Research and Instruction	4
Literacy Research, Practice And Evaluation	4
Reading Research Quarterly	4
Techtrends	4
Computers in The Schools	3
Total	**58**

Table 4 on publication sources shows that the distribution of articles on digital learning is concentrated in several major journals and conference proceedings, with varying contributions. The Reading Teacher ranks highest with 17 articles, indicating that issues of digital learning are frequently examined within the context of literacy and primary education. The next position is held by Computers and Education with 7 articles, indicating the important role of educational technology-based journals in developing this field of study. Other sources, such as the ACM International Conference Proceedings Series (6 articles) and Lecture Notes in Networks and Systems (5 articles), show that contributions also come from conference-based scientific forums focusing on technological and systems aspects.

In addition, several journals such as AIP Conference Proceedings, Literacy Research and Instruction, Literacy Research, Practice and Evaluation, Reading Research Quarterly, and TechTrends each contributed four articles, whilst Computers in the Schools produced three articles. This pattern indicates that publication contributions do not originate from a single type of source but are distributed across scientific journals and conference proceedings with diverse focuses, ranging from literacy to educational technology. With a total of 58 publications and an average of 5.8 articles per source, this distribution reflects that digital learning is an interdisciplinary topic that is published through various academic channels. This cross-disciplinary distribution, spanning the boundaries of technology and pedagogy, confirms that digital learning studies are interdisciplinary in nature, where the evolution of knowledge is no longer confined to a single pure discipline (Bond et al., 2020).

3.1.4 Distribution of Documents and Citations by Country

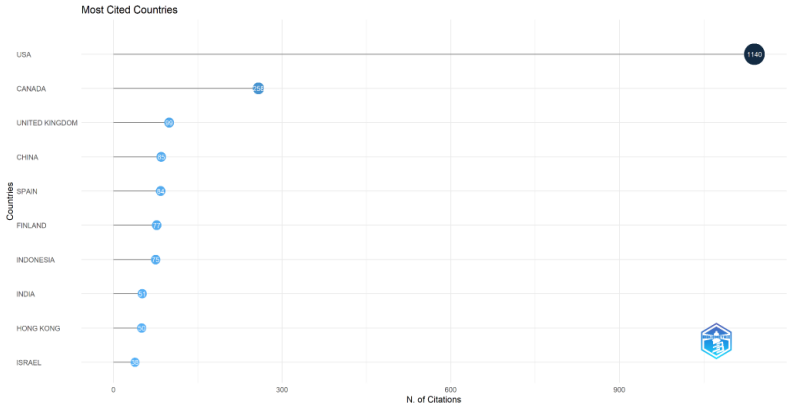

Figure 4. Countries by number of publications

Based on the 'Most Cited Countries' chart, the distribution of research citations shows an uneven pattern and tends to be concentrated in certain countries. This disparity indicates differences in research capacity, scientific productivity, and the visibility of publications between countries within the topics under study. Consequently, the number of citations may reflect a country's level of influence on the development of scientific literature in that field.

The United States ranks first with the highest number of citations, namely 1,140 citations. According to this study, the United States leads in both the number of publications (1,547 articles) and citation impact (5,422 citations) within the topic of digital media literacy, followed by Spain, Indonesia, and Australia (Sakinah, R. A. N., et al., 2024). This dominance indicates that the publications produced have a high level of relevance and connection to other research and are therefore frequently cited in various studies. The high citation figures also reflect the strength of the research ecosystem, international collaboration, and access to reputable journals within that country.

In second place, Canada received 258 citations. Although this figure remains well below that of the United States, this achievement nonetheless demonstrates a significant contribution to the advancement of knowledge in the field under study. This suggests that publications from Canada are of a sufficiently high standard and are capable of attracting the attention of the global academic community.

Next, the United Kingdom ranked third with 99 citations, followed by China (85 citations) and Spain (84 citations). These three countries show relatively similar citation counts, suggesting they make a balanced contribution. This situation reflects a more even distribution of scientific influence among the middle-ranking countries on the list.

In the next group, Finland (77 citations) and Indonesia (75 citations) show fairly competitive contributions. The presence of these two countries in the top ten indicates that the publications they produce are beginning to gain recognition internationally, although their influence remains below that of countries with higher citation counts.

Meanwhile, India (51 citations), Hong Kong (50 citations), and Israel (38 citations) have relatively low citation counts. This suggests that the scientific contributions from these countries remain limited within the context of the research topics analysed. Nevertheless, their participation still reflects engagement within the global research network.

Overall, these findings confirm that the distribution of research citations is uneven and dominated by certain countries, particularly the United States. Nevertheless, the involvement of various countries in the list demonstrates that this study has an international scope. According to this study, developed countries such as the United States and Germany dominate scientific influence in research on the digital transformation of education, although researchers from developing countries such as Indonesia and Thailand are among the most productive in publishing (Nguyen et al., 2024). Therefore, improving the quality of publications, strengthening research collaboration, and expanding access to reputable journals are key factors in enhancing a country's visibility and scientific impact.

Table 5. The 10 Countries with the Most Publication

TC	Country	Average Article Citations
1140	USA	16,10
258	Canada	21,50
99	United Kingdom	19,80
85	China	10,60

TC	Country	Average Article Citations
84	Spain	16,80
77	Finland	77,00
75	Indonesia	2,90
51	India	12,80
50	Hong Kong	25,00
38	Israel	12,70

Table 5 shows the distribution of the citation impact of digital learning publications by country, measured by total citations (TC) and average citations per article. The United States ranks first, with a very high total of citations (1,140) and an average of 16.10 citations per article, indicating dominance in both productivity and academic influence. Nevertheless, several other countries exhibit higher average citations, such as Finland with an average of 77.00 and Hong Kong with 25.00, indicating that publications from these countries have a strong impact despite their total citation counts not being as high as those of the United States. Research (Wen, X., & Li, Y., 2024) analysed 479 articles from the Scopus database (2020–2023) and examined citation distribution patterns, the most productive institutions, and the characteristics of journals and countries contributing to digital literacy research, including differences in total citation counts and average impact per article across countries.

Countries such as Canada (21.50), the United Kingdom (19.80) and Spain (16.80) demonstrate a balance between the number of citations and the quality of the publications' impact. Meanwhile, China (10.60), India (12.80), and Israel (12.70) are at an intermediate level in average citations. Indonesia has a total of 75 citations with an average of 2.90, indicating that the contribution of its publications is evident, yet their impact remains relatively lower compared to other countries. Overall, this data reveals variations between the number of citations and the average citation count, reflecting differences in the influence and visibility of publications across countries in the field of digital learning.

3.1.5 Distribution of Countries

One indicator for assessing the development of a research field is the distribution of publications by country. Therefore, a Country Scientific Production analysis was conducted to identify the countries contributing to research in digital learning. The results of the publication distribution visualisation are shown in Fig 5, whilst the ten countries with the highest number of publications are presented in Table 6.

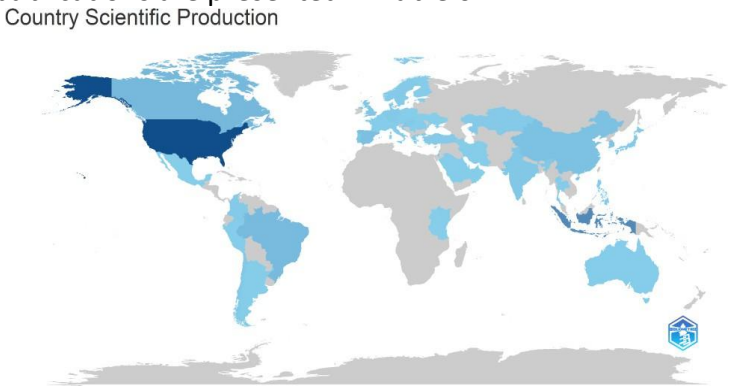

Figure 5. Country Scientific production

Table 6. Top 10 Countries by Scientific Production

Country	Freq
USA	200
Indonesia	102
Canada	31
Brazil	28
Spain	21
China	18
South Korea	15
UK	13
Portugal	11
Chile	10
Total	449
Average	44,9

Based on the results of Biblioshiny's analysis presented in Fig 5 and Table 6, it is clear that scientific production on digital learning has grown globally and involves contributions from various countries. However, the distribution of these publications still shows a fairly high concentration in certain countries. The United States ranks first with 200 publications, followed by Indonesia with 102 publications. Furthermore, Canada (31 publications), Brazil (28 publications), Spain (21 publications), China (18 publications), South Korea (15 publications), the United Kingdom (13 publications), Portugal (11 publications), and Chile (10 publications) also contribute to the development of digital learning research. The distribution of publications on the map indicates that the study of digital learning has attracted researchers' attention across the world. This finding is supported by Vičič Krabonja et al. (2024), who stated that digital transformation in education encourages the formation of increasingly broad and collaborative research networks between countries.

The high number of publications produced by the United States underscores the country's position as a leading hub for digital learning research. This dominance can be attributed to strong research capacity, funding support, and high levels of technology adoption in education. This finding aligns with Wang et al. (2024), who revealed that developed countries tend to be the primary drivers of educational technology research due to their mature research ecosystems and high levels of technology adoption. Additionally, Maral (2024) emphasizes that a country's scientific publication productivity is significantly influenced by the strength of its higher education institutions, research funding support, and a sustainable academic culture. These results also align with Ozyurt and Ayaz (2022), who demonstrated that advancements in educational technology research tend to be concentrated in countries with robust research infrastructure. On the other hand, Indonesia ranks second with a notably high number of publications compared to other nations, indicating that research on digital learning is also actively developing in developing countries and gaining increasing attention within the academic community. The high number of publications produced by the United States demonstrates its position as a hub for digital learning research and development.

This dominance can be attributed to its strong research capacity, funding support, and high level of technology utilization in education. This finding aligns with Wang et al. (2024), who stated that developed countries tend to be the primary drivers of educational technology

research due to their mature research ecosystems and high levels of technology adoption. Furthermore, Maral (2024) emphasized that a country's scientific publication productivity is strongly influenced by the strength of its higher education institutions, research funding support, and a sustainable academic culture. These findings also align with Ozyurt and Ayaz (2022), who showed that educational technology research development tends to be concentrated in countries with strong research infrastructure. On the other hand, Indonesia ranks second with a relatively high number of publications compared to other countries, indicating that studies on digital learning are also actively developing in developing countries and gaining increasing attention within the academic community.

3.2 Keywords Analysis of Research Hotspots

The development of research on elementary school teachers' digital literacy in the digital era demonstrates the interconnectedness of various research themes that continue to evolve with advances in educational technology. To examine the relationships between topics and identify the most frequently discussed research foci, this study employed keyword co-occurrence analysis with VOSviewer software. This analysis maps the relationships between keywords, thus providing an overview of the direction and trends of research in the field of digital literacy.

A keyword analysis was conducted to identify the primary research topics in studies on elementary school teachers' digital literacy. Through co-occurrence analysis, it is possible to determine the frequency of keyword appearances and the relationships among keywords that frequently co-occur in scientific publications. The keyword co-occurrence network for research on elementary school teachers' digital literacy is presented in Figure 6.

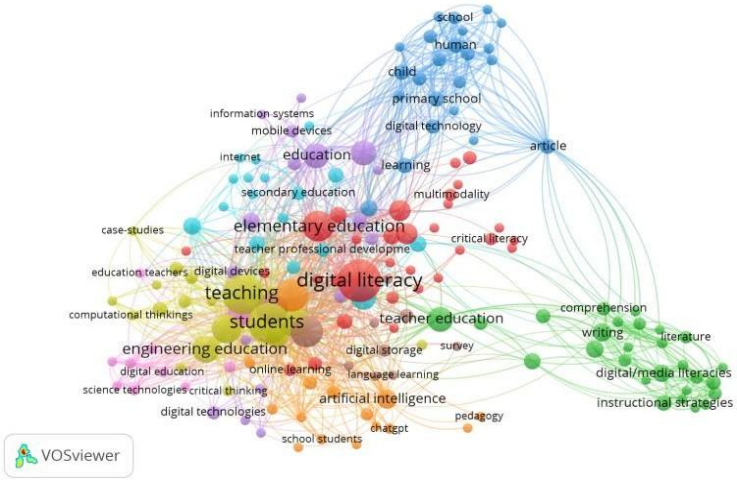

Figure 6. Co-occurrence network of publication keywords related to elementary school teachers' digital literacy.

The keyword network visualization resulting from the VOSviewer analysis is shown in Fig 6. In the visualization map, the node size indicates the keyword's occurrence rate in various scientific publications. The larger the node, the more frequently the keyword is used in research. Meanwhile, connecting lines between nodes indicate relationships between research topics, while different colors depict different groups or clusters of research themes. Keyword co-occurrence analysis is used to identify key themes and emerging conceptual relationships within a research field (Donthu et al., 2021).

Based on the analysis, the keyword "digital literacy" appears to be the main hub in the research network, with the largest node size among the keywords. This indicates that digital literacy is a primary focus in studies on elementary school education in the digital era. This

keyword is also closely linked to several other themes, including "students," "teaching," "teacher education," "elementary education," and "education." This relationship indicates that research on digital literacy is largely linked to the learning process, teacher competency, and educational development in elementary schools. This finding aligns with research by Ng et al. (2024), which asserts that digital literacy has become an essential competency for teachers in designing, implementing, and evaluating learning in an increasingly digitalized educational environment.

Furthermore, the network visualization demonstrates the interrelationships among digital literacy and other themes, including artificial intelligence, digital technologies, critical literacy, instructional strategies, professional development, and writing. The emergence of these keywords indicates that research in this field is not solely focused on the utilization of digital technology but is also beginning to shift toward developing innovative learning strategies, enhancing teachers' professional competence, and strengthening students' literacy skills to face the challenges of 21st-century learning. This finding aligns with research by Holmes et al. (2022), which states that the development of artificial intelligence in education is driving the emergence of new learning approaches that require continuous improvement in the digital competence of teachers and students. The emergence of keywords such as artificial intelligence, professional development, and digital technology indicates a trend toward more complex research issues. These findings suggest that research on elementary school teachers' digital literacy is no longer solely focused on basic technological mastery but is also beginning to address teacher preparedness for new technological developments and the transformation of digital education. The emergence of artificial intelligence and critical literacy also reflects growing concerns about the ethical use of technology, the evaluation of information, and teachers' readiness to integrate emerging digital tools into classroom practice. These themes are likely to become important research directions in the coming years.

The diversity of clusters seen in the visualization also indicates that research on elementary school teachers' digital literacy is developing in various interrelated areas. This indicates that digital literacy has become a crucial element in educational transformation in the digital era, particularly in supporting learning innovation, utilizing educational technology, and improving the quality of elementary school teachers' competencies. These findings are supported by Falloon (2022), who emphasized that digital literacy is no longer viewed solely as a technical skill but as a multidimensional competency that plays a crucial role in supporting effective learning practices relevant to the needs of the 21st century.

3.3 Co-authorship Analysis on AR and VR Research

Figure 7. Co-authorship network between countries in publications related to primary school teachers' digital literacy.

Figure 7. shows the inter-country co-authorship network for publications on primary school teachers' digital literacy. This visualization, generated using VOSviewer, demonstrates

patterns of international collaboration, the level of country contribution, and the intensity of research relationships among countries involved in the study of primary school teachers' digital literacy. In the map, node sizes represent a country's contribution level based on the number of publications, while connecting lines indicate collaborative relationships between countries. The larger the node size and the stronger the interconnectedness among countries, the greater the role of that country in the development of research on primary school teachers' digital literacy. According to van Eck and Waltman (2020), network visualization in VOSviewer enables clearer identification of collaborative relationships and the structure of interrelationships among research actors.

Based on this visualization, the United States appears to be the most dominant country in the collaborative network. This is evident from its larger node size compared to other countries, indicating a high contribution to publications and its role as a research network hub. Its position in the network indicates its role as a hub connecting several countries, including Indonesia, Germany, and Spain. According to Tomczyk (2024), teachers' digital competence has become a global issue, prompting the involvement of many countries in the development of technology-based education. Thus, the United States' dominance in this network demonstrates its strategic role in guiding international research on teacher digital literacy.

Indonesia has emerged as one of the countries with direct collaborative relationships with the United States. Although Indonesia's node size is relatively small, its presence in the network indicates that research on elementary school teachers' digital literacy in Indonesia is beginning to be integrated into global academic discourse. This relationship is reflected in co-authored publications, demonstrating the involvement of Indonesian researchers in international research networks. This finding aligns with research by Khoerunnisa and Fathurochman (2025), which shows that research on teachers' digital skills continues to advance through cross-national collaboration. Therefore, Indonesia's position in this network indicates an increasing contribution and visibility of national research on teachers' digital literacy at the global level.

Furthermore, European countries such as Spain, Germany, Portugal, and Croatia have formed interconnected collaborative networks. Spain and Germany appear to occupy relatively strategic positions, serving as links between other European countries and the United States. On the other hand, Brazil maintains collaborative relationships with Portugal and Spain, reflecting a pattern of regional cooperation in research on teachers' digital literacy. According to Kiryakova and Kozhuharova (2024), the growing attention to teachers' digital competence across countries underscores the importance of developing educators' digital capabilities to meet the demands of 21st-century learning. These findings suggest that research on teacher digital literacy is driven not only by dominant countries but also by increasingly active regional collaborative networks.

Overall, this co-authorship map shows that research on elementary school teachers' digital literacy is still dominated by countries with strong research capacity and academic networks. The United States serves as a major hub for global collaboration, while Indonesia, Spain, Germany, Portugal, and Brazil help expand research networks through various forms of academic collaboration. This dominance may be attributed to stronger research funding systems, advanced digital infrastructure, and long-term investment in educational technology research. As a result, developed countries continue to play a central role in shaping global research agendas related to teachers' digital literacy. These results also demonstrate that cross-border collaboration is a crucial factor in accelerating knowledge exchange and the development of digital education innovations. Consistent with the findings of Gökdaş et al.

(2024), the development of research on teachers' digital competencies is increasingly supported by the growth of international collaborative networks post-pandemic. Therefore, cross-border collaboration is crucial to strengthening the quality and sustainability of research on elementary school teachers' digital literacy in the future.

3.4 Co Citation Analysis

A co-citation analysis was conducted to identify articles with high scientific impact in the field of study. A high number of citations indicates that these articles are frequently cited by other researchers and contribute to the development of theoretical foundations and the direction of research. The five articles with the highest number of citations are listed in Table 7.

Table 7. Top 5 papers citations

Title	Journal	Authors	Years	Citation
Effects of text messaging using digital Pinyin input on literacy skills of elementary school Chinese immersion learners	Language Teaching Research	Harvey R.E.; Brooks P.J.	2025	173
Using a multicomponent multimedia shared story intervention with an iPad to teach content picture vocabulary to students with developmental disabilities	Education and Treatment of Children	Rivera C.J.; Hudson M.E.; Weiss S.L.; Zambone A.	2017	142
The digital economy: A case study of designing for classrooms	ACM International Conference Proceeding Series	Cramer M.; Hayes G.R.	2013	89
Preinanku: A Virtual Reality Game as an Innovative Media for Javanese Language Learning	Proceedings of ICITDA 2025 - 10th International Conference on Information Technology and Digital Application	Cahya J.A.; Hartono S.	2025	82
Digital storytelling in teacher professional development	Proceedings of the European Conference on e-Learning, ECEL	Henningsen B.; Orngreen R.	2018	81

Based on Table 7, the article "Effects of Text Messaging Using Digital Pinyin Input on Literacy Skills of Elementary School Chinese Immersion Learners" by Harvey and Brooks (2025) has the highest number of citations, with 173. This high number of citations indicates that the study has made a significant contribution to explaining the relationship between digital technology use and the development of elementary school students' literacy skills. This

study is an important reference because it discusses how digital media can be used to improve literacy skills in the context of language learning.

The second publication with a high number of citations is an article entitled "Using a multicomponent multimedia shared story intervention with an iPad to teach content picture vocabulary to students with developmental disabilities" by Rivera et al. (2017), which discusses the use of iPad-based multimedia to help students with developmental disabilities learn visual vocabulary. This article received 142 citations, indicating that interactive multimedia technology is an important focus in the development of inclusive digital learning. The high number of citations in this study also shows that the use of digital devices not only supports general learning but also has great potential in special education.

Furthermore, the article titled "The digital economy: A case study of designing for classrooms" by Cramer and Hayes (2013) received 89 citations. This study highlights the importance of technology design in the classroom environment. The presence of this article in the list of most cited publications shows that technology integration in learning requires design planning that suits the needs of teachers and students. Furthermore, the article titled "The digital economy: A case study of designing for classrooms" by Cramer and Hayes (2013) received 89 citations. This study highlights the importance of technology design in the classroom environment. The presence of this article in the list of the most-cited publications shows that technology integration in learning requires design planning that meets the needs of teachers and students.

Next up is a study on virtual reality in Javanese language learning, titled "Preinanku: A Virtual Reality Game as an Innovative Media for Javanese Language Learning" by Cahya and Hartono (2025), with 82 citations. These findings indicate that recent research is beginning to shift toward the use of immersive technologies, such as virtual reality, as innovative learning media. This indicates a shift in research trends from simply using basic digital media to more interactive and contextual learning technologies.

Meanwhile, Henningsen and Orngreen's (2018) article, "Digital Storytelling in Teacher Professional Development," received 81 citations. This study confirms that teacher professional development through a digital storytelling approach is a crucial strategy for improving educators' digital competence. The presence of this research in the co-citation network demonstrates that teachers' digital literacy is not only related to technical skills but also to pedagogical skills and creativity in delivering learning.

Overall, the co-citation analysis table shows that research on elementary school teachers' digital literacy is advancing in various directions, ranging from developing students' literacy skills, using interactive multimedia, and digital learning design to utilizing virtual reality and teacher professional development. The high number of citations in these publications indicates that these works have a significant influence and serve as a primary foundation for the development of digital literacy research in elementary education.

3.4.1 Reference Co Citation Analysis

Reference co-citation analysis was used to map the intellectual relationships among references that form the basis for research on digital literacy among elementary school teachers. The resulting co-citation network provides an overview of groups of thematically related references that are frequently cited together by researchers. The results of the reference co-citation analysis are shown in Figure 8.

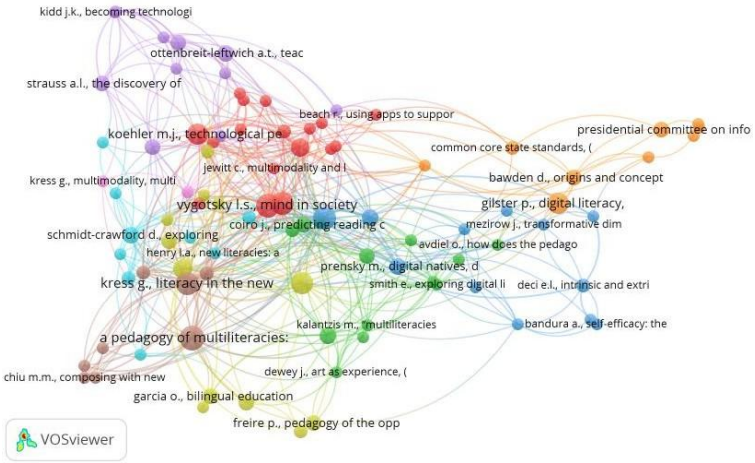

Figure 8. Co-citation network of references to publications related to digital literacy of elementary school teachers

Figure 8. is a Reference Co-citation Network Map generated with VOSviewer to visualize the relationships among frequently cited references in digital learning research. The node size indicates the strength of a reference's co-citation, while the connecting lines (edges) indicate the intensity of the relationships between references. Based on this visualization, Vygotsky's work Mind in Society appears to be the most dominant node, indicating that sociocultural constructivism is one of the main theoretical foundations in digital learning research. In addition, works such as Koehler (TPACK), Kress (Literacy in the New Media Age), Prensky (Digital Natives), and A Pedagogy of Multiliteracies also have relatively large node sizes. These findings indicate that digital learning studies evolve through the integration of multiple perspectives, including educational technology, digital literacy, multimodality, and pedagogy, as explained by Makda (2025), who notes that digital education research is multidisciplinary and encompasses interrelated conceptual approaches. Thus, the references that occupy central positions in the co-citation network can be considered the intellectual foundation that shapes the direction of development in digital learning research.

Structurally, the co-citation network is divided into several clusters representing specific groups of thought. The red cluster focuses on the integration of technology and pedagogy; the yellow-orange cluster relates to digital literacy; the green cluster addresses digital natives and new literacies; the blue cluster highlights the psychological aspects of learning; and the purple and dark brown-green clusters relate to sociocultural theory and critical pedagogy. These groupings demonstrate the complex and interconnected intellectual structure of digital learning research. According to Santoveña-Casal and López (2024), cluster patterns in co-citation analysis reflect the body of knowledge that underpins the development of a research field. Thus, this visualization demonstrates that digital learning is evolving as a field of study supported by diverse, complementary theories and approaches.

Analytically, the presence of Freire and Dewey in this network is quite significant because it shows that the discourse of digital learning is not merely technical-instrumentalist but also rooted in emancipatory traditions and experiences as a knowledge base. Furthermore, several nodes function as bridges between clusters, such as Kress, who connects multimodality with new literacies, and Koehler, who bridges the TPACK framework with pedagogical practices. The existence of these connecting nodes confirms a dynamic intellectual structure in which scientific thinking develops through cross-disciplinary integration rather than being isolated within rigid theoretical boundaries (Van Eck &

Waltman, 2014). This phenomenon indicates a strong interdisciplinarity in the field of digital learning.

Critically, it is worth noting that this network is dominated by Western and Anglo-Saxon literature. The lack of references from the Global South, including Southeast Asia, indicates a geographic bias in the analyzed corpus. This aligns with global criticism that digital learning discourse is often trapped in "Western epistemological hegemony," which tends to ignore the realities of infrastructure, local culture, and digital inequality faced by developing countries (Czerniewicz et al., 2020). This represents a relevant research gap to be addressed in a bibliometric paper, given that the context of digital learning implementation is heavily influenced by cultural factors, local policies, and unequal access to technology, which vary across regions. Thus, this visualization not only maps the intellectual structure of the digital learning field but also implicitly reveals the epistemological boundaries of the corpus of literature that has dominated global discourse.

3.4.2 Journal co citation analysis

Journal co-citation analysis is essential for understanding the general overview of research on elementary school teachers' digital literacy. This analysis can identify the most influential journals, the intellectual relationships between publications, and the development of the research themes that are the focus of the study. The analysis also helps map the theoretical foundation and direction of research development, providing a more comprehensive picture of the trends and dynamics of elementary school teachers' digital literacy studies. The results of the journal co-citation analysis are presented in the following figures and tables.

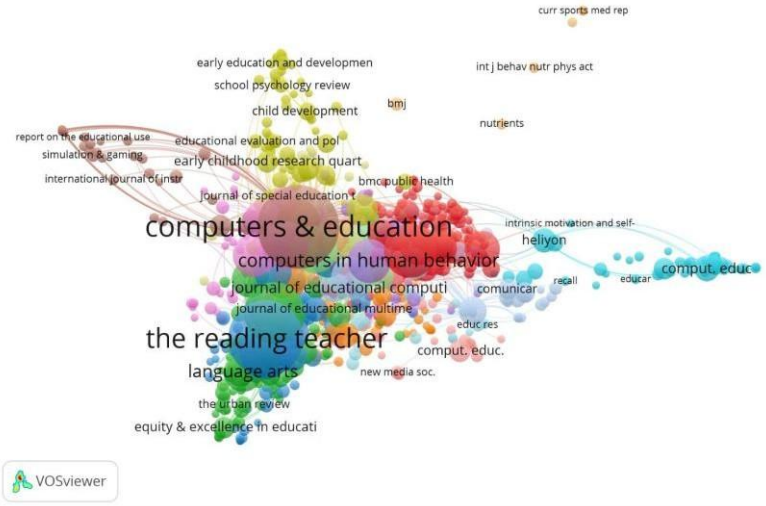

Figure 9. Journal citation network of elementary school teachers' digital literacy

Figure 9 shows that the Computers & Education journal has the largest node size and is centrally positioned in the co-citation network. This indicates that the journal is a primary reference for research on elementary school teachers' digital literacy. Furthermore, The Reading Teacher, Computers in Human Behavior, Journal of Educational Computing Research, and Education and Information Technologies also appear to have strong connections with other journals. The presence of several clusters with different colors indicates the grouping of interrelated research themes, such as educational technology, reading literacy, technology use behavior, and digital learning. The following table lists the five most cited journals.

Table 8. Top 5 Journal citation network of elementary school teachers' digital literacy

Journal	Subject	Citation
Computers and Education	Social Sciences: Education; Computer Science: General Computer Science	212
Reading Teacher	Arts and Humanities: Language and Linguistics | Social Sciences: Linguistics and Language | Medicine: Pharmacology (medical) | Pharmacology, Toxicology and Pharmaceutics: Pharmacology	176
Reading Research Quarterly	Social Sciences: Education | Psychology: Developmental and Educational Psychology	116
Education and Information Technology	Social Sciences: Education | Computer Science: Computer Science Applications	88
Computers in human behavior (Computers in Human Behavior Reports)	Neuroscience: Neuroscience (miscellaneous)|Neuroscience: Cognitive Neuroscience | Psychology: Applied Psychology | Computer Science: Computer Science Applications | Computer Science: Artificial Intelligence | Computer Science: Human-Computer Interaction	59

Table 8. lists the five journals with the highest co-citation scores. Computers and Education ranked first with 212 citations. This high number of citations indicates that research on elementary school teachers' digital literacy is closely related to the integration of computer technology in education. The Reading Teacher, with 176 citations, follows, indicating that digital literacy issues are inseparable from elementary school students' reading, language, and basic literacy development. This confirms that digital technology is used not only as a learning tool but also to strengthen teachers' literacy skills (Fallon, 2020). Next, Reading Research Quarterly, with 116 citations, focuses on education and developmental and educational psychology. The existence of this journal indicates that digital literacy research is also closely related to aspects of students' cognitive and psychological development. Then there is Education and Information Technology with 88 citations, which focuses on education and computer science applications. As well as Computers in Human Behavior, with 59 citations, and a multidisciplinary scope spanning applied psychology, human-computer interaction, artificial intelligence, and cognitive neuroscience.

These findings indicate that research on elementary school teachers' digital literacy largely focuses on studies on educational technology, reading literacy, and the use of technology in the learning process. This aligns with Reyna et al.'s (2018) findings, which suggest that digital literacy is not solely related to mastery of information and communication technology, but also to the ability to think, communicate, and collaborate. This means that research on elementary school teachers' digital literacy focuses not only on how to use digital devices but also on how teachers and students interact with technology in the learning environment to create a comfortable learning space. Therefore, these journals can be considered primary sources of reference that shape the development of research in this field.

Discussion of the Result

The purpose of this study is to conduct a bibliometric analysis of publications related to the digital literacy of elementary school teachers in the digital era. Although publications on the topic of "digital literacy" in the context of elementary school educators have begun to appear since 2005, it is clear that until 2012 (the embryonic phase), the growth in the number of papers published on this new competency approach based on digital technology was not significant, with the number ranging from 0 to 6 articles per year. From 2013 to 2017 (the growth phase), there was a more consistent increase in the number of publications at a moderate level; however, it was not until 2018 (the acceleration phase) that the topic of "digital literacy of elementary school teachers" began to gain significant attention in the scientific community worldwide, which then triggered exponential growth until it peaked in 2025 with a total of 53 articles published in a year.

The United States, Indonesia, and Canada are the top three countries with the most papers published on elementary school teachers' digital literacy. "Reading Teacher" and "Computers and Education" are the top two journals with the most papers published globally. As for papers published in conference proceedings, the most important proceedings on this topic (based on the number of papers published) are "ACM International Conference Proceedings Series," "Lecture Notes in Networks and Systems," and "AIP Conference Proceedings." At the national institutional level, Padang State University and Yogyakarta State University lead in active research publication contributions.

An analysis of the number of citations (citations) shows an unequal distribution of scientific influence, with the United States, Canada, and the United Kingdom among the top three most cited countries worldwide. However, an analysis of impact using average citations reveals an interesting phenomenon: Finland and Hong Kong have the highest average citation impact per article. Meanwhile, Indonesia's position demonstrates a substantial contribution to scientific output (ranked second globally with 102 publications), although its accumulated citation impact remains relatively low, averaging 2.90 citations per article.

One of the most relevant components of a research paper is the set of keywords that classify it. Therefore, by analyzing the collection of papers sampled in this study, it is known that "digital literacy" is the main hub in the research network with the most dominant node size, followed by other important keywords such as "students", "teaching", "teacher education", and "elementary education".

Given that articles tend to have many keywords, analyzing the strength of the relationships among them is relevant. The results revealed that the strongest keyword relationships were between "digital literacy" and "students," "digital literacy" and "teaching," and "digital literacy" and "teacher education." Furthermore, the network analysis captured a recent trend of renewed research focus, as evidenced by the close association between digital literacy and cutting-edge themes such as "artificial intelligence," "digital technologies," and "critical literacy" in supporting 21st-century learning innovations.

Regarding citation impact and international collaboration networks, the United States has solidified its role as a major global hub, directly connected to other productive countries, including Indonesia, Germany, and Spain. Although the number of publications from developing countries like Indonesia has increased sharply in recent years—primarily driven by the need for post-pandemic learning transformation—the distribution of high citation impact has historically remained firmly anchored by global collaboration networks led by the United States and several Western European countries.

Based on further analysis of the study sample, journals and primary publication sources that publish papers related to elementary school teachers' digital literacy can be classified

into three main groups or clusters. The first cluster focuses on Literacy and Basic Education and is dominated by journals such as Reading Teacher, Literacy Research and Instruction, and Reading Research Quarterly. The second cluster focuses more on publications from the fields of Educational Technology and Computer Science, such as Computers & Education, ACM scientific proceedings, and Lecture Notes. Meanwhile, the third cluster consists of journals on teacher professional development and instructional strategies for elementary schools, including TechTrends and Computers in the Schools.

The findings of this study highlight the importance of designing digital competency development strategies for policymakers, educational institutions, and teacher training program providers that better align with the needs of 21st-century education. Furthermore, the mapping results can serve as a reference for researchers in identifying research topics with potential for further development.

4. CONCLUSIONS

This study provides a comprehensive overview of the development of digital literacy research on elementary school teachers during 2005–2025, using a bibliometric approach. By describing publications, citations, collaborative networks, and the resulting intellectual structures, this study not only illustrates the growth of literature in this field but also reveals the dynamics of knowledge development that shape the direction of digital literacy research on elementary school teachers in the context of digital education. The research findings indicate that the period 2005–2025 represents a phase of learning for elementary school teachers' digital literacy, characterized by increased publication productivity, broader international scientific collaborations, and the development of increasingly diverse and complex research themes.

The results indicate that elementary school teachers' digital literacy has evolved from studies focused on technology use skills to a more multidimensional field of research. This evolution highlights the growing importance of integrating technological, pedagogical, and professional dimensions to understand and develop teachers' digital literacy in the digital era. This development is reflected in the increasingly strong links among digital literacy, pedagogical aspects, teacher professional development, critical literacy, and the use of digital technology to support the learning process. This shift in research focus demonstrates that digital literacy is no longer understood solely as a technical skill but as a competency that plays a crucial role in helping teachers design, manage, and develop learning relevant to the needs of 21st-century education. The emergence of themes such as artificial intelligence, critical literacy, and professional development further emphasizes that research developments align with evolving educational needs and ongoing technological transformations.

From an intellectual structure perspective, this study demonstrates that the study of elementary school teachers' digital literacy is grounded in integrating multiple scientific perspectives, particularly educational technology, pedagogy, literacy, and educational psychology. The strong connections among the main concepts, the theories underlying the research, and the dominant reference sources indicate that this field of study has a growing theoretical foundation. This situation indicates that the development of teachers' digital literacy cannot be understood solely through a technological approach but must be viewed as the result of interactions among pedagogical competence, the learning context, student development, and changes in an increasingly digitalized educational environment.

Furthermore, the research findings demonstrate that research on the development of elementary school teachers' digital literacy is supported by an expanding international collaborative network. The United States remains the primary center of global scientific production and influence, both in terms of publications, citations, and research collaborations. However, Indonesia has emerged as a significant contributor to publication productivity, indicating growing attention to developing teachers' digital competence in elementary education. Although the contribution of developing countries continues to increase, the resulting publication and citation structures still demonstrate inequities in the distribution of scientific influence. This condition indicates that the construction of knowledge on the digital literacy of elementary school teachers is still heavily influenced by the academic perspectives of developed countries, so that the diversity of social, cultural, and educational contexts in developing countries has not been fully accommodated in international literature.

Overall, this research confirms that elementary school teachers' digital literacy has become an increasingly mature, multidisciplinary, and strategic area of study in contemporary educational research. The consistent growth of publications, the expanding network of scientific collaborations, and the expanding focus of research toward more complex issues indicate that this field continues to undergo significant conceptual evolution. Thus, research on elementary school teachers' digital literacy not only reflects the development of technology use in education but also illustrates the transformation of teachers' roles, the shifting of learning paradigms, and the evolution of competencies required in education systems in the digital era. From a practical perspective, these findings suggest that teacher professional development programs should place greater emphasis on advanced digital competencies, including digital pedagogical competence, artificial intelligence literacy, and critical digital literacy. Strengthening these competencies is essential for preparing teachers to respond effectively to ongoing educational transformation.

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