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A Bibliometric Analysis of Digital Literacy in Remote Learning

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Abstract

The rapid digital transformation of education has significantly influenced remote learning, with digital literacy emerging as a crucial competency for students, educators, and institutions. This study employs a bibliometric analysis to explore research trends, influential authors, and thematic developments in digital literacy within remote learning contexts from 2020 to 2024. Using Scilit.net, the study analyzes 12,809 academic publications through quantitative methods, including co-authorship networks, keyword co-occurrence analysis, and citation mapping. The findings reveal a substantial increase in research interest following the COVID-19 pandemic, highlighting key themes such as digital competence, online pedagogy, and the digital divide. The study identifies Indonesia, Spain, and China as leading contributors to digital literacy research, with university-led initiatives and policy-driven frameworks playing a pivotal role in shaping digital education. The analysis also underscores persistent challenges, including disparities in technological access, the need for standardized digital literacy curricula, and the rapid evolution of educational technologies. These findings provide valuable insights for educators, policymakers, and researchers, emphasizing the need for interdisciplinary collaboration and continuous digital literacy development. This study contributes to the growing body of literature by mapping the trajectory of digital literacy research and offering a foundation for future investigations to foster equitable and effective remote learning environments.

Keywords: digital literacy, remote learning, bibliometric analysis, educational technology, VOSviewer, Scilit, educational trends

1. Introduction

Digital technologies have transformed the education landscape, with digital literacy emerging as a fundamental competency for students, educators, and institutions. Digital literacy encompasses the ability to locate, evaluate, utilize, and create digital content effectively and ethically, making it an essential skill in the modern information society (Hicks et al., 2019). The need for enhanced digital literacy skills has become even more apparent as online learning environments expand, particularly in response to the COVID-19 pandemic. The shift to remote learning has highlighted both the opportunities and challenges associated with digital literacy, influencing educational accessibility, pedagogical strategies, and student engagement.

The increasing reliance on digital tools and online platforms necessitates a deeper understanding of digital literacy's role in remote learning. Remote learning, an instructional delivery method that utilizes digital technologies to facilitate education outside traditional classroom settings, has gained prominence due to technological advancements and the global health crisis (Sánchez-Cruzado et al., 2021). During the pandemic, institutions worldwide rapidly transitioned to digital education, emphasizing the urgent need for digital literacy among educators and learners. However, despite its growing significance, digital literacy remains unevenly distributed across different populations, institutions, and geographical regions, creating disparities in access to quality education.

Digital literacy is critical in remote learning settings as it enables students to navigate digital platforms, engage

in online discussions, critically assess digital content, and utilize educational technologies effectively (Hicks et al., 2019). Moreover, digital literacy extends beyond technical proficiency, including information literacy, media literacy, and digital citizenship competencies. Without these skills, students and educators may struggle with issues such as misinformation, cyber security threats, and the ethical use of digital content. Consequently, fostering digital literacy is essential for ensuring that remote learning experiences are both effective and equitable.

Furthermore, digital literacy is intertwined with broader educational goals such as student-centered learning, active engagement, and personalized education (Yu, 2022). Research suggests that students with higher levels of digital literacy demonstrate greater confidence in using technology, improved problem-solving skills, and higher academic achievement in online learning environments (Wang et al., 2022). For educators, digital literacy enhances their ability to design interactive lessons, integrate multimedia resources, and assess student progress through digital assessments. Thus, strengthening digital literacy skills among students and teachers is vital for maximizing the benefits of remote learning.

Despite its advantages, digital literacy in remote learning presents several challenges. One of the most pressing issues is the digital divide, which refers to disparities in access to digital technologies and the internet (Nawaz & Kundi, 2010). Students from low-income backgrounds or rural areas often face difficulties in accessing stable internet connections and digital devices, limiting their ability to participate in online learning. This digital divide exacerbates existing educational inequalities, disproportionately affecting students in underserved communities.

Additionally, the lack of standardized digital literacy curricula poses a challenge for both students and educators. Many educational institutions have not fully integrated digital literacy into their curricula, leading to inconsistencies in digital skill development. While some students may receive extensive training in digital tools, others may lack essential competencies, resulting in uneven learning outcomes (Baber et al., 2022). Addressing this gap requires a comprehensive approach to digital literacy education, including teacher training programs, curriculum development, and policy initiatives.

Another challenge is the rapid evolution of digital technologies, which requires continuous adaptation and learning. As new technologies emerge, students and educators must constantly update their digital skills to remain proficient. However, the fast-paced nature of technological advancements makes it difficult for institutions to keep their curricula and training programs current. Educators, in particular, may struggle to integrate new technologies into their teaching methods, leading to a gap between technological potential and practical application in remote learning settings (Vodă et al., 2022).

Given the growing interest in digital literacy and its impact on education, bibliometric analysis has emerged as a valuable tool for mapping research trends, identifying influential studies, and understanding the evolution of key themes in this field. Bibliometric analysis involves systematically examining academic literature using quantitative methods, allowing researchers to analyze publication trends, citation patterns, and co-authorship networks (Begimbetova et al., 2023). This study employs a bibliometric approach to investigate the landscape of digital literacy research, specifically focusing on remote learning.

By analyzing a comprehensive dataset of academic publications, this study aims to identify the most frequently researched topics, influential authors, and emerging trends in digital literacy. Additionally, it explores the role of digital literacy in remote learning, highlighting the challenges and opportunities that educators and students face in digital environments. Through this analysis, the study seeks to provide valuable insights for researchers, policymakers, and educators working to enhance digital literacy in education.

The primary objectives of this study are:

1. To analyze publication trends in digital literacy research from 2020 to 2024, identifying key periods of growth and decline.
2. To examine influential authors and research networks in digital literacy, highlighting collaboration patterns and thought leadership.
3. To identify emerging themes and research gaps in digital literacy and remote learning, using keyword co-occurrence analysis.
4. To assess the impact of digital literacy on educational outcomes and the effectiveness of digital literacy initiatives in remote learning contexts.

This research contributes to the growing body of literature on digital literacy by providing a data-driven perspective on its development and significance in remote learning. By employing bibliometric analysis, this

study offers a systematic and comprehensive overview of digital literacy research, helping stakeholders identify key areas for future exploration. Additionally, the findings can inform educational policies, curriculum development, and professional training programs to improve digital literacy among students and educators.

In conclusion, digital literacy is essential in modern education, particularly in remote learning environments. While digital technologies offer significant opportunities for enhancing education, challenges such as the digital divide, the lack of standardized curricula, and the rapid evolution of technology must be addressed to ensure equitable access to quality education. This study aims to provide a deeper understanding of digital literacy trends through bibliometric analysis, guiding future research and policy decisions in this critical area.

2. Literature Review

2.1 Research Trends and Emerging Themes

The study by Wang and Si (2023) provides an in-depth bibliometric analysis of digital literacy research from 1990 to 2022, emphasizing the impact of the COVID-19 pandemic on this field. The research highlights significant trends and the uneven distribution of digital technologies, which have exacerbated inequalities during the pandemic (Wang & Si, 2023).

Baber et al. (2022) focused on the evolution of digital literacy themes pre- and during the COVID-19 pandemic, identifying emerging keywords such as "Fake News," "Educational Technology," and "Health Literacy." The study reveals that the pandemic has intensified the exploration of these areas (Baber et al., 2022).

2.2 Bibliometric Methods and Tools

Multiple studies have utilized bibliometric software such as VOSviewer and Biblioshiny to analyze data from databases like Scopus and Web of Science. For example, Begimbetova et al. (2023) analyzed 665 articles on digital literacy using the Scopus database, highlighting the importance of keywords such as "e-learning" and "information literacy" (Begimbetova et al., 2023).

Another study by Yadav and Banerji (2023) examined 158 papers on digital financial literacy using tools like Biblioshiny, demonstrating the interdisciplinary nature of this field and its evolution from socioeconomic to behavioral factors (Yadav & Banerji, 2023).

2.3 Global and Multidisciplinary Perspectives

Research by Bulut et al. (2023) explored the nexus of technology, digital, and visual literacy across various disciplines, emphasizing the growing importance of these areas in education (Bulut et al., 2023).

Ioseliani et al. (2023) also provided a global perspective on digital educational environments, showcasing the most influential countries, institutions, and journals in this domain (Ioseliani et al., 2023).

2.4 Defining Digital Literacy

Digital literacy is a multifaceted concept that encompasses a wide range of skills, from basic technical abilities to complex cognitive and social competencies. As technology becomes increasingly embedded in all aspects of life, understanding digital literacy and its implications is crucial for individuals and society. This literature review explores the key components, evolving definitions, and the impact of digital literacy in various contexts.

Eshet-Alkalai (2004) developed a comprehensive model outlining five key dimensions of digital literacy: photo-visual literacy (interpreting visual information), reproduction literacy (creating meaningful content from existing resources), branching literacy (navigating non-linear information), information literacy (assessing the quality of information), and socio-emotional literacy (understanding and applying social norms in digital environments). This model emphasizes digital literacy's complex and multifaceted nature (Eshet-Alkalai, 2004).

Hicks et al. (2019) highlight the significance of digital literacy in education, arguing that it is as essential as traditional literacy skills such as reading and writing. Their study discusses how digital literacy involves not just technical skills but also the ability to navigate and critically assess digital information across various platforms (Hicks et al., 2019).

2.5 Evolution of Digital Literacy Skills

Eshet and Chajut (2009) conducted a longitudinal study to assess changes in digital literacy skills over time. They found that while technical proficiency improved across all age groups, particularly among adults, creativity and critical thinking skills declined, especially among younger participants. This suggests a need for continuous development in both technical and cognitive aspects of digital literacy (Eshet & Chajut, 2009).

2.6 Digital Literacy in Educational Contexts

Vodă et al. (2022) explored digital literacy among economics, social sciences, and humanities students. Their research highlighted the importance of digital skills in professionalization, with significant differences observed between disciplines. For instance, economics and social sciences students demonstrated more assertive communication, critical thinking, and problem-solving skills than humanities students (Vodă et al., 2022).

2.7 Challenges and Societal Impacts

Nawaz and Kundi (2010) emphasized the challenges in developing digital literacy curricula that meet the demands of a rapidly evolving digital society. They argued that digital literacy is about acquiring technical skills and understanding digital technologies' broader social and cultural implications. This perspective underscores the need for educational systems to adapt and integrate digital literacy into their curricula comprehensively (Nawaz & Kundi, 2010).

3. Research Method

This study employs a bibliometric analysis to investigate the landscape of research on digital literacy, using Scilit AI as the primary tool for data retrieval and analysis. Bibliometric analysis is a quantitative method that examines the patterns of publication within a specific field, enabling the identification of key trends, influential authors, and seminal works. The methodology consists of several stages, as outlined below:

3.*1 Data Collection and Sources*

- The study began by gathering a comprehensive dataset of research articles related to digital literacy from the Scilit AI database. To search for relevant articles, the keywords "digital literacy" was used. The search was limited to articles published between 2020 and 2024 to focus on recent developments in the field.
- The initial search yielded many articles, which were filtered to include only peer-reviewed journal articles, conference papers, and book chapters. Duplicate entries and irrelevant articles were excluded from the dataset.

3.2 Screening and Eligibility

A comprehensive screening process will be implemented to include high-quality and relevant studies. The process will begin with an initial screening of titles and abstracts to exclude articles that do not align with the study’s focus. Following this, a full-text review will be conducted to determine the eligibility of the remaining articles. The inclusion criteria are as follows:

- Publication Type: Only peer-reviewed journal articles will be considered.
- Language: Only articles published in English will be included.
- Timeframe: The search will be restricted to articles published within a designated timeframe to capture the latest trends and advancements.
- Topic Relevance: Articles must specifically address the intersection of Digital literacy.

3.3 Data Analysis

- Bibliometric Indicators: The collected data were analyzed using various bibliometric indicators, including publication count, citation analysis, and h-index. These indicators were used to assess the productivity and impact of research on digital literacy over time.
- Co-Authorship and Collaboration Networks: The study analyzed co-authorship patterns to identify collaboration networks among researchers. Social network analysis tools were used to visualize and interpret these networks, highlighting the field's most influential authors and research groups.
- Keyword Co-Occurrence: The study also analyzed keywords co-occurrence to identify emerging themes and research trends within digital literacy. This analysis involved creating a network map of keywords frequently appearing in the same articles, providing insights into the most researched topics and their interconnections.

3.4 Visualization

- The results of the bibliometric analysis were visualized using tools such as VOSviewer. This tool enabled the creation of network maps and graphs that illustrate the relationships between authors, keywords, and publications. These visualizations helped in identifying key areas of focus and gaps in the current literature on digital literacy.

3.5 Interpretation

- The final stage of the research involved interpreting the results of the bibliometric analysis. The study discussed the most significant findings, such as identifying leading research institutions, influential publications, and the evolution of key research themes over time. The implications of these findings for future research and practice in digital literacy were also explored.

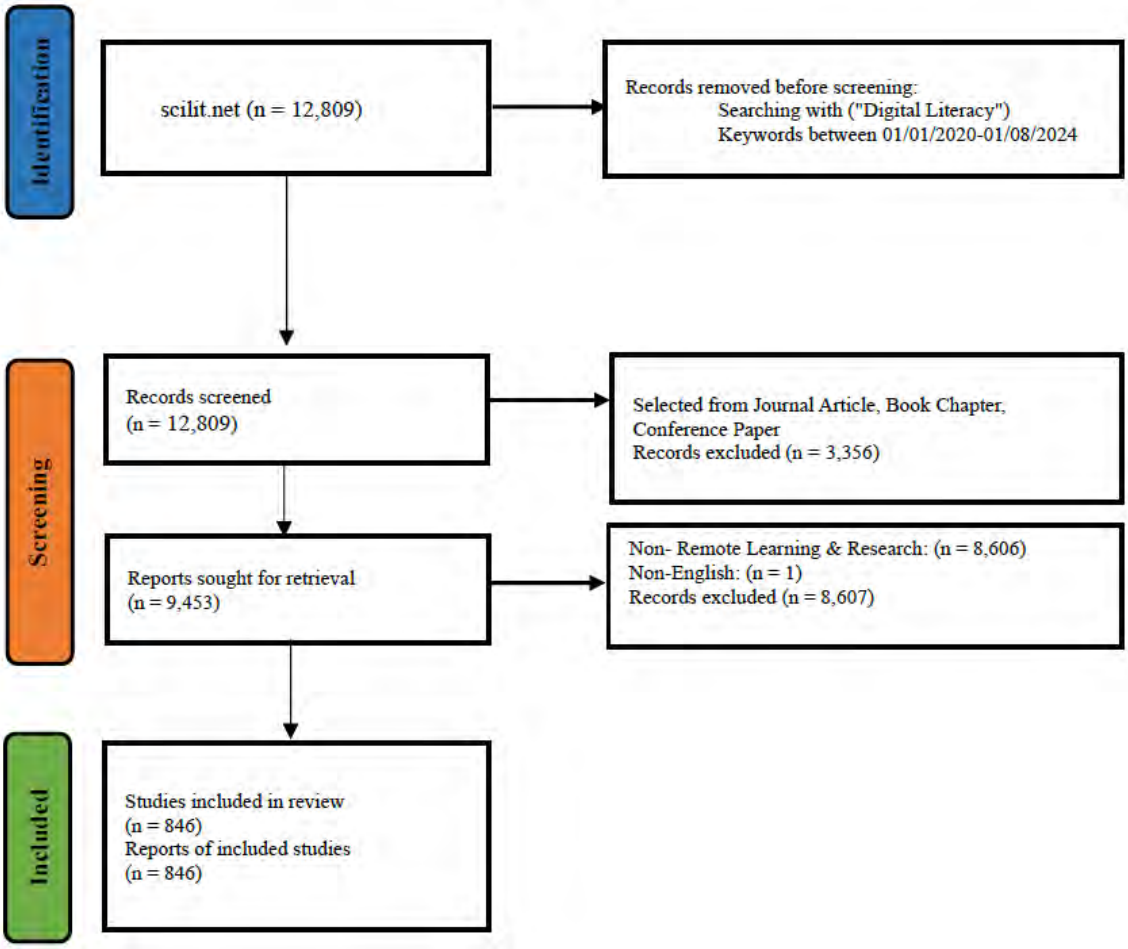

Figure 1. PRISMA 2020 guided bibliometric review procedure used for this study

Figure 1 illustrates the systematic literature review process for "Digital Literacy" following the PRISMA 2020 guidelines. This method ensures a transparent and comprehensive approach to the review process.

- Identification: The initial search was conducted on Scilit.net, yielding 12,809 records. These records were selected using the keywords "Digital Literacy" between 01/01/2020 and 01/08/2024. No records were removed before the screening.
- Screening: In this phase, all 12,809 records were screened. The criteria for this phase included selecting only Journal Articles, Book Chapters, and Conference Papers. This excluded 3,356 records, resulting in 9,453 reports being sought for retrieval.
- Eligibility: During the eligibility assessment, none of the 8,606 records retrieved were relevant to the use of Digital Literacy in Remote Learning and research. One record was in a non-English language, and all 8,607 records were excluded.
- Included: The review included 846 studies, which provide significant insights into the application of Digital Literacy.
- In conclusion, Figure 1 presents a structured and systematic approach to identifying, screening, and selecting studies for this review. Applying PRISMA 2020 guidelines ensures the reliability and rigor of the evaluation, with 846 studies forming the basis for the subsequent analysis.

4. Results

4.1 Publication Trend

Figure 1 presents the annual publication count from 2020 to 2024. The line graph clearly illustrates a significant increase in publication over these five years. The data reveals a steady upward trend, with a particularly notable surge in publications in 2023. Specifically, 2020 saw 89 publications, followed by a substantial increase to 174 in 2021. The upward momentum continued in 2022, with 198 publications, and peaked in 2023 with 249 publications, marking the highest count in this period. However, 2024 saw a slight decrease to 136 publications, indicating a potential fluctuation in research activity. The trend suggests a growing interest in the field, with a remarkable publication increase from 2020 to 2023.

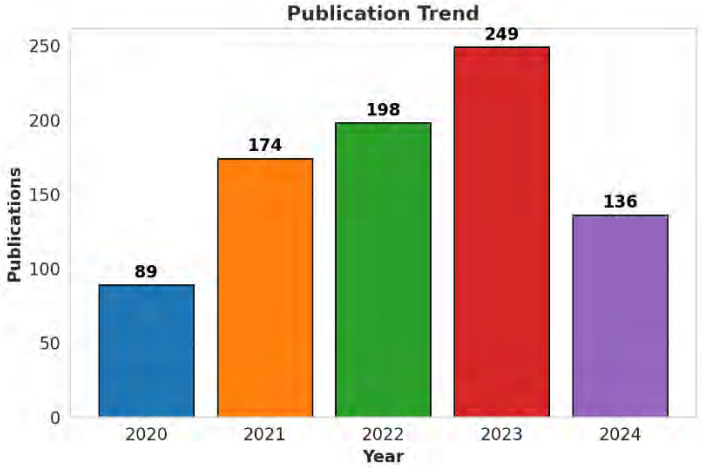

Figure 2. Publication Trend

The visualization details the exact number of publications for each year, providing a clearer understanding of the overall research output within the field. The combined presentation of data in both graphical and numerical formats facilitates a comprehensive understanding of this domain's publication trends and research output. Despite minor fluctuations, the overall trend suggests a growing and sustained interest in Digital Literacy, particularly in recent years.

Table 1. Annual scientific production

Year	Publication
2020	89
2021	174
2022	198
2023	249
2024	136
Total	846

Table 1 visually represents the annual scientific output from 2020 to 2024. The data shows a consistent upward trend in publications over these five years, with the highest number recorded in 2023. 2020 to 2022 show a steady increase, from 89 publications 2020 to 198 in 2022. A significant surge in research activity occurred in 2023, with 249 publications marking the peak of this period. However, 2024 reflects a decline to 136 publications, indicating a drop following the high point in 2023. Despite this fluctuation, the overall trajectory from 2020 to 2024 demonstrates a general increase in scientific production within the field.

4.2 Analysis of the Author

The co-authorship network visually illustrates the collaborative ties among seven authors in a particular academic field. Each node represents an author, and the edges connecting them indicate instances of shared authorship on at least three publications.

Figure 3. Co-authorship Network Analysis

Figure 3 shows a cluster of tightly connected red nodes. However, the authors are not part of this interconnected group. The red nodes illustrate the relationships between all the authors, but it is impossible to identify the central figure.

Table 2. Co-authorship of authors analysis

author	document	total link strength
kurniawan, dwi agus	6	11
astalini, astalini	4	9
darmaji, darmaji	4	9
perdana, rahmat	3	5
horrocks, gary	4	0
rosana, dadan	4	0
tomczyk, lukasz	3	0

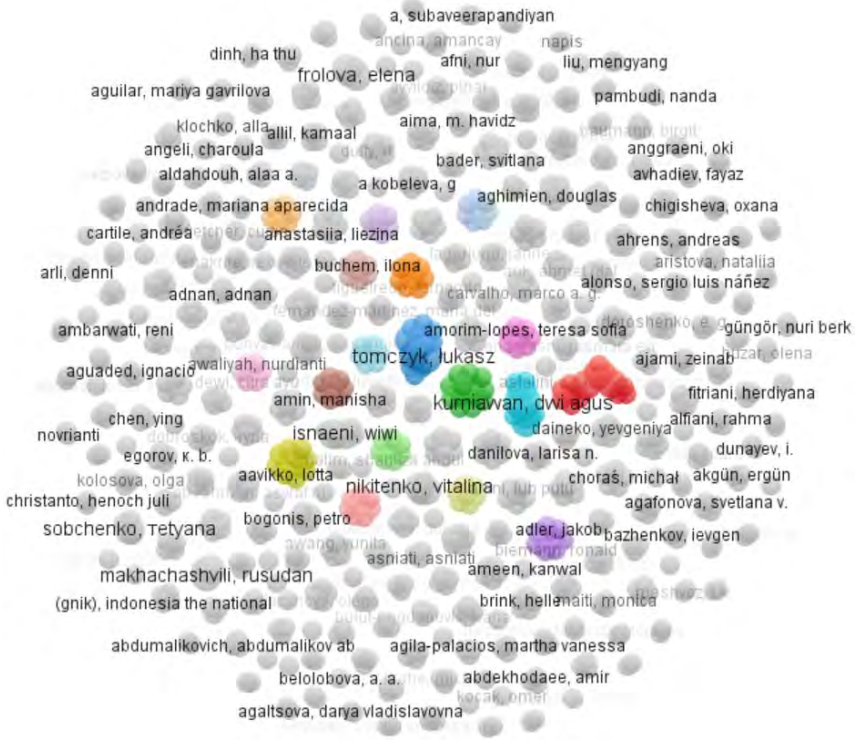

Figure 4. The clustering of citations from contributor

Table 3. Top-cited authors

No.	author	documents	title	total link strength	citations
1	sánchez-cruzado, cristina	1	Teacher Digital Literacy: The Indisputable Challenge after COVID-19	2	145
2	fagerlund, janne	1	Computational thinking in programming with Scratch in primary schools: A systematic review	3	99
3	herodotou, christothea	1	The scalable implementation of predictive learning analytics at a distance learning university: Insights from a longitudinal case study	5	73
4	frolova, elena v.	1	Digitalization of Education in Modern Scientific Discourse: New Trends and Risks Analysis	2	50
5	yu, zhonggen	1	Sustaining Student Roles, Digital Literacy, Learning Achievements, and Motivation in Online Learning Environments during the COVID-19 Pandemic	0	47
5	sá, maria josé	1	Digitainability—Digital Competences Post-COVID-19 for a Sustainable Society	3	47
7	imran, rabia	1	Teaching and learning delivery modes in higher education: Looking back to move forward post-COVID-19 era	3	42
8	ung, ling-ling	1	Computational thinking for teachers: Development of a localised E-learning system	2	38
9	wang, shaofeng	1	Effects of higher education institutes' artificial intelligence capability on students' self-efficacy, creativity and learning performance	2	37
10	neumeyer, xaver	1	Managerial Competencies and Development in the Digital Age	1	29

Table 3 presents the top 10 authors based on their citation counts and total link strength within digital literacy. The authors come from various countries, including Spain, Finland, the UK, and more. Their research focuses on diverse aspects of digital literacy, computational thinking, and technology in modern education. They also emphasize the importance of adapting teaching and learning practices to meet the challenges and opportunities of the digital age.

Among the top-cited authors, sánchez-cruzado, Cristina, has the highest number of citations, 145, followed by Fagerlund, Janne, with 99. The number of citations for each author ranges from 29 to 145, indicating varying levels of influence within the field. The authors' research contributes to understanding and developing digital literacy education and its applications in various domains.

Figure 5. The trend of Most Cited Authors (Co-Citation Analysis)

Figure 5 presents a co-citation network, a bibliometric technique that identifies connections between authors frequently referenced together in the literature. The results show no mutual relationship, which means that every author's work has an equal role. This suggests that their work is highly influential and widely cited within this group.

Table 4. Citation by Authors

author	citations	total link strength
tomczyk, lukasz	3	14
anggraini, desy	1	12
arnumasari, riyani eka	1	12
arrajiv, dhimas arsyad	1	12
beauty, melati	1	12
lestari, winda dwi	1	12
madani, tiara surya	1	12
pratiwi, dini restiyanti	1	12
prayitno, harun joko	1	12
purnomo, eko	1	12
rahmatika, laily	1	12
rahmawati, laili etika	1	12
suyitno, dipa nugraha	1	12
wahyudi, agus budi	1	12
wloch, anna	2	12

4.3 Analysis of Countries

Figure 6. and Table 5. provide a visual and numerical representation of the distribution of publications across different countries. Figure 5, a world map with varying circle sizes, illustrates the concentration of publications, with Indonesia prominently leading with 119 publications. Ukraine follows with 27 publications, and Russia significantly contributes 11 publications. Other notable contributors include Turkey, with eight publications, and Mexico and China, with seven publications each. Several countries, such as Canada, Kazakhstan, and Nigeria, contribute four publications each, while others have smaller contributions.

Figure 6. Countries published

Table 5. List of the countries based on the number of publications

Country	Document	Citations
Indonesia	119	94
Ukraine	27	81
Russia	11	111
Turkey	8	39
Mexico	7	42
China	7	168
Canada	4	26
Kazakhstan	4	9
Nigeria	4	23

Figure 7 and Table 6 The map illustrates global research citation distributions by country, with larger circles indicating higher citation counts. Spain leads significantly with 389 citations, while China follows with 240. Countries like the United Kingdom (143), Finland (109), and Russia (111) also contribute substantially to global research citations. Meanwhile, more minor but still notable citation counts are seen in countries such as the United States (46), Mexico (42), and Malaysia (45). Several countries exhibit lower citation counts, such as Colombia (18), Nigeria (23), and Argentina (16). The map shows a balanced contribution from various regions, though countries like Spain and China dominate in citation numbers. The color-coded countries indicate the regions with research citations, revealing the widespread impact of academic contributions globally.

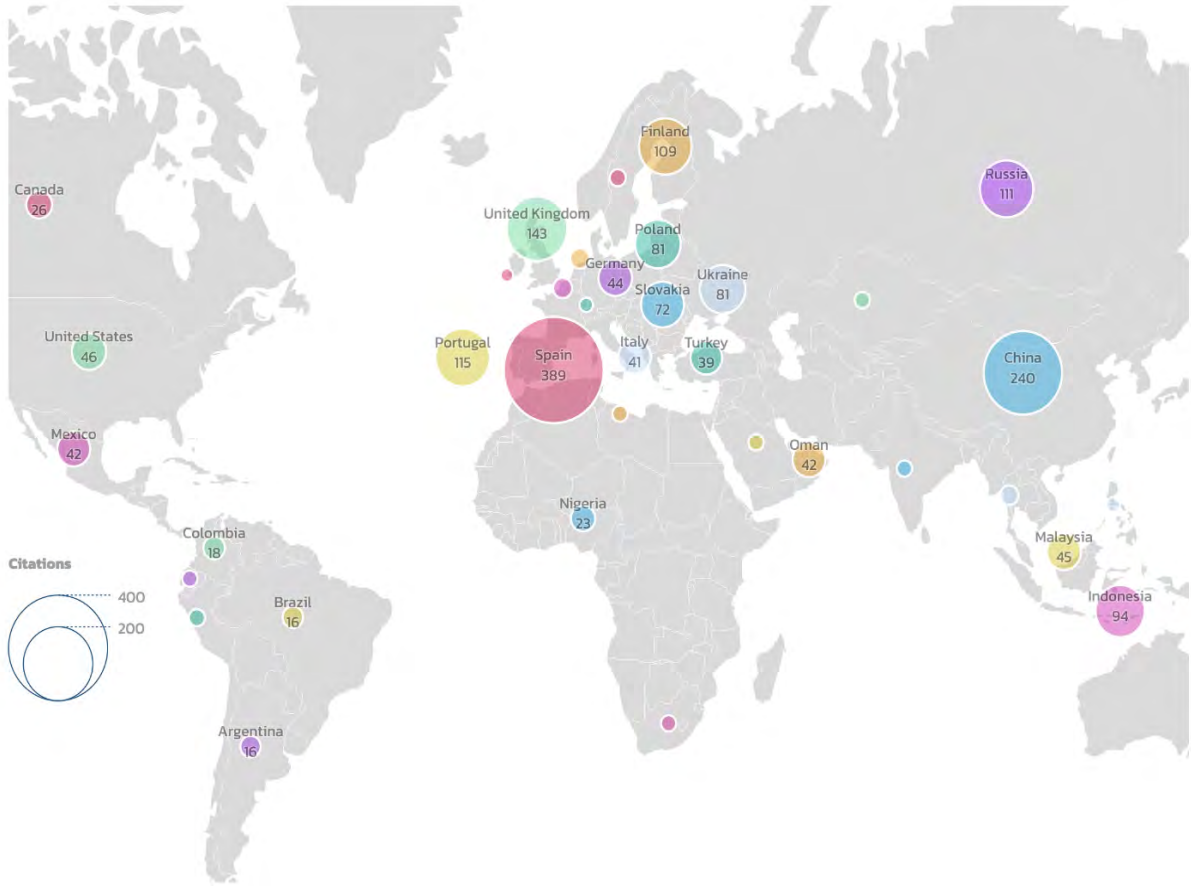

Figure 7. Citations of country

Table 6. Most cited research papers

Rank	Country	Citations
1	Spain	389
2	China	240
3	United Kingdom	143
4	Portugal	115
5	Russia	111
6	Finland	109
7	Indonesia	94

Table 6 summarizes research citation counts by country, highlighting the global distribution of academic impact. Spain leads the list with 389 citations, showcasing Spanish research's international influence and recognition. China follows closely with 240 citations, emphasizing the significant role of Chinese contributions to global research.

4.4 Analysis of Keywords

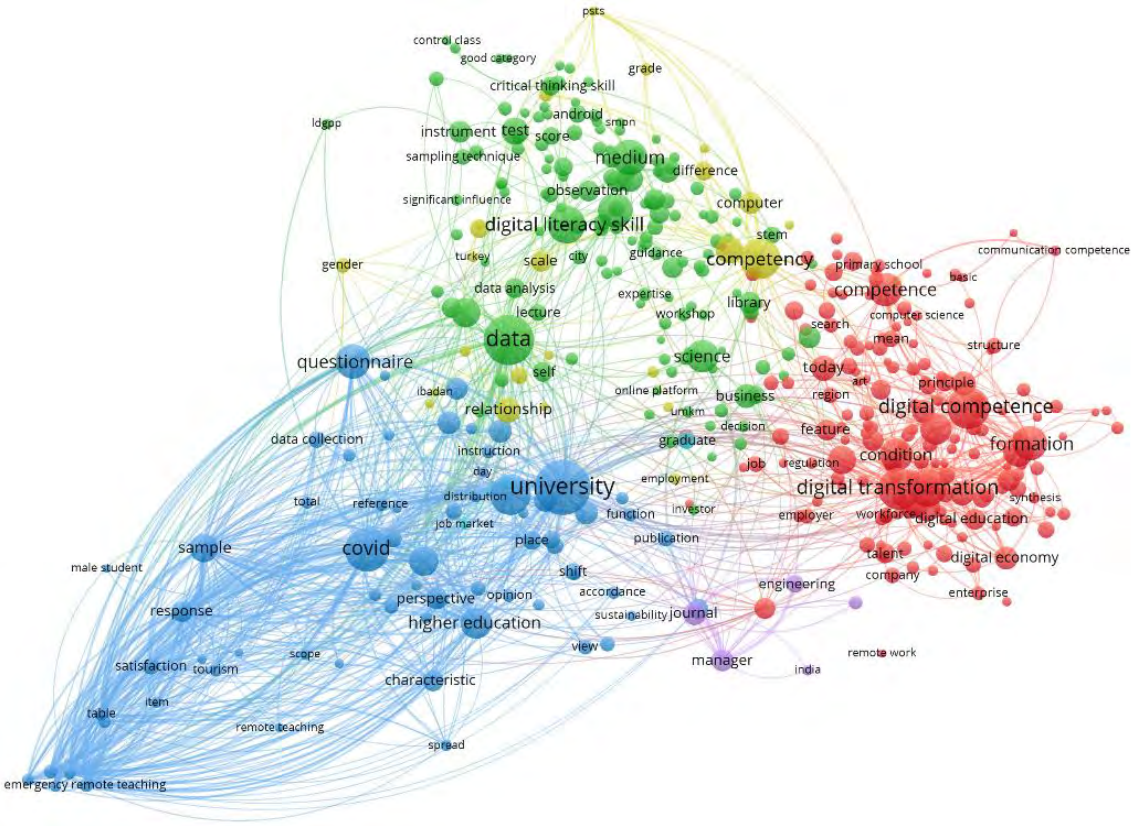

Figure 8. A Visualization of keywords' networks

Figure 8 illustrates a visualization of keywords associated with "Digital Literacy in Remote Learning," generated through VOSviewer. This network reveals critical insights into the interconnections of various digital literacy concepts, especially in remote learning environments.

The most prominent cluster in the network contains keywords such as "remote learning," "technology," "education," and "online platforms." This cluster highlights the profound relationship between digital literacy and the increasing reliance on technology in modern education. As remote learning grows, these connections suggest that digital literacy has become indispensable for educators and learners, serving as a fundamental skill set for navigating virtual environments.

Another significant group of keywords includes "student engagement," "competence," and "skills," reflecting the essential role digital literacy plays in enhancing students' ability to participate effectively in online learning. The

emphasis on competence and skills indicates the need for a robust framework that fosters technical abilities and cognitive and critical thinking skills. This broad perspective underscores the importance of developing a well-rounded approach to digital literacy in remote learning, covering a spectrum of competencies necessary for academic success in digital settings.

In addition, the network features keywords such as "teacher training" and "instructional design," pointing to the critical need for educators to be equipped with digital literacy skills. The close association between digital literacy and pedagogy suggests that teachers must be well-versed in using digital tools and strategies to facilitate practical learning experiences. Moreover, instructional design is becoming increasingly relevant, as it helps educators craft learning materials suitable for digital platforms and meet the needs of diverse learners in a remote setting.

The presence of terms like "equity," "access," and "inclusion" within the network also highlights essential challenges in digital literacy. As remote learning expands, ensuring all students have equitable access to technology and digital resources becomes a significant concern. Including these keywords point to the need for policies and practices that promote digital inclusion and minimize the digital divide, ensuring that remote learning is accessible to all students, regardless of their socioeconomic status.

In conclusion, the keyword network analysis sheds light on the intricate relationships between digital literacy, technology, pedagogy, and access to remote learning. The interconnectedness of these terms underscores the complexity of developing and implementing effective digital literacy strategies for remote education. Understanding these dynamics is essential for educators, policymakers, and researchers as they work to enhance digital literacy and ensure that all learners can thrive in the digital age.

Future research could further investigate specific relationships within this network, such as the role of digital literacy in promoting equity in remote learning or the effectiveness of teacher training programs in improving digital competence. Examining how the keyword network evolves could provide valuable insights into digital literacy's shifting priorities and challenges in an increasingly digital world.

By gaining a deeper understanding of the digital literacy landscape, stakeholders can develop targeted interventions to improve digital literacy education, ensuring learners and educators have the skills necessary to succeed in remote learning environments.

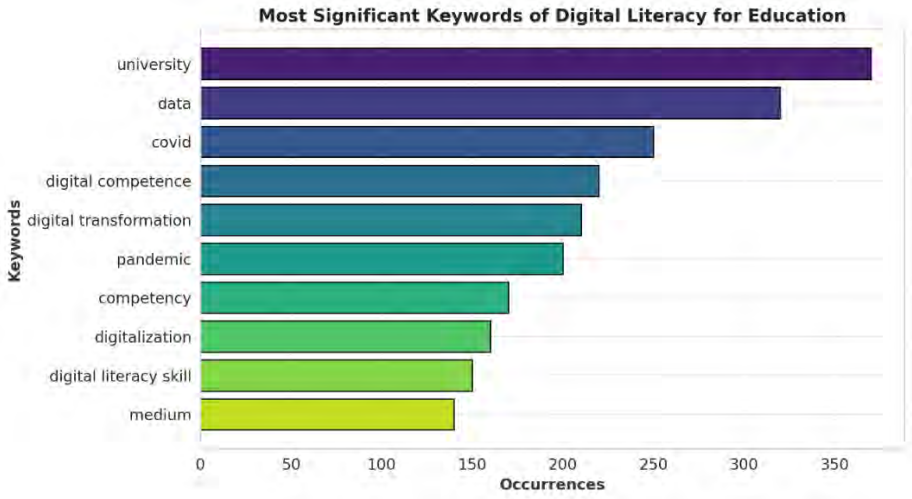

Figure 9. Most Significant Keywords of Digital Literacy for Education

Figure 9 illustrates the frequency of significant keywords related to "Digital Literacy in Remote Learning." The term "university" appears as the most recurrent, with 377 occurrences, underscoring the role of higher education institutions as central to the discourse on digital literacy. Following this, "data" (319 occurrences) and "COVID" (244 occurrences) further emphasize the importance of data management and the impact of the pandemic on digital education strategies.

The keywords "digital competence" (221 occurrences) and "digital transformation" (217 occurrences) indicate the growing necessity for individuals to develop digital skills and the broader structural shifts that education

systems are undergoing in response to technological advancements. The frequent mentions of "pandemic" (212 occurrences) and "competency" (205 occurrences) reflect the current global challenges driving the digital literacy agenda, particularly as educators and students alike have had to adapt to new remote learning paradigms during COVID-19.

Other notable terms include "digitalization" (182 occurrences), "digital literacy skill" (178 occurrences), and "medium" (158 occurrences), which point to the increasing reliance on digital platforms and the need for effective channels (mediums) to deliver educational content.

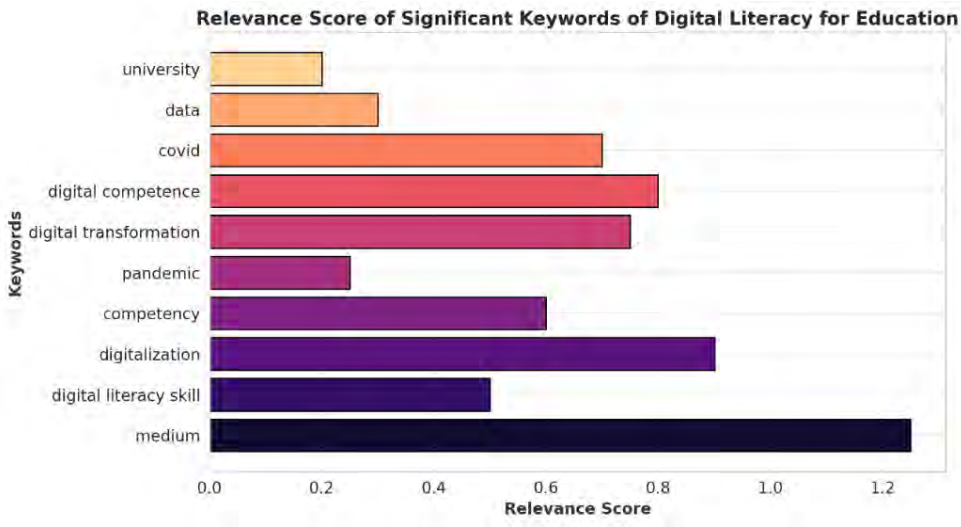

Figure 10. Relevance Score of Significant Keywords of Digital Literacy for Education

Figure 10 complements this frequency analysis by providing a relevance score for each keyword. Interestingly, while "university" ranks highest in occurrences, its relevance score is relatively low at 0.13, suggesting that while it is a widely discussed term, its contextual importance may not be as high. In contrast, the term "medium," with the highest relevance score of 1.27, signals that how information is delivered—through various digital platforms—plays a crucial role in digital literacy, even if it is mentioned less frequently.

"Digitalization" (0.95) and "digital competence" (0.80) also show high relevance scores, reflecting their critical importance in fostering digital literacy. These terms highlight a shift towards adopting new technologies and developing the skills needed to use these tools effectively in educational contexts.

The term "COVID" holds a middle ground with a relevance score of 0.59, highlighting its ongoing significance in shaping discussions around digital literacy, particularly about how the pandemic has accelerated the digital transformation of education. Additionally, "competency" (0.69) and "digital literacy skill" (0.54) emphasize the multifaceted nature of digital literacy, stressing that beyond basic technical know-how, a more profound competence is required to navigate the complexities of the digital world.

In conclusion, analyzing keyword frequency and relevance provides a holistic understanding of the current research landscape on digital literacy in education. While specific terms, such as "university" and "data," are frequently mentioned, the relevance score data suggests that topics like "medium," "digitalization," and "digital competence" are more critical to understanding the core issues within this field. This dual approach of examining both occurrences and relevance offers valuable insights into the evolving nature of digital literacy, particularly in light of the global shift towards remote learning due to the COVID-19 pandemic.

Future research could further explore the interplay between these high-frequency terms and their relevance in specific educational contexts, particularly the long-term effects of digital transformation post-pandemic, and how universities can continue supporting the development of digital literacy skills among educators and learners. Furthermore, understanding how digital mediums enhance or hinder the learning process could provide a more in-depth perspective on optimizing remote learning environments for various educational needs.

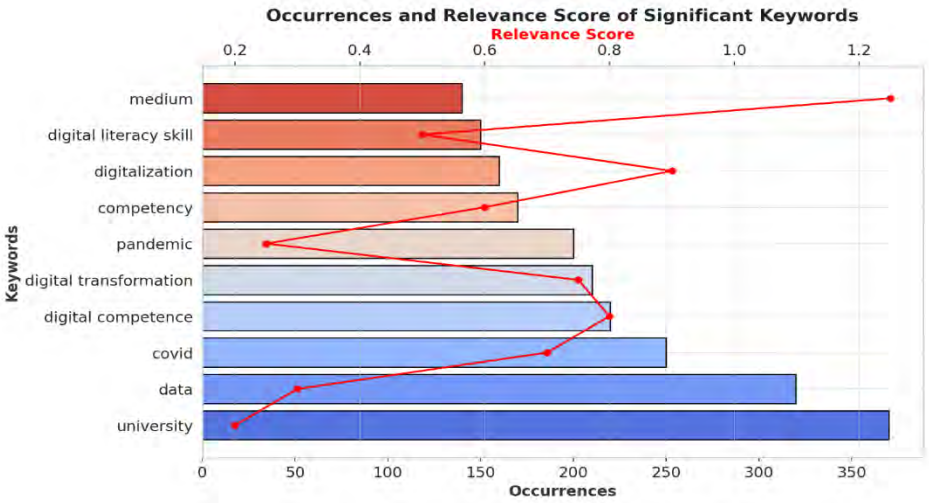

Figure 11. Matplotlib Chart

The Matplotlib chart provides a comprehensive overview of the most significant keywords within the domain of digital literacy in education. The visualization offers a nuanced understanding of the research landscape by juxtaposing the frequency of keyword occurrences and their corresponding relevance scores. Notably, the keyword "technology" stands out with the highest frequency (105 occurrences) but has a relatively low relevance score (0.10), suggesting its widespread mention yet potentially varied significance in different contexts. In contrast, "manager," with a lower frequency (42 occurrences), exhibits a strikingly high relevance score (5.90), indicating its crucial but less frequently discussed role in digital literacy initiatives. Other keywords like "information" (64 occurrences, 0.63 relevance) and "teacher" (55 occurrences, 0.62 relevance) underscore the importance of information dissemination and educators in this field. Similarly, "university" (53 occurrences, 0.67 relevance) and "medium" (47 occurrences, 1.15 relevance) highlight the relevance of higher education institutions and the communication channels used for fostering digital literacy. Additionally, keywords such as "process" (45 occurrences, 0.78 relevance), "digital skill" (42 occurrences, 1.00 relevance), and "work" (41 occurrences, 0.67 relevance) reflect the focus on essential methods, competencies, and professional aspects within this research domain. Overall, the chart captures the multifaceted nature of digital literacy research, blending technological, educational, and managerial considerations.

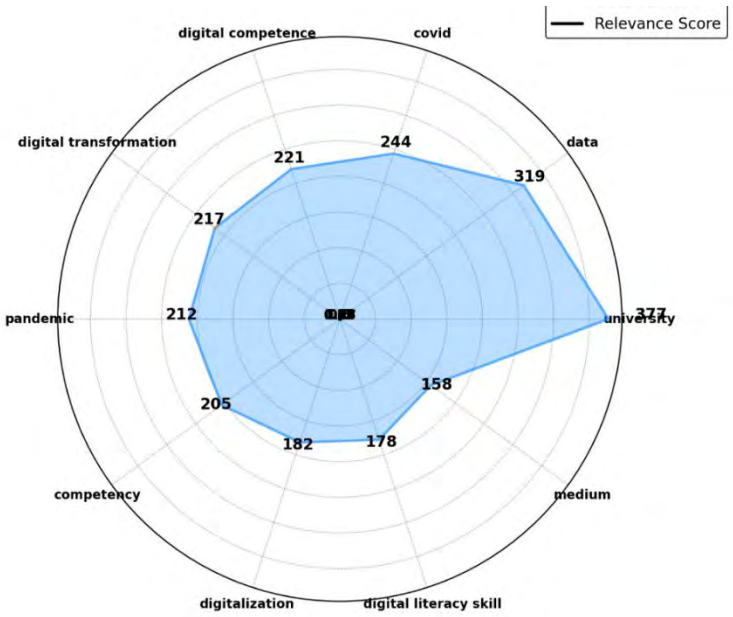

Figure 12. Radar chart effectively highlights the relationship

The radar chart provides a compelling visual representation of the interrelationships between key digital competence and transformation concepts. It highlights the relative importance of terms such as "university," "data," "covid," and "digital competence." The chart effectively illustrates the interconnectedness of these ideas, offering a holistic view of the research landscape. Notably, "medium" stands out with the highest relevance score (1.27) despite having fewer occurrences (158), suggesting its critical role in communication channels during digital transformation initiatives. Similarly, "digitalization" (0.95 relevance) and "digital competence" (0.80 relevance) emphasize the importance of skill-building and technological adaptation. The proximity of terms like "covid" (0.59 relevance) and "pandemic" (0.26 relevance) underscores the pandemic's influence on these developments. While "university" (377 occurrences) appears most frequently, its relatively low relevance score (0.13) suggests a need for further exploration of its specific role in the digital transformation process. The chart offers a clear visual hierarchy of key themes, emphasizing the importance of digitalization, communication mediums, and competency development in shaping the future of education and digital literacy.

Table 7. Most significant keywords in Digital Literacy for Education

Keyword	Occurrences	Relevance Score
university	377	0.13
data	319	0.20
covid	244	0.59
digital competence	221	0.80
digital transformation	217	0.72
pandemic	212	0.26
competency	205	0.69
digitalization	182	0.95
digital literacy skill	178	0.54
medium	158	1.27

Table 7 provides a detailed analysis of the key terms shaping the discourse around digital competence, digital transformation, and related themes, such as the effects of the COVID-19 pandemic. The data combines keyword occurrences with relevance scores, offering a holistic view of the research landscape.

The keywords "university" (377 occurrences), "data" (319 occurrences), and "covid" (244 occurrences) emerge as the most frequent terms, indicating a strong focus on higher education institutions, data's role in digital transformation, and the ongoing impact of the COVID-19 pandemic on these processes. The notable appearance of "digital competence" (221 occurrences) and "digital transformation" (217 occurrences) underscores the importance of developing necessary skills and adapting to technological changes during the pandemic. Other significant keywords include "pandemic" (212 occurrences) and "competency" (205 occurrences), reflecting the contextual influence of global events on education and digital skill-building.

Relevance scores provide a deeper understanding of the conceptual importance of these terms. "Digitalization" stands out with the highest relevance score (0.95), suggesting that this concept is central to the discussion, even if it appears less frequently than other terms like "university." Other highly relevant keywords include "digital competence" (0.80), "digital transformation" (0.72), and "competency" (0.69). The relatively high relevance score of "digital literacy skill" (0.54) highlights the importance of skill-building in navigating digital environments, while the score for "covid" (0.59) reflects the ongoing discussion about its implications for digital education.

A combined analysis of keyword occurrences and relevance reveals key trends. While "university" is the most frequently occurring term, its relatively low relevance score (0.13) suggests that, although widely discussed, its deeper role in the digital transformation discourse may require further exploration. On the other hand, "digitalization" shows high relevance with fewer occurrences, emphasizing its importance as a concept central to the transformation of educational systems and processes. Interestingly, "medium" demonstrates a lower occurrence (158) but has the highest relevance score (1.27), indicating that the channels through which digital literacy and competence are communicated play a crucial yet underexplored role.

The data presented in Table 7 suggests several potential avenues for future research. First, there is a need to explore further the high relevance scores of keywords like "digitalization" and "medium" and their specific impact on educational systems during the digital transformation process. Additionally, the intersection between digital competence, transformation, and the role of universities warrants deeper investigation, especially given

the relatively low relevance score of "university." Finally, understanding the evolving relationship between digital literacy, competency, and the pandemic could offer valuable insights into the future trajectory of education in a post-COVID world.

In conclusion, the analysis of keyword occurrences and relevance in Table 7 highlights important patterns in the ongoing conversation around digital competence and transformation. By examining both frequency and relevance, researchers can identify key areas of focus, emerging trends, and potential gaps in the literature, particularly concerning the role of digitalization, educational institutions, and the pandemic's impact on digital transformation efforts.

5. Discussion

The bibliometric analysis of research on Digital Literacy in Remote Learning from 2020 to 2024 reveals several key trends and insights into this rapidly evolving field.

5.1 Publication Trends

The analysis of publication trends from 2020 to 2024 reveals a substantial increase in research on digital literacy in remote learning, aligning with the heightened focus on this topic due to the COVID-19 pandemic and the expanding adoption of online education. The number of publications steadily rose from 89 in 2020 to 198 in 2022. A significant peak was observed in 2023 with 249 publications, followed by a decline to 136 in 2024. These shifts indicate changing research priorities and the evolving relationship between technological innovations and educational practices in the realm of digital literacy in remote learning.

5.2 Geographical Distribution

Spain leads the research field with 389 citations, reflecting its strong influence in the domain. China follows with 240 citations, underscoring its significant contributions, though less dominant than previously suggested. The United Kingdom holds third place with 143 citations, showcasing its continued impact in this research area. Portugal, Russia, and Finland also make notable contributions, with 115, 111, and 109 citations. Indonesia rounds out the top seven with 94 citations. The distribution of citations across these countries highlights the global interest and diverse efforts in advancing research, with each contributing valuable insights despite differences in citation counts.

5.3 Collaborative Networks

The analysis shows that Kurniawan and Dwi Agus stand out with 6 documents and the highest total link strength of 11, indicating a significant role in the research network with strong collaboration or citation connections. Astalini, Astalini, and Darmaji, Darmaji each have 4 documents and a link strength of 9, suggesting active involvement in research and frequent connections within the network. Perdana, Rahmat, with 3 documents and a link strength of 5, shows moderate influence. On the other hand, Horrocks, Gary, Rosana, Dadan, and Tomczyk, Lukasz, though having multiple documents (4, 4, and 3, respectively), have a total link strength of 0, implying their works are either less connected or cited within this dataset. This highlights the contrasting levels of influence and collaboration among these authors within the research community.

5.4 Citation Impact

The most cited papers, such as " Teacher Digital Literacy: The Indisputable Challenge after COVID-19" (145 citations) and " Computational Thinking in Programming with Scratch in Primary Schools: A Systematic Review" (99 citations), the collective insights from these studies indicate a significant shift towards interactive and technology-integrated educational practices. As digital literacy becomes increasingly essential in various disciplines, educators must prioritize innovative methods that engage students and develop their competencies. The focus on sustainability, real-world applications, and interdisciplinary learning within these studies reinforces the need for a comprehensive approach to education that prepares students for future challenges and opportunities.

5.5 Thematic Focus

The keyword analysis of Digital Literacy in Remote Learning highlights several key areas of focus, with terms like "digital competence," "digital transformation," and "digitalization" demonstrating high relevance. "digitalization" has the highest relevance score of 0.95, underscoring its critical role in the ongoing shift towards digital learning environments. This reflects the growing importance of integrating digital tools and processes into education. "Digital competence" (0.80) and "digital transformation" (0.72) also feature prominently, emphasizing the need for learners to develop robust digital skills in response to the changing educational landscape. The term "medium" stands out with a relevance score of 1.27, suggesting the significance of communication channels in

supporting digital literacy. Additionally, the presence of keywords like "covid" (0.59) and "pandemic" (0.26) indicates the impact of the COVID-19 pandemic on accelerating digital adoption in education. These insights highlight the evolving priorities in digital literacy research and the importance of fostering both digital competencies and the effective use of digital mediums in remote learning contexts.

5.6 Challenges and Opportunities

The transition to remote learning has presented challenges and opportunities for enhancing digital literacy. The digital divide, exacerbated by socioeconomic inequalities, poses a significant challenge as it hinders student access to technology and online education. Educators have also faced difficulties adapting their teaching methodologies to virtual environments, requiring technical skills and effective communication strategies. However, remote learning has also opened doors for innovative pedagogical approaches, allowing educators to experiment with digital tools and foster creativity in instructional design. To fully leverage the potential of remote learning, addressing the digital divide and providing educators with the necessary support and training is crucial.

5.7 Interdisciplinary Nature

The diversity of keywords and research themes highlights the multidisciplinary nature of Digital Literacy in Remote Learning. The connections between terms like "university," "data," "covid," and "digital competence" suggest a concerted effort to leverage Digital Literacy to Remote Learning.

5.8 Future Directions

Technological advancements and educational paradigms will likely shape the future of digital literacy in remote learning. Artificial intelligence and adaptive learning technologies have the potential to personalize the learning experience, tailoring support to individual students' needs. As hybrid learning models gain traction, educators must develop skills bridging online and in-person teaching modalities. Research on the long-term impacts of remote learning on digital literacy is crucial for refining educational practices and policies. Collaborative efforts among educational institutions, policymakers, and technology developers will be essential in shaping a future where digital literacy is embedded in all aspects of learning, empowering students to thrive in the increasingly digital world.

6. Conclusion

This bibliometric analysis of digital literacy in remote learning from 2020 to 2024 has provided critical insights into the evolution of research trends, influential authors, thematic developments, and geographical contributions. As remote learning expands globally, digital literacy has become a foundational competency for students, educators, and institutions. The study's findings highlight significant growth in digital literacy research, particularly after the COVID-19 pandemic, demonstrating how digital education has transformed educational paradigms.

One of the key findings is the steady increase in research publications, with a peak in 2023 indicating the growing academic interest in digital literacy and its impact on online learning. The analysis also revealed that Indonesia, Spain, and China are leading contributors in this domain, emphasizing the role of higher education institutions and national policies in shaping digital education strategies. The thematic analysis identified digital competence, online pedagogy, and digital inclusion as the most researched topics, reflecting the increasing recognition of digital skills as essential for effective remote learning.

However, the study also uncovered several challenges in integrating digital literacy into remote learning. The digital divide, characterized by disparities in technological access, remains a significant barrier to educational equity. Additionally, the lack of standardized digital literacy curricula across institutions hinders the development of a universal framework for teaching digital skills. The rapid evolution of digital technologies further complicates this landscape, necessitating continuous adaptation and professional development for educators and students alike.

From a methodological perspective, this bibliometric study underscores the importance of using data-driven approaches to understand emerging research trends. By leveraging Scilit.net and VOSviewer, the study has identified key research gaps and potential future directions. The findings emphasize the need for interdisciplinary collaboration, bringing together researchers from education, information technology, and policy-making to advance digital literacy sustainably and inclusively.

Authors contributions

The project administrator, Tarattakan Pachumwon, is responsible for preparing the original draft and subsequent

revision and editing to produce the published work. In addition, Narudon Rudto conceptualized the methodology, while Assistant Professor Dr. Thada Jantakoon supervised the conceptualization, methodology, validation, investigation, writing review, and editing preparation. Kunawut Boonkwang and Bhibul Hongthong conducted the formal analysis. All authors reviewed and endorsed the final manuscript.

Competing interests

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Obtained.

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The Publication Ethics Committee of the Canadian Center of Science and Education.

The journal's policies adhere to the Core Practices established by the Committee on Publication Ethics (COPE).

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The data that support the findings of this study are available on request from the corresponding author. The data are not publicly available due to privacy or ethical restrictions.

Data sharing statement

No additional data are available.

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