

Review Article

A Systematic Literature Review on the Impact of Digital Literacy on Online Learning Effectiveness

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Article Info	Abstract
Article History	This study integrates bibliometric analysis and a systematic literature review (SLR) to examine the role of digital literacy in enhancing the effectiveness of online learning and its influence on educational outcomes. Although research on digital literacy in online learning has increased, many studies remain limited to isolated analyses without presenting global publication trends or addressing contextual challenges across different regions. Through bibliometric analysis of 266 Scopus-indexed documents published between 2015 and 2025, this study revealed a significant upward trend in research focusing on the integration of digital skills and technological tools to support quality education. Furthermore, the SLR conducted using the PRISMA framework showed that digital literacy plays a consistent role in improving student engagement, motivation, and academic performance in online learning settings. Despite these benefits, key challenges persist, including unequal access to technology, insufficient digital competence among educators, and limited curriculum integration. The novelty of this study lies in combining bibliometric analysis with SLR to provide a more comprehensive and holistic mapping of research developments. This study has contributed to the understanding of the importance of digital literacy as a foundation for developing inclusive, adaptive, and sustainable online learning ecosystems and supports evidence-based policy formulation.
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1. Introduction

Technology and digitalization have transformed the educational paradigm by introducing more

effective and flexible forms of online learning [1, 2]. For example, during the pandemic, home-based learning was optimized through Android applications and online platforms that facilitated virtual interactions between teachers and students [3]. Digitalization allows for the dynamic storage and refinement of subject matter while opening up opportunities for innovation in teaching, such as using digital media to reach a wider audience and increase learning effectiveness [4]. In addition, technology integration ensures flexibility of time and place, facilitates access to information, and improves the digital literacy of students and educators [5]. However, adopting online systems also demands significant adaptation by educators to manage virtual classrooms and respond to new challenges, especially in improving interaction and motivation to learn [6, 7]. Digital literacy has become increasingly critical in modern education as it supports students' ability to interact with digital learning environments. This is consistent with the findings of Juliarti et al.[5], who emphasized that digital teaching materials can significantly improve students' conceptual understanding.

Digital literacy encompasses the ability to identify, evaluate, and use digital information, which plays a crucial role in students' adaptation to online learning [8, 9]. Students with good digital literacy can access and manage learning materials, critically analyze information, and communicate effectively in a virtual environment [10]. These capabilities not only facilitate adaptation to online tools and platforms, but also improve digital security and reduce associated risks [11]. In addition, the development of digital literacy supports online formal learning that is more independent and responsive to the dynamics of the digital era [12]. Thus, increasing digital literacy is an essential foundation in creating an educational ecosystem that is adaptive and resilient to change, as well as preparing students for the demands of future competencies [13, 14].

Although research on digital literacy and online learning has expanded rapidly, there is a significant gap in the existing literature. Many studies still focus on individual analyses or narrow quantitative approaches, often failing to integrate publication trends and research content comprehensively. Additionally, most studies fail to combine bibliometric perspectives to map global research patterns while conducting a systematic review of the impact of digital literacy on the effectiveness of online learning. This gap limits the understanding of how research developments are interconnected and leaves key barriers and opportunities underexplored. Therefore, this study aims to fill this gap by combining bibliometric analysis and a systematic literature review (SLR), offering a comprehensive overview of research trends and critically assessing the influence of digital literacy on online learning outcomes. This study is expected to provide more holistic and strategic insights into developing more effective and inclusive digital education policies and practices. The significance of this study lies in its ability to provide a broader understanding of the relevance of digital literacy in contemporary education and its contribution to the creation of adaptive policies in the ever-evolving digital era. By bridging this gap, the study also seeks to lay a strong foundation

for future research and the development of educational technologies that can enhance the quality of online learning in the future [15, 16].

2. Literature Review

Globally, significant disparities exist in digital literacy between developed and developing countries [17]. In developed countries, where technological infrastructure is stronger, access to digital devices and fast internet connections allows students and educators to optimize online learning more effectively [18]. However, in developing countries, the biggest challenge faced is the technological access gap [19]. Many areas of these countries still face challenges in obtaining stable internet access and adequate technological devices. According to the UNESCO report [20], nearly 50% of the population in developing countries still struggles to access the internet at home, which limits their ability to participate in online learning. In addition, there is a difference in digital competence between students and educators, where in developed countries, digital education is more accessible and teachable. In contrast, in developing countries, digital skills are still limited, thus hindering students' ability to use technology optimally. However, digital literacy also offers substantial opportunities for developing countries, such as increased access to global education resources and the potential to engage students more inclusively through affordable online learning platforms [21, 22]. The development of digital literacy faces various challenges for students and educators. Students often have difficulty accessing the necessary technology and using learning platforms effectively. This limitation is especially noticeable in areas with poor internet infrastructure [23, 24]. In addition, many students do not have adequate digital skills to adapt to online learning, leading to a lack of confidence in learning [25]. On the educator side, the main challenges include the need to master new technologies and digital-based learning methodologies. Many educators feel unprepared for rapid changes in educational technology, which require additional training [26]. In addition, the lack of access to adequate resources and training for teachers is also a barrier to implementing digital literacy-based teaching [27]. Therefore, collaboration between educational institutions and stakeholders is needed to overcome these challenges to provide effective training programs and adequate infrastructure.

Digital literacy is widely conceptualized as a multidimensional construct encompassing technical, cognitive, and socio-emotional competencies required for effective engagement in digital environments [20, 27]. UNESCO's Digital Competence Framework [20, 28,29] similarly emphasizes the importance of ethical, critical, and creative uses of technology in education. These frameworks highlight that digital literacy is not limited to operational skills but extends to critical thinking, communication, and responsible digital engagement. This conceptual foundation is essential for analyzing how digital literacy contributes to online learning effectiveness across diverse educational contexts.

The primary objective of this study is to provide a comprehensive understanding of the role of digital literacy in enhancing the effectiveness of online learning and its impact on educational outcomes. To

achieve this, the study employs a dual methodological approach, combining bibliometric analysis and systematic literature review (SLR). The bibliometric analysis maps global trends in digital literacy and online learning research by examining selected documents from the Scopus database (2015–2025), including key themes, publication growth, and author collaborations. Meanwhile, the SLR, conducted using the PRISMA framework, critically evaluates the existing literature, offering in-depth insights into the direct impact of digital literacy on student engagement, motivation, and academic achievement in online learning. By integrating these two approaches, this study aims to fill gaps in the current literature and provide a more holistic, evidence-based perspective on the relationship between digital literacy and the effectiveness of online learning.

3. Materials and Method

This study employed a combined methodological approach integrating bibliometric analysis and systematic literature review (SLR). Bibliometric analysis was used to identify publication trends on digital literacy in online learning, while the SLR was used to evaluate the impact of digital literacy on educational outcomes. Data collection was conducted using eight main keywords identified from relevant literature. All data were obtained from the Scopus database and underwent a filtering process spanning the publication period from 2015 to 2025. This range was selected to ensure inclusion of the most recent relevant studies. The keywords used in the search were combined into several groups. The first and second keywords relate to terms such as "e-learning" AND "student achievement". These keywords were selected because they are relevant to the research topic and questions, and are frequently used in documents published in the Scopus database

Table 1. Search topics and keyword strategies used for literature retrieval.

Search Topics	Keywords
Digital Literacy and Online Learning	"digital literacy" AND "online learning" AND "learning effectiveness"
Digital Literacy and Online Learning	("digital literacy" OR "ICT literacy" OR "media literacy") AND ("online learning" OR "e-learning" OR "distance learning") AND ("educational outcomes" OR "learning outcomes" OR "academic achievement")
The Influence of Literacy on Learning Outcomes	"digital literacy" OR "ICT literacy" AND "media literacy"

All article data downloaded in CSV format were combined into one zip file. After the merging process, the number of articles was checked, and the total remained unchanged. Furthermore, the merged CSV file was processed using OpenRefine, which was used to clean the data by removing duplicates and minimizing keyword-related bias [30]. The next stage was interpreting bibliometric data using the Biblioshiny application. This application provided various important information such as keyword metadata, key data sheets details, graphs and tables showing growth of articles per year, citations trends, Three-Field Plot

diagrams, lists of the most relevant sources, local impact of sources, core sources based on Bradford's Law, cumulative frequency of occurrences, author production over time, distribution of corresponding authors by country, as well as visualizations related to the scientific contributions of countries in the field [31]. Next, the data were visualized using the VOSviewer application, which displayed relationships between articles, authors, and topics through Overlay Visualization and Network Visualization [32]. This visualization aided in understanding the patterns of linkages in the analyzed literature. As a complement, the data were also analyzed using Elicit AI, a web-based platform which supported the process of drafting research questions, literature reviews, and evidence-based decision-making. Before using Elicit AI, the previously cleaned CSV file was filtered again using Microsoft Excel to identify articles available in PDF format. The use of the OpenRefine application was highly effective in filtering data, particularly in eliminating biases from the keyword data obtained from documents [33]. This ensured that the data were more valid and clearer for interpretation. Elicit AI assisted in classifying the documents, making it easier to interpret them in line with the research questions. With proper classification, conducting a critical analysis of each document became easier, leading to more accurate and reliable findings. The choice of the 2015–2025 period was based on the increasing integration of digital technologies in education, especially during and after the COVID-19 pandemic, when online learning practices became globally widespread. Scopus was selected as the primary database because it provides comprehensive multidisciplinary coverage and ensures data validity across high-quality journals. To enhance reliability, the data cleaning process in OpenRefine was followed by manual verification to eliminate duplicates and irrelevant items. The integration of Elicit AI further supported content validation by automatically classifying studies according to methodological relevance and research questions.

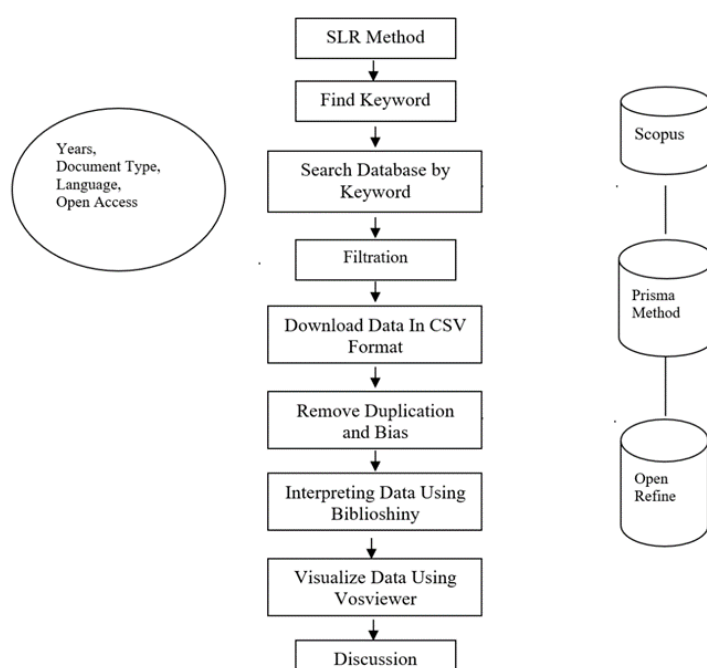


Figure 1. Research method flow diagram.

This methodological rigor ensured that the dataset used for both bibliometric and SLR analysis was accurate, comprehensive, and replicable. The combination of Biblioshiny and VOSviewer tools enabled both quantitative and visual analyses of the dataset, ensuring that publication patterns, co-authorship networks, and thematic clusters were interpreted from multiple perspectives. This visual triangulation strengthened the methodological validity and provided a more nuanced understanding of the relationships between research themes, authors, and sources.

3.1. PRISMA Method

The article selection process in the Systematic Literature Review (SLR) followed the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines, which systematically describe identification, screening, feasibility assessment, and study inclusion process. PRISMA aims to improve the quality of research reporting by providing a clear and structured framework, so the process of selection, analysis, and synthesis of studies can be understood and replicated by readers or other researchers.

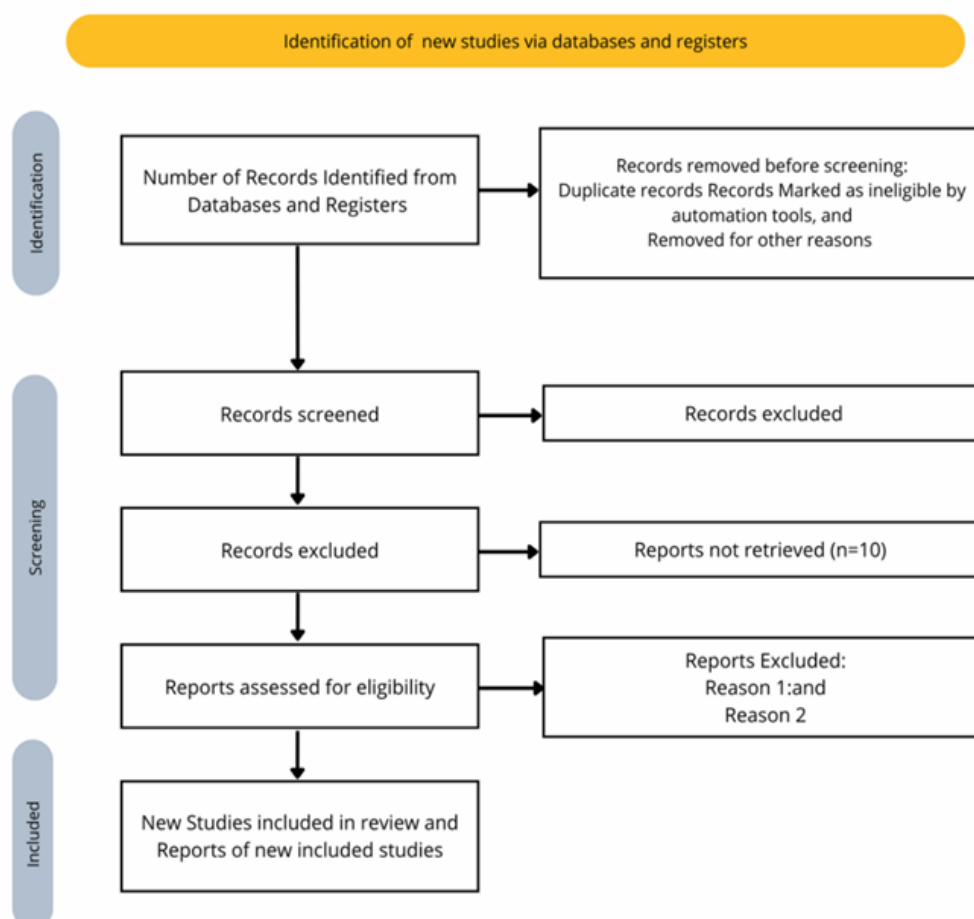


Figure 2. PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) method.

One of the main components of PRISMA is the flowchart, which outlines the steps of the identification, screening, feasibility assessment, and inclusion of studies. This chart illustrates the number of studies found through databases and other sources, the number removed due to duplication or irrelevance,

the number that are inaccessible, and the reasons for excluding studies that do not meet the criteria [34]. Thus, PRISMA not only enhances the transparency of the review process but also helps to minimize bias and increase the credibility of research results. The results of the PRISMA procedure steps were presented in Figure 17.

4. Result and Discussions

4.1. Bibliometric Study

The search strategy used Scopus data sources related to this study theme in the bibliometric analysis. Three keywords were chosen from several keywords, namely keywords for a broad search for digital literacy, a focus on digital literacy in online learning, and keywords for articles that discuss the influence of literacy on learning outcomes.

Table 2. Articles retrieved for each keyword search.

Search Topics	Keywords	Number of Articles (2015-2025)	Total Articles
Digital Literacy and Student Achievement (e-learning)	"e-learning" AND "student achievement"	120	267
Digital Literacy in Online Learning and Learning Effectiveness	"digital literacy" AND "online learning" AND "learning effectiveness" and ("digital literacy" OR "ICT literacy" OR "media literacy") AND ("online learning" OR "e-learning" OR "distance learning") AND ("educational outcomes" OR "learning outcomes" OR "academic achievement") AND ("systematic review" OR "literature review" OR "meta-analysis")	5	
The Influence of Digital Literacy on Learning Outcomes	"digital literacy" OR "ICT literacy" AND "media literacy"	142	

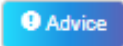
4.2. Reducing Duplicate Data

The search results from the three keywords datasets were exported, compressed into a Zip file, and imported into OpenRefine for cleaning. This application filters data, especially to see whether data were obtained from search results. In addition, this application can also be used to eliminate keyword bias contained in the data obtained. Initially, the dataset contained 267 articles; after processing in OpenRefine, the total became 266 articles.

The metadata presented in Figure 3 highlights key publication patterns that characterize the evolution of digital literacy research. The relatively young average document age (4.18 years) suggests that the field remains dynamic, reflecting the post-pandemic acceleration of studies on digital education. Moreover, the average citation per document (18.18) indicates that most publications have achieved a notable scholarly impact. The collaboration index (3.11 co-authors per document) and the international co-authorship rate (11.20%) reveal that research on digital literacy and online learning is increasingly collaborative and cross-

national. These patterns demonstrate that the topic has matured from individual local studies to globally networked investigations emphasizing shared educational challenges. These bibliometric indicators collectively provide a foundation for understanding the intellectual evolution of the field and serve as a baseline for subsequent network and thematic analyses presented in the following sections.

Metadata	Description	Missing Counts	Missing %	Status
AB	Abstract	0	0.00	Excellent
AU	Author	0	0.00	Excellent
CR	Cited References	0	0.00	Excellent
DI	DOI	0	0.00	Excellent
DT	Document Type	0	0.00	Excellent
SO	Journal	0	0.00	Excellent
PY	Publication Year	0	0.00	Excellent
TI	Title	0	0.00	Excellent
TC	Total Citation	0	0.00	Excellent
C1	Affiliation	1	0.38	Good
DE	Keywords	29	10.90	Acceptable
RP	Corresponding Author	70	26.32	Poor
ID	Keywords Plus	183	61.28	Critical
LA	Language	266	100.00	Completely missing
WC	Science Categories	266	100.00	Completely missing



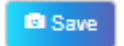
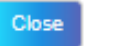



Figure 3. The metadata on DE/Keyword is good.

Furthermore, the process of interpreting bibliometric data can be carried out using the Biblioshiny application as follows. The main information data as a whole is the information obtained in the following image.

Table 3 summarizes the key bibliometric information for the dataset covering 2015-2025. Based on this table, 161 sources (journals, books, etc.) were used, and a total of 266 documents were recorded during the period. The Annual Growth Rate (AGR) of -1.81% indicates a slight overall decline in publication frequency across the decade. The documents in question have an average age of 5.18 years, which indicates that most of them are relatively recent, with an average citation per document of 18.18. This shows that the papers have had a considerable impact in their field. These sources have a total of 11257 references, which shows how extensively the references are used in each document.

In the document content, there are 850 Plus (ID) keywords that indicate a wider spread of topics, while 865 keywords from authors (DE) indicate more specific keywords for the author. This table also reveals information about author collaborations. There are 786 authors in total publications, with 47 documents written by only one author, indicating that most publications are done collaboratively. An average of 3.09 co-authors per document shows a relatively high level of collaboration between authors. In addition, 18.05% of publications were conducted internationally, reflecting global cooperation in this field.

Table 3. Key information on the data sheet.

Description	Results
Main Information About Data	
Timespan	2015 : 2025
Sources (Journals, Books, etc)	161
Documents	266
Annual Growth Rate %	-1.81
Document Average Age	5.18
Average citations per doc	18.18
References	11257
Document Contents	
Keywords Plus (ID)	850
Author's Keywords (DE)	865
Authors	
Authors	786
Authors of single-authored docs	47
Authors Collaboration	
Single-authored docs	52
Co-Authors for Doc	3.09
International co-authorships %	18.05
Document Types	
Article	211
Conference paper	42
Review	13

Regarding document type, the majority consisted of 211 articles, followed by 42 conference papers and 13 reviews. This shows that this study is more about articles and conference papers than literature reviews. Overall, this data provides an overview of collaboration trends, publication growth, the distribution of topics, and the impact of documents published in that period. The following is a graph showing the annual scientific production trends.

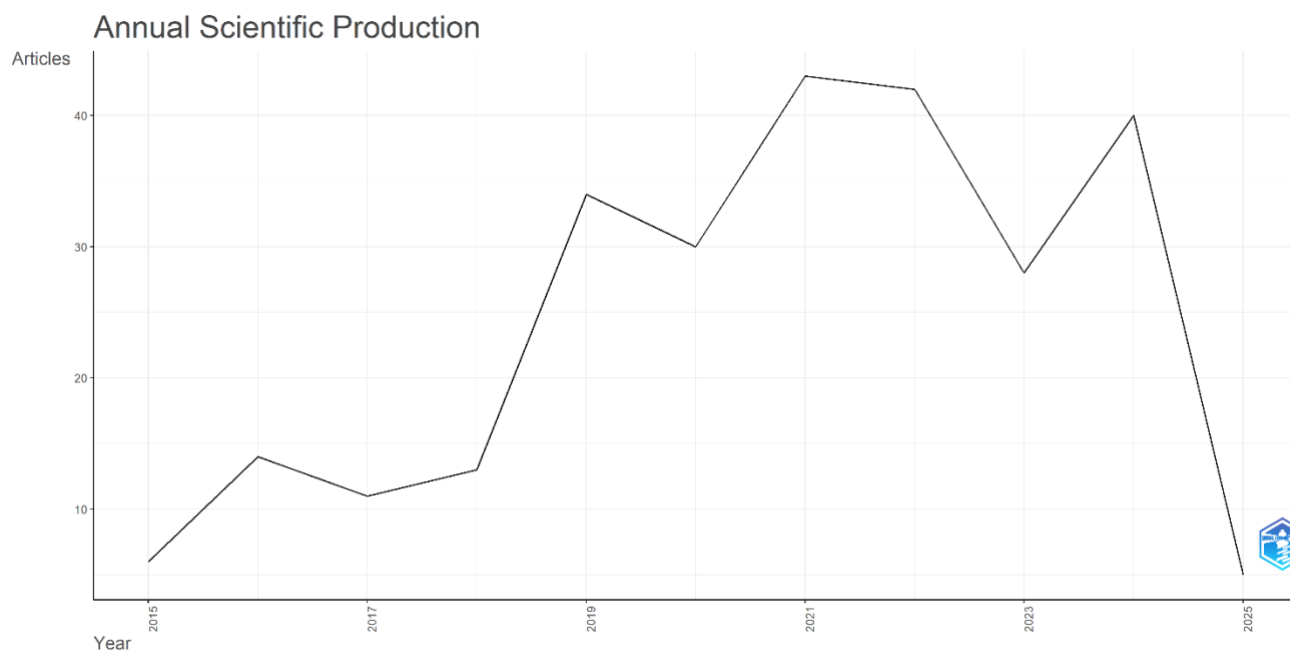


Figure 4. Year-over-year growth chart.

This can be seen in the distribution of the data table below.

Table 4. Growth every year.

Year	Articles
2015	6
2016	14
2017	11
2018	13
2019	34
2020	30
2021	43
2022	42
2023	28
2024	40
2025	5

From Figure 4 and Table 4, it is observed that the annual trend of scientific production shows an increase in the number of articles published over time. In the early period, namely 2015, the number of articles published was relatively low, remaining below 10. Then there was a significant increase in 2016, followed by a slight decline in 2017, and again a small increase in 2018. A sharp surge was seen in 2019, where the number of articles increased to more than 30, the starting point of a productive period in publication. After a slight decline in 2020, the number of articles increased again and peaked in 2021 with over 40 articles, indicating the most productive year of the decade. Although it declined slightly in 2022, the number of articles is still relatively high, only slightly down from its peak. However, a sharp decline

occurred in 2023, although the number of articles again increased significantly in 2024. A drastic decline followed this trend in 2025, where the number of articles dropped to even lower than in earlier years.

The sharp decline in 2025 is likely due to data that has not yet fully accumulated, given that the year is still ongoing or has just ended. Overall, this graph illustrates a significant upward trend in scientific publications from 2015 to peaking in 2021, followed by a plateau and declines in sharpness that require further attention to analyze whether caused by external factors, decreased topic interest, or technical reasons such as delays in data indexation.

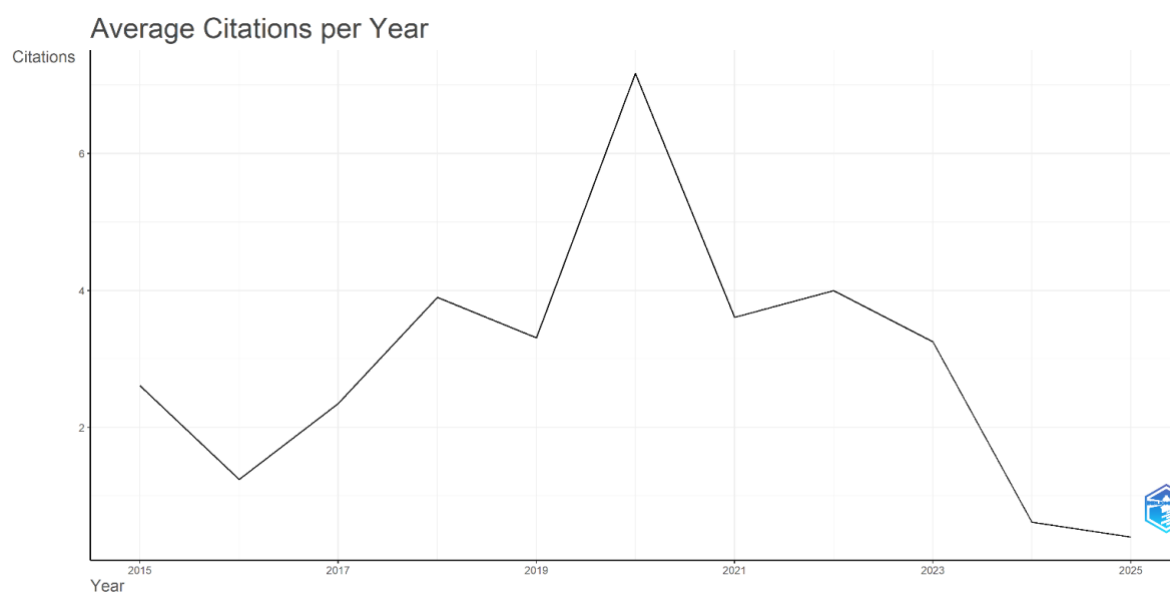


Figure 5. Graph of citations per year.

It can be explained in the form of a table distribution as below.

Table 5. Annual citation.

Year	MeanTCperArt	N	MeanTCperYear	CitableYears
2015	28.67	6	2.61	11
2016	12.43	14	1.24	10
2017	21.18	11	2.35	9
2018	31.23	13	3.90	8
2019	23.15	34	3.31	7
2020	43.00	30	7.17	6
2021	18.07	43	3.61	5
2022	15.98	42	4.00	4
2023	9.75	28	3.25	3
2024	1.25	40	0.62	2
2025	0.40	5	0.40	1

Figure 5 and Table 5 present information about the annual production of scientific articles based on several parameters, namely MeanTCperArt (average number of citations per article), N (number of articles published in that year), MeanTCperYear (average number of citations per year), and CitableYears (number

of years articles can be cited). From Table 5, the number of published articles (column *N*) tends to increase from 2015 (6 articles) to a peak in 2021 (43 articles), then decrease slightly in the following years. TCperArt shows that 2020 had the highest average citations per article (43.00), although the number of articles published was not the highest. This indicates that articles published in 2020 have a high academic impact. 2018 also stood out with an average citation per article of 31.23, despite only publishing 13 articles. MeanTCperYear, which shows how often articles are cited per year, also shows that articles from 2020 are the best performing (7.17 citations per year), followed by 2018 (3.90) and 2022 (4.00). This value decreased drastically in the following years, especially in 2024 and 2025, with only 0.62 and 0.40 citations per year, respectively. It is natural to remember that articles from recent years have less time to be cited (also reflected in the CitableYears column). The CitableYears column shows the number of years the article has a chance of being cited. Articles from 2015 have 11 years to be cited, while articles from 2025 only have 1 year. In general, there is a tendency that the longer an article is available, the greater the chance of getting more citations, but this also depends largely on the quality and relevance of the article.

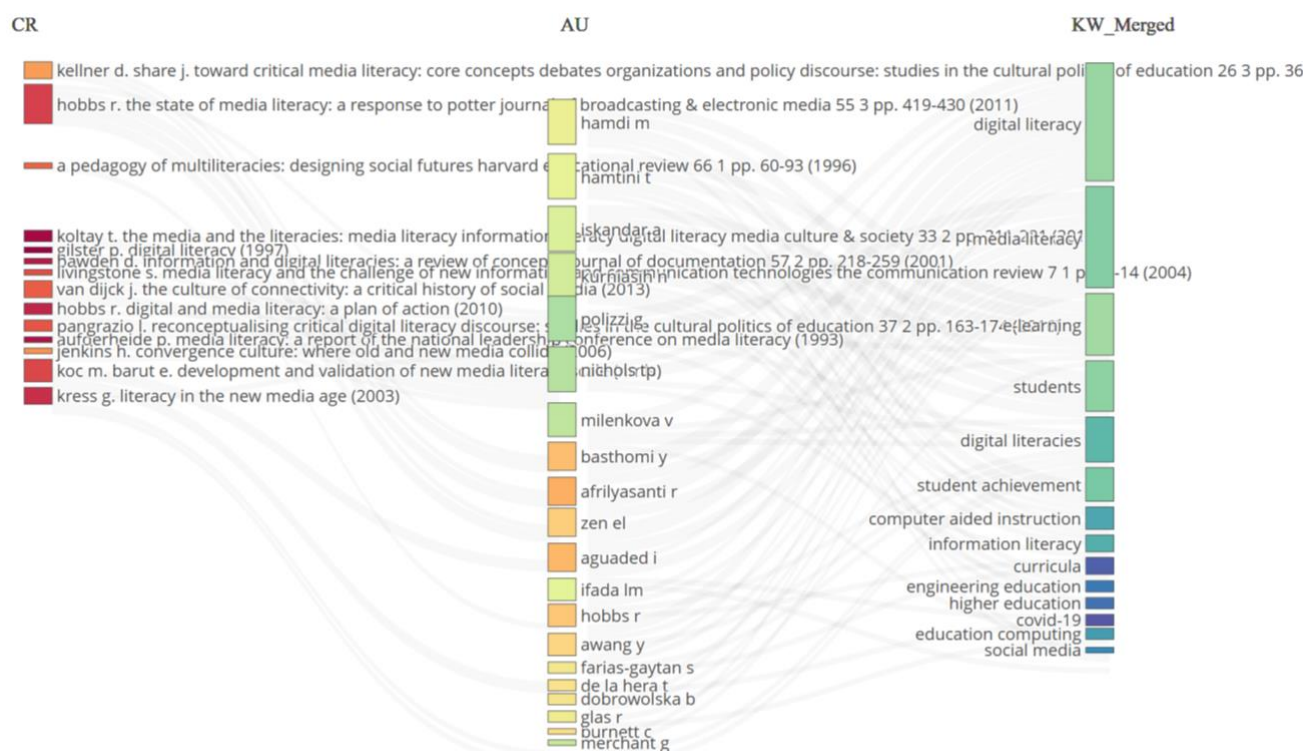


Figure 6. Diagram three-field plot.

Figure 6 shows a Three-Field Plot diagram that illustrates the relationship between three different categories, namely CR (reference scientific paper), AU (author), and DE (related topic or theme). This plot is used to show the connection between the referenced scholarly work, the authors associated with it, and the research topics they are discussing. In the CR category, two primary references are most often referenced, namely Hobbs R. with a work on media literacy, Kellner D. on media literacy, Kellner D. & Share J. on critical media literacy, and Kress G. on literacy in the new media era. These works dominate as

the primary references in the plot. In the AU category, authors who often appear include Nichols TP, Hobbs, Aguaded, and Zen et al., who refer to various key references and are involved in writing articles on digital literacy and online learning. Meanwhile, the DE category shows key themes related to research topics, such as digital literacy, e-learning, new literacy, digital/media literacy, academic achievement, and social media technology. This shows that the research referenced and written by these authors is often related to the influence of online and digital literacy on the learning process.

Figure 6 further illustrates the intellectual structure of the field by linking key references, authors, and thematic keywords. The strong co-occurrence between authors such as Hobbs, Aguaded, and Nichols and topics like “media literacy,” “digital learning,” and “student achievement” suggests that media literacy serves as the conceptual foundation of digital literacy research. The recurring appearance of journals such as *Comunicar* and the *Journal of Media Literacy Education* indicates that the discourse has gradually shifted toward interdisciplinary intersections between pedagogy, technology, and social communication. This alignment between authors, sources, and thematic focus underscores the integrative nature of the research landscape—where technological innovation, educational theory, and literacy practices converge to shape learning effectiveness in digital environments.

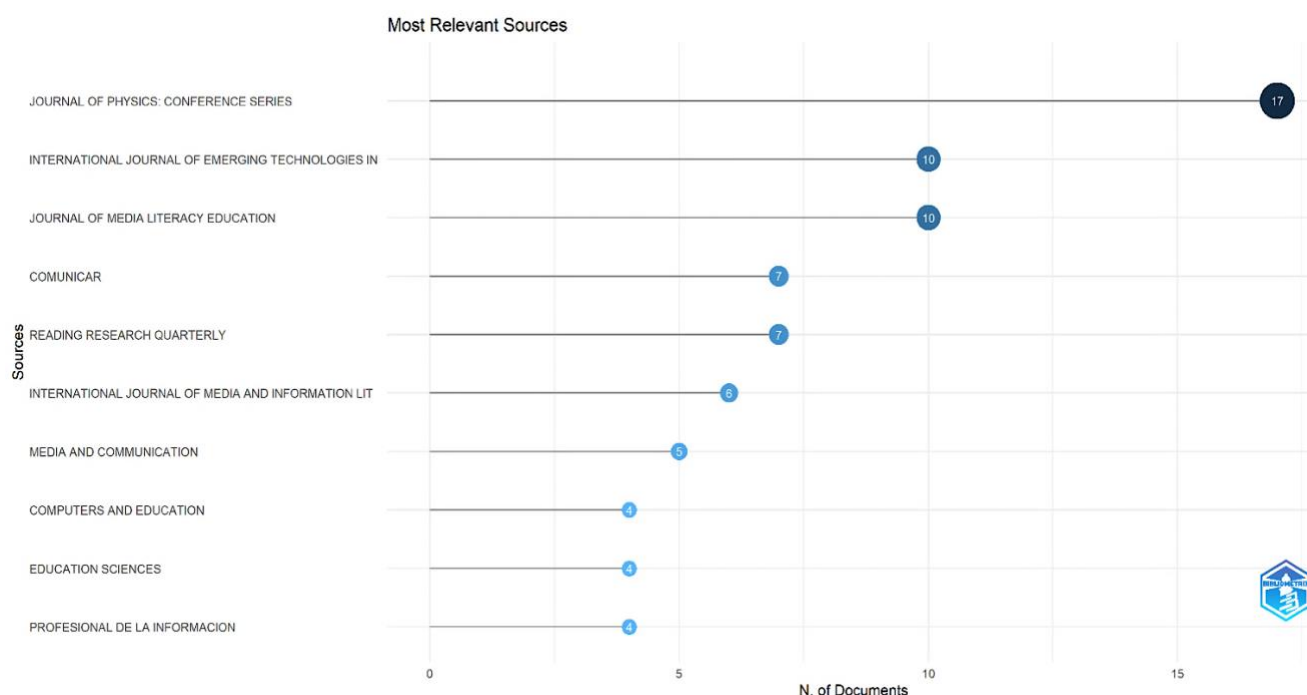


Figure 7. Most relevant source.

Figure 7 shows that the "Journal of Physics: Conference Series" is the most productive source with 17 published papers. This is quite interesting because those journals are generally related to physics; however, many conference articles relevant to the technology or digital education theme are published there. Next in order are two journals with the same number of documents, 10 documents each: namely, the "International Journal of Emerging Technologies in Learning" and the "Journal of Media Literacy

Education". Both are journals that are directly relevant to the field of educational technology and media literacy. Other journals that are also quite productive are "Comunicar" and "Reading Research Quarterly," each with 7 documents, then there is the journal; "International Journal of Media and Information Literacy" which publishes six documents, and "Media and Communication" publishes five papers, while several other journals such as "Computers and Education," "Educational Sciences," and "Profesional de la Información," publish between 3 and 4 documents. The interpretation of this image shows that publications on the topics discussed are spread across various journal types, focusing on literacy, educational technology, and multidisciplinary journal conferences. This indicates the cross-field linkage in the research being described, and highlights which journals are the most strategic to use as references or target publications for researchers in that field.

The following table is the Sources' Local Impact data. This data is taken from the top 10.

Table 6. Sources' local impact.

Source	H_Index	G_Index	M_Index	TC	For example	PY_Start
International Journal of Emerging Technologies In Learning	8	10	0.800	204	10	2016
Communicate	7	7	0.636	193	7	2015
Reading Research Quarterly	6	7	0.750	305	7	2010
Journal Of Media Literacy Education	5	10	0.714	172	10	2019
Computers And Education	4	4	0.667	376	4	2020
Education Sciences	4	4	0.667	58	4	2020
Journal Of Physics: Conference Series	4	7	0.500	59	17	2010
Information Professional	4	4	0.667	72	4	2020
Acm International Conference Proceeding Series	3	3	0.300	45	3	2016
British Journal Of Educational Technology	3	3	0.429	42	3	2014

Table 6 contains an evaluation of the top ten journals based on various bibliometric indicators, namely: h_index, g_index, m_index, TC (Total Citations), NP (Number of Publications), and PY_start (Early Year of Publication). This table is useful for assessing each journal's productivity and scientific impact in the context of relevant research. In terms of h_index (which measures productivity and the impact of citations), the International Journal of Emerging Technologies in Learning occupies the highest position with a score of h_index =8, followed by Comunicar and Reading Research Quarterly with h-indexes of 7 and 6, respectively. This value indicates that at least eight articles from the first journal have been cited at least 8 times. Meanwhile, g_index, which gives more weight to frequently cited articles, shows that the International Journal of Emerging Technologies in Learning and the Journal of Media Literacy Education are in the top position with a g_index of 10. This indicates that several articles have very high citations in these journals. For m_index (the ratio of h-index to the length of time since first publication), which is

useful for comparing the productivity of authors or journals with different publication times, the highest score of 0.800 belongs to the International Journal of Emerging Technologies in Learning, followed by the Reading Research Quarterly (0.750) and the Journal of Media Literacy Education (0.714). This shows that these journals are influential and efficient in building impact in a relatively short time.

Regarding Total Citations (TC), the journal Computers and Education stands out with 376 citations, although it has only been registered since 2020, which shows the high impact of its publications. The Reading Research Quarterly journal also has a high citation value of 305, although the number of publications (NP) is only 7, indicating the excellent quality of the publication. The PY_start column, showing the journal's initial year, is included in this analysis calculation. Journals with more recent PY_start, such as Education Sciences and the Journal of Physics: Conference Series (2020), continue to perform well, indicating a rapid growth in their influence. Overall, this data shows a combination of publication quantity (NP), quality and impact of citations (TC, h/g/m-index), and speed of growth of scientific influence (m_index), which can be an essential reference in determining relevant, quality, and strategic journals for publication or reference in the field of education and media/digital literacy.

Next is the Core Sources by Bradford'd Law data, which is taken from the top 10.

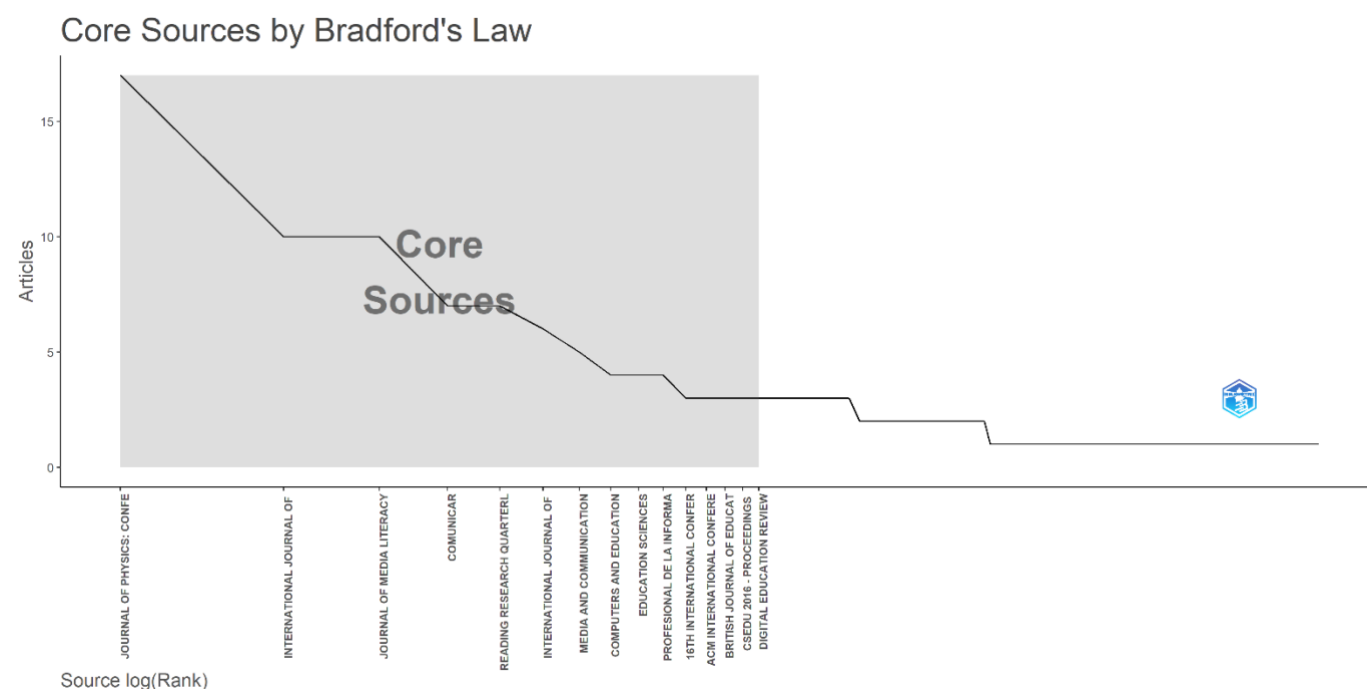


Figure 8. Core sources by Bradford'd law.

The image features Core Sources by Bradford's Law, which depicts the distribution of articles published by various sources using the principles of Bradford's Law of Scattering. In this plot, the horizontal axis shows the ranking of sources based on logs (Rank), while the vertical axis shows the number of articles published by each source (Articles). Bradford's Law describes a phenomenon in which a few journals or sources produce a large number of articles on a particular topic, while the majority of sources produce only

a small number of articles. In this plot, the Journal of Physics: Conference Series is the most dominant source, with 16 articles, followed by other sources with fewer articles. Sources such as the International Journal of Emerging Technologies in Learning and the Journal of Media Literacy Education have 10 articles each. However, after these core sources (included in the Core Sources marked with gray areas), the number of published articles began to decrease sharply. The next source has three or fewer articles, indicating that the farther the source is from the core, the less it contributes to the number of publications. Overall, the plot illustrates the distribution of articles that show a significant concentration in a few core sources, with most other sources contributing a smaller amount. This aligns with Bradford's principle that most research in a field will be concentrated in a small number of publication sources.

Next is the Cumulative Occurrences graph data.

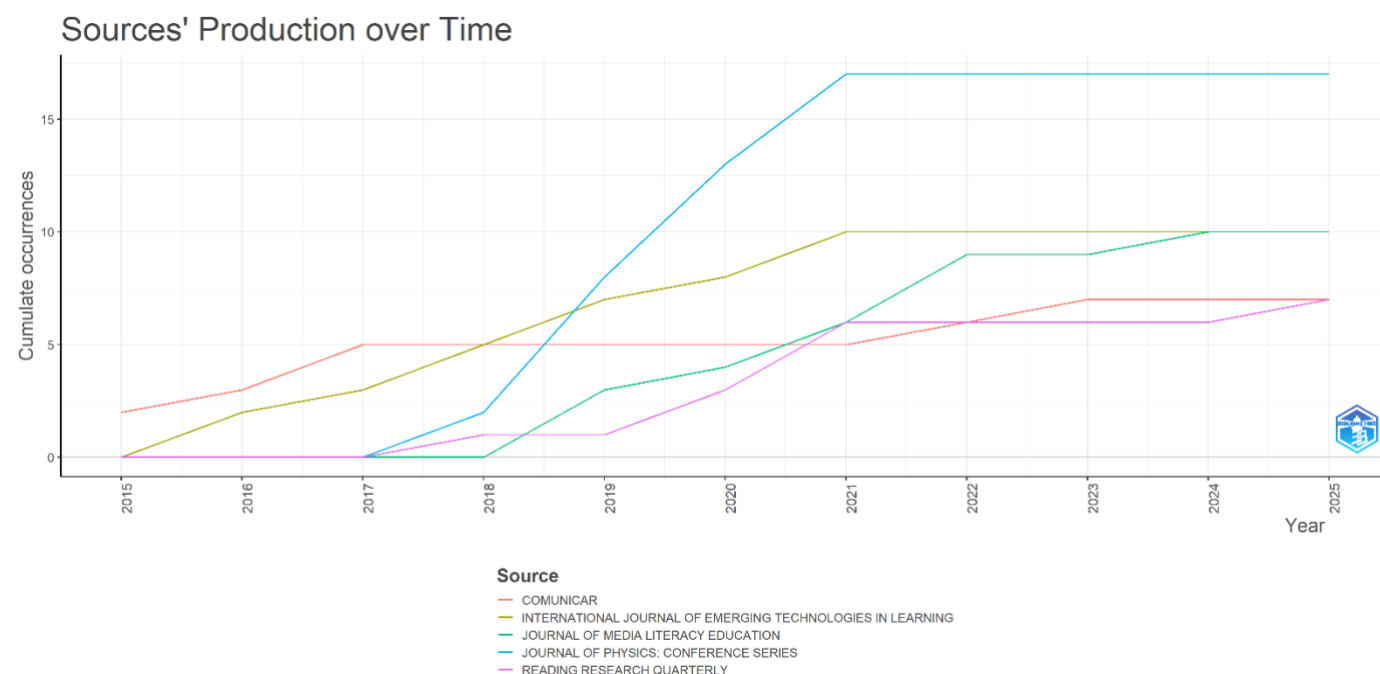


Figure 9. Cumulative occurrences.

Figure 9 shows the Cumulative Occurrences graph for various publication sources from 2016 to 2025. This graph shows the cumulative progress of publications from each source by year. Each color line represents a different journal or conference source. The graph shows that "Journal of Physics: Conference Series" (light blue line) shows the most rapid increase, especially between 2018 and 2021, until it peaked at 17 appearances and then stagnated until 2025. This indicates that although the publication of this journal was very active in certain periods, its growth stopped after 2021. The journal "International Journal of Emerging Technologies in Learning" (green line) also shows significant and consistent growth, especially from 2017 to 2022, with 10, stable contributions in this field. The journal "Journal of Media Literacy Education" (yellow line) experienced a steady increase from 2018 to 2021 and remained at number 10 until 2025. Meanwhile, "Comunicar" (red line) experienced slower and flatter growth after 2017, ending at

number 7, and "Reading Research Quarterly" (purple line) showed a steady increase to match "Comunicar" by 2025. Overall, this graph shows that there is a difference in speed and consistency in the contributions of individual journals, with some journals such as the "Journal of Physics: Conference Series" and the "International Journal of Emerging Technologies in Learning" dominating publications in certain periods.

4.3. Authors Information

The data on the most relevant authors are presented in Table 7 below.

Table 7. Most relevant authors.

Authors	Articles	Articles Fractionalized
Afriliyasanti R	3	1.00
Aguaded I	3	1.00
Basthomi Y	3	1.00
Hobbs R	3	3.00
Zen The	3	1.00
Awang Y	2	0.33
Burnett C	2	1.00
De La Hera T	2	0.34
Dobrowolska B	2	0.10
Dr	2	0.50

Table 7 presents the most relevant author data published under analysis, with two main columns: Number of Articles and Fractionalized Articles. The Number of Articles column shows the total articles published by each author. In contrast, the Fractionalized Articles column shows the author's relative contribution to the article based on their collaborations with other authors. Based on the table, there are five authors with the highest number of articles, each with three articles, namely Afrilyasanti R, Aguaded I, Basthomi Y, Hobbs R, and Zen El. However, in terms of fractional articles, only Hobbs R has a value of 3.00, indicating that he is the sole author of his third article, so his contribution is full on each. Other authors have a Fractionalized value of 1.00, which indicates that their articles are most likely the result of collaboration (for example, each article was co-authored with two other authors). Some authors with two articles, such as AWANG Y, DE LA HERA T, DOBROWOLSKA B, and DR, had lower fractionalization values (between 0.10 and 0.50), which reflects that their contributions are scattered across collaborative articles involving multiple authors. Overall, this table shows the difference between the quantity of articles produced and the weight of individual contributions in each publication, which is important to understand the level of active participation of each author in scientific publications.

Figure 10 shows a chronological visualization of the author's contribution in a bubble timeline chart from 2017 to 2025. Each circle (bubble) represents one publication, with a size and color that reflects the

frequency or intensity of the contribution (the larger and darker the color, the more likely it is to indicate a more dominant contribution). The authors of Hobbs R show engagement from 2019 to 2021, with relatively stable contributions. Authors such as Afrilyasanti R, Aguaded I, Bashthomi Y, and Zen El began to appear in publications since 2021 and are pretty active until 2023, with some larger bubbles, signifying meaningful participation in some articles. Awang Y, Dob, and Dobrowolska B also appear active in the last two years, although their contributions appear smaller. Meanwhile, B has been active in the past two years, although his contribution is smaller. Meanwhile, Burnett C and De La Hera T have a more extended range of engagements (2017–2023 and 2022–2024, respectively), albeit with lighter intensities (indicated by smaller bubbles). Overall, this graph provides a comprehensive overview of the time and intensity of each author's contribution to the field of study, as well as indicates trends in collaboration and scientific productivity from year to year.

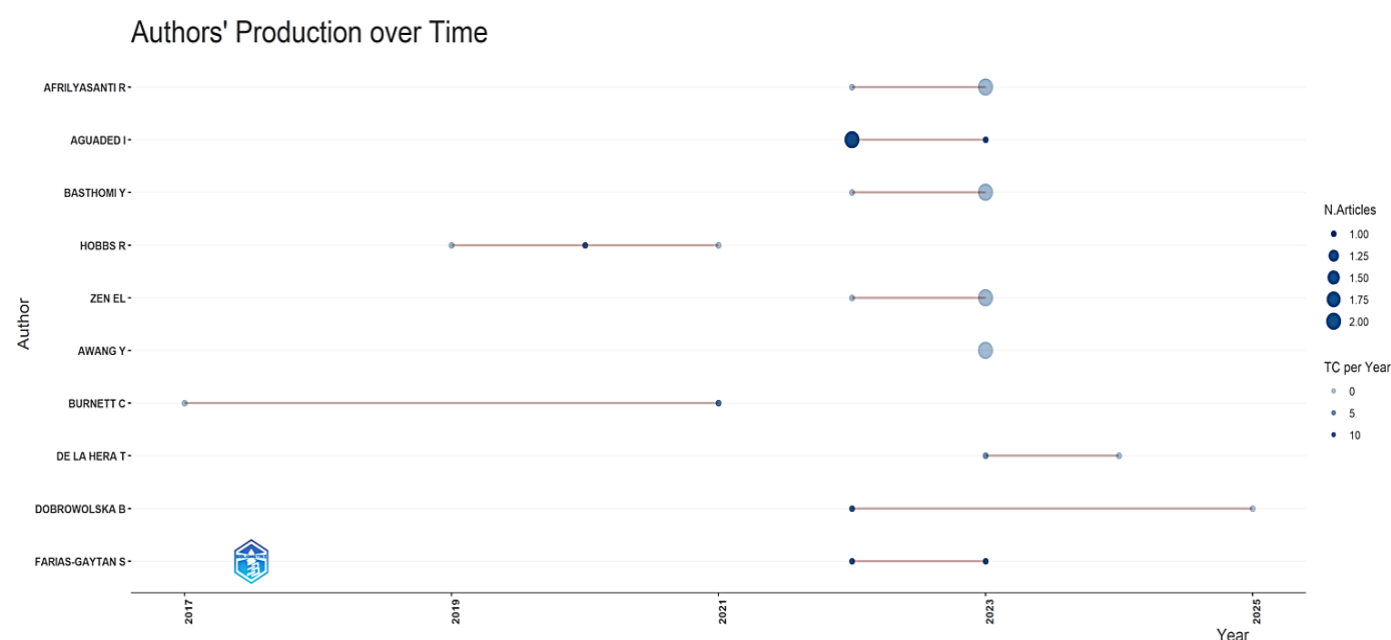


Figure 10. Authors' production over time.

Figure 11 shows the distribution of the number of scientific papers by author's country of origin by differentiating the types of collaborations, namely Single Country Publications (SCP) and Multiple Country Publications (MCP). From this graph, the United States (USA) is the most contributor with more than 25 documents, one of the most contributors with more than 25 documents, mostly in the form of domestic publications (SCPs), but also shows cross-border collaborative contributions (MCPs). Indonesia and China followed in second and third place, with a relatively high number of documents, but Indonesia showed more international collaboration (MCP) than China. Countries such as the United Kingdom, Germany, and Spain also have significant contributions, with the dominance of SCPs, indicating the strength of strong domestic research. Meanwhile, some countries, such as Malaysia, Saudi Arabia, and Korea, have moderate publications that balance SCP and MCP. Other countries such as Thailand, Turkey, and Australia also

actively participate in scientific journals, albeit in smaller numbers. This graph reflects the strength of national research and engagement in international collaborative networks, which are important indicators in the dynamics of global science development. Figure 11. shows he author's correspondence by country.

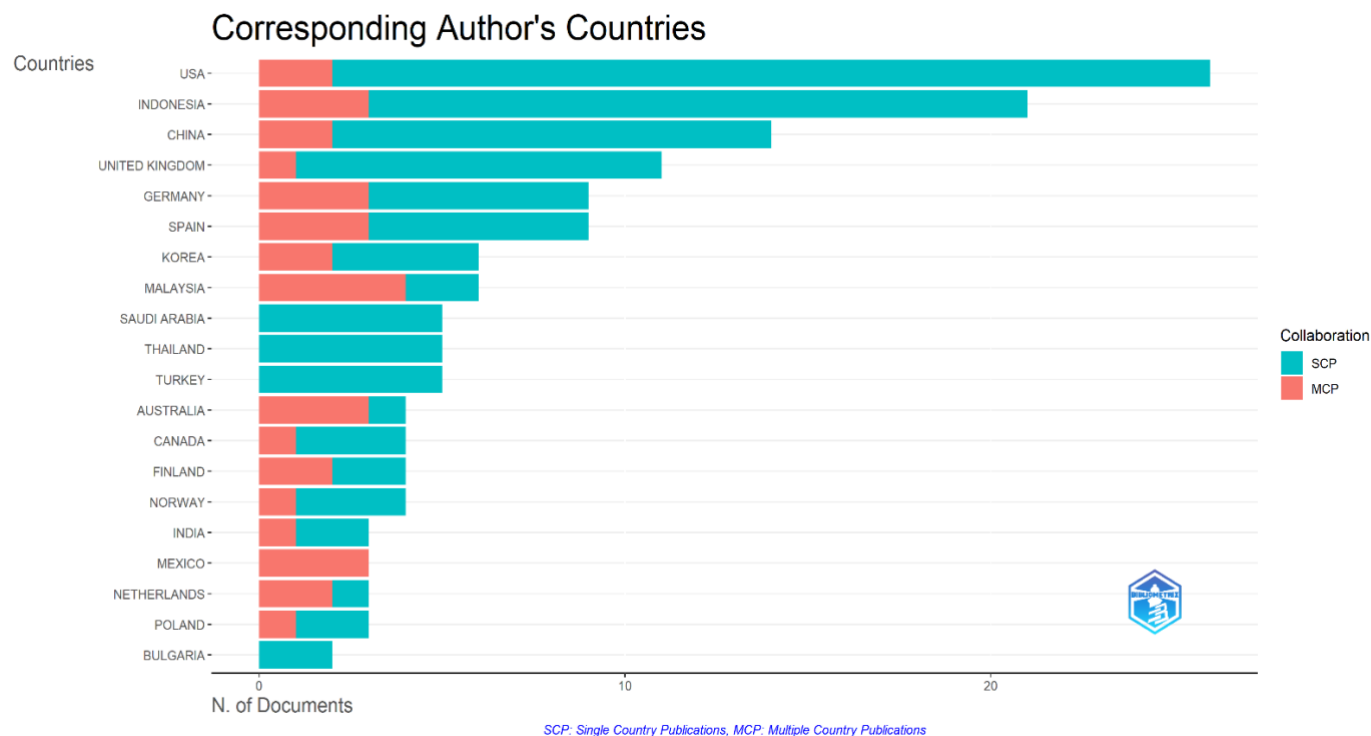


Figure 11. Author's Correspondence by country.

The following is the data on the top 10 countries' scientific production.

Table 8. Top 10 Countries' scientific production.

Country	Freq
Indonesia	138
Usa	83
Spain	64
China	42
Uk	39
Malaysia	36
Germany	21
Poland	21
Canada	19
India	19

Table 8 shows scientific production by country between 2015 and 2025, with the number of publications recorded in the Frequency column. Based on this data, Indonesia has the highest number of publications, with 138 documents, showing the country's dominance in scientific contributions in that

period. The USA follows with 83 documents, making it the country with the second-largest contribution. Spain is recorded with 64 documents, while China has slightly fewer, at 42 documents, signifying a significant contribution to global science. The UK and Malaysia have 39 and 36 documents, respectively, which show their involvement in scientific research, albeit in smaller numbers than large countries such as Indonesia and the USA. Germany and Poland have 21 documents, while Canada and India each have 19 documents. Despite their smaller contributions, these countries still play an important role in global scientific production. Overall, these data reflect considerable inequality in scientific output between countries, with large countries such as Indonesia and the USA dominating. In contrast, other countries such as Canada and India have smaller contributions. The following is the data on Countries' Production over Time. The data can be seen in the graph below.

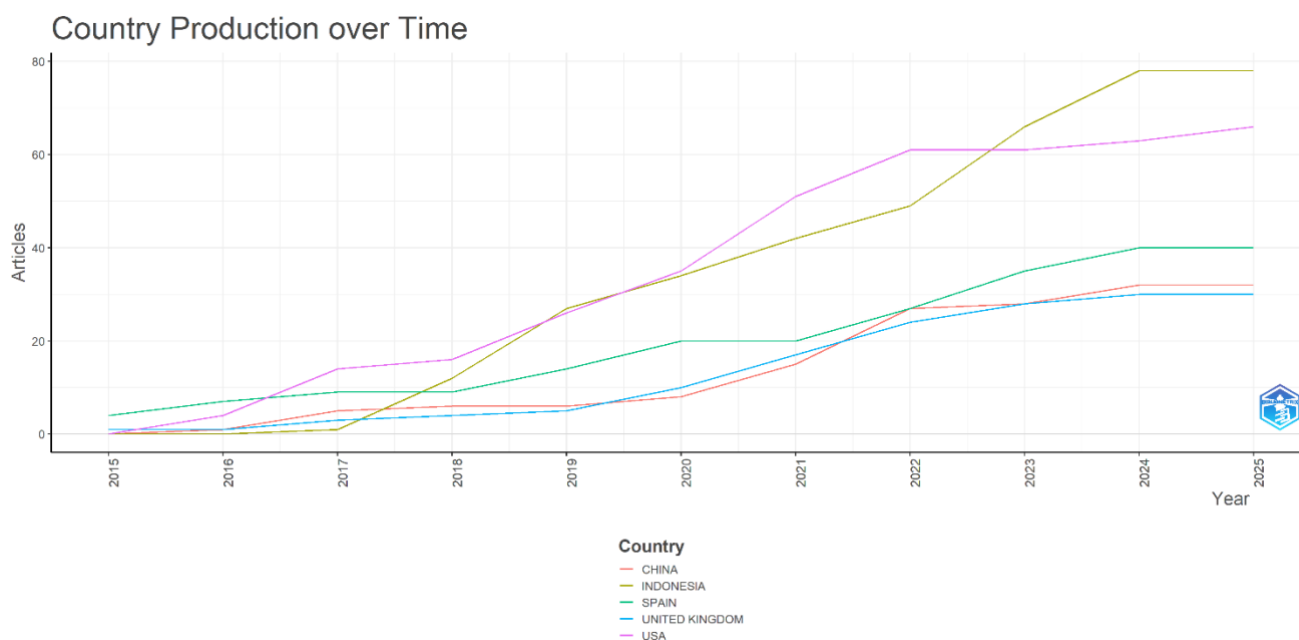


Figure 12. Graphic countries' production over time.

Figure 12 shows the trend in the number of articles published from the five main countries, China, Indonesia, Spain, the United Kingdom, and the USA, in the period from 2015–2025. From the graph, Indonesia has experienced the most significant increase in the number of publications, especially starting in 2018, and continues to increase sharply until it reaches more than 130 articles in 2024, and remains stable in 2025. The United Kingdom also shows a consistent upward trend, occupying second place after Indonesia, with the number of articles continuing to grow year on year, reaching more than 70 articles by 2025. Meanwhile, Spain and the USA showed steady but slower growth than Indonesia and the UK, with article numbers in the 60s and 40s, respectively, in 2025. China experienced significant growth until 2022, but then stagnated at around 40 articles. This graph reflects the dynamics of countries' contributions in the field of research studied, with Indonesia as the main actor, showing rapid development in the past decade.

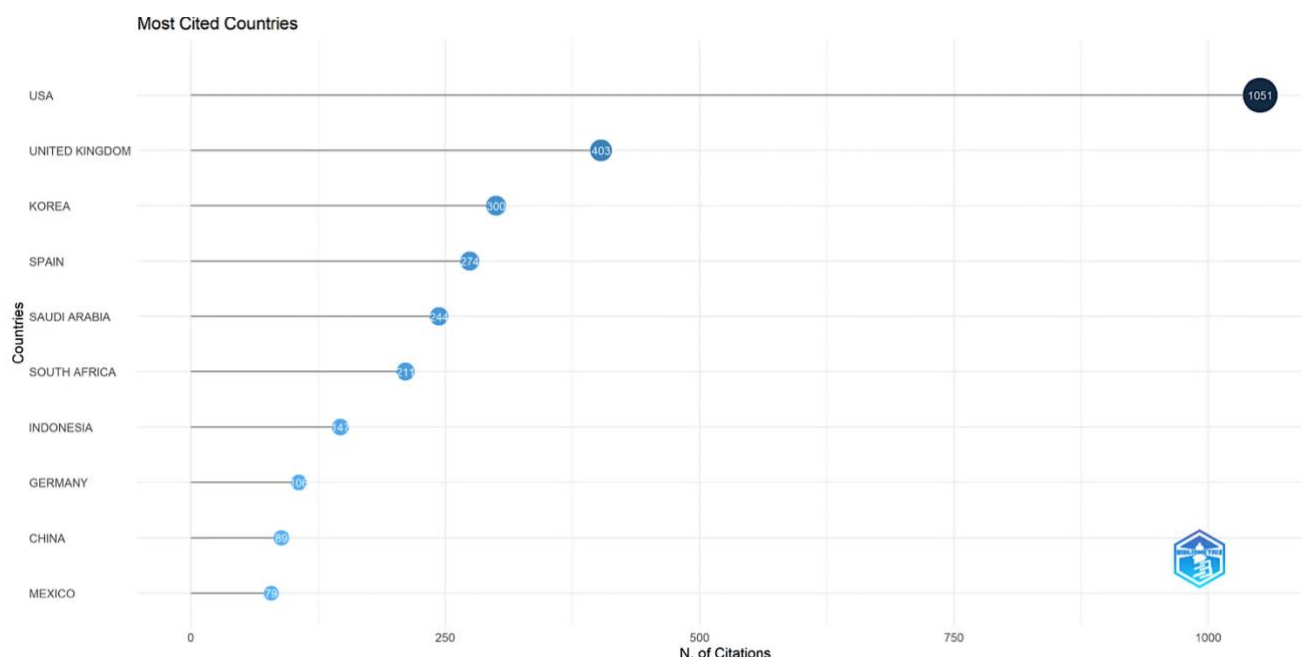


Figure 13. Most cited countries.

Figure 13 shows the number of citations by country, which shows the level of influence and recognition of scientific publications from each country. The United States (US) occupies the highest position with 1,051 citations, showing great dominance and influence in the scientific literature studied. The United Kingdom proposed it with 403 citations, and Korea and Spain with 300 and 274 citations, respectively. Saudi Arabia and South Africa followed with relatively high citations, 244 and 211, respectively, indicating activeness and involvement in the research that received recognition. Meanwhile, despite having a high number of publications, as seen in the previous graph, Indonesia produced only 141 citations, indicating that the influence or impact of its publications is still relatively low. Countries such as Germany, China, and Mexico are at a lower level with fewer than 110 citations. Overall, this graph highlights the difference between the quantity of publications and their quality or scientific impact, which is reflected in the number of citations received.

Figure 14 shows a visualization of a keyword network that illustrates the thematic relationships between research topics that often appear together in publications, particularly in the context of digital literacy and education. The node size represents the frequency with which a keyword appears, while the node color indicates the chronology of occurrence by year, ranging from blue (2020) to yellow (2022). Keywords such as "digital literacy," "media literacy," and "e-learning" emerged as the largest nodes, indicating the dominant topics that were most frequently discussed. Topics such as "students," "education," "social media," and "digital literacies" also show high connectivity, which shows the close interconnectedness between these concepts. The varied colors show a shift in research focus from early topics such as "educational technology" and "student achievement" (purplish) to more cutting-edge issues such as "fake news," "misinformation," "COVID-19," and "digital citizenship" (greenish). This indicates

the evolution of issues and the increasing relevance of digital literacy in the social and educational context, in line with the development of the times and global challenges.

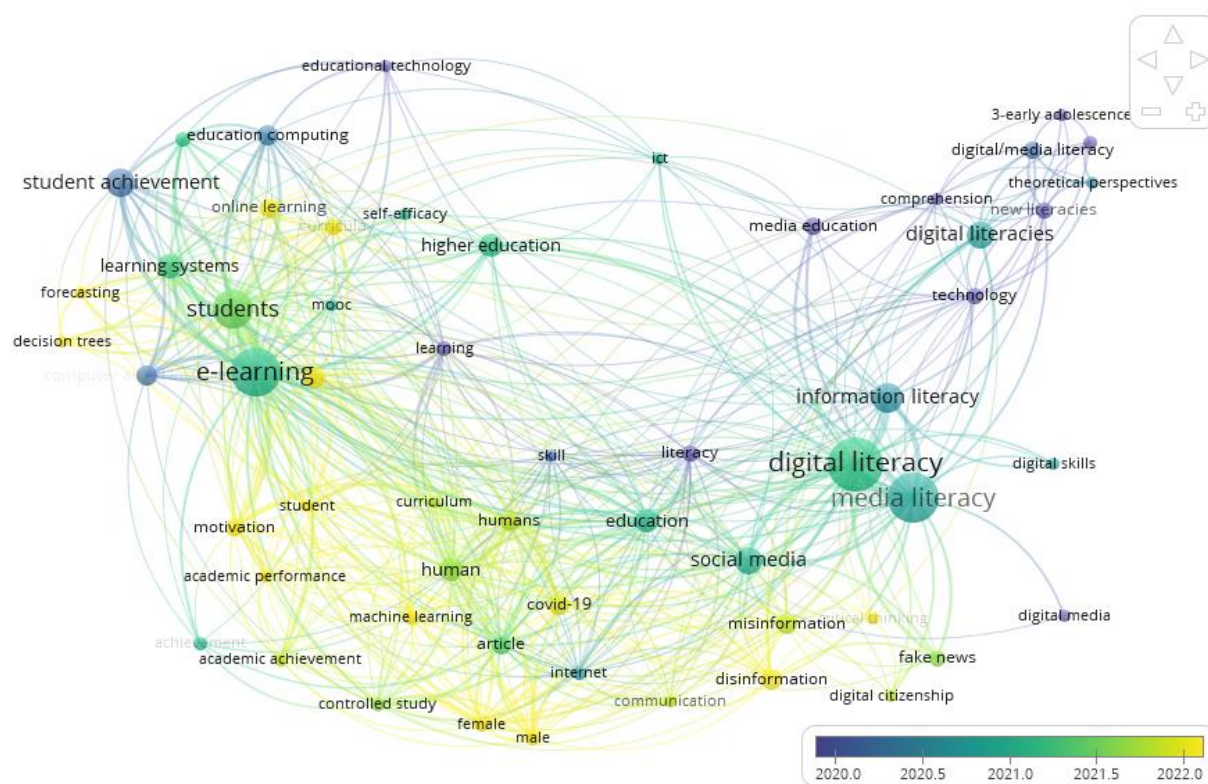


Figure 14. Overlay visualization.

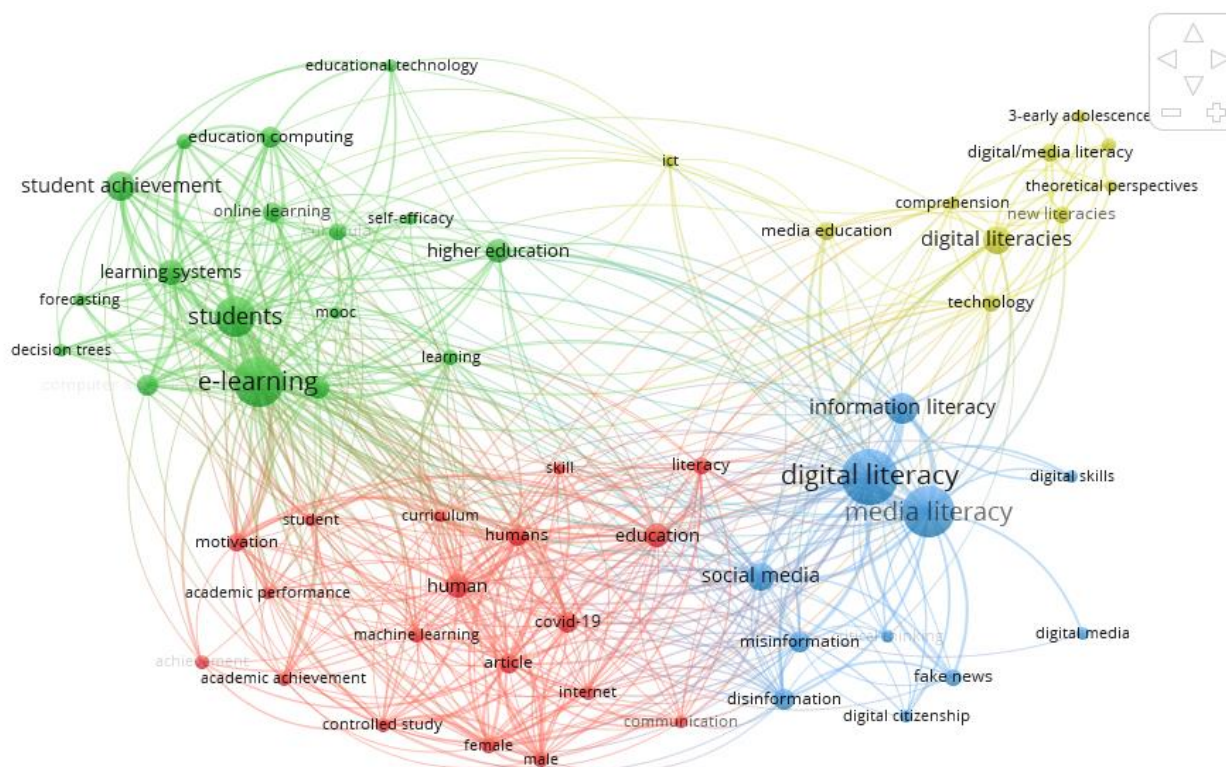


Figure 15. Network visualization.

The image is a visualization of a cluster-based keyword network (keyword co-occurrence network clustering) that groups research topics based on their thematic relevance. Each color indicates a cluster or group of topics that are closely related to each other. The green cluster dominates topics around "e-learning," "students," "learning systems," and "student achievement", reflecting the research focus on digital learning effectiveness and student achievement. The red cluster addresses issues such as "machine learning," "COVID-19," "academic performance," and "motivation," indicating the approach to technology and human factors in the context of digital education. Meanwhile, the blue cluster focuses on "digital literacy," "media literacy," "social media," and "misinformation," reflecting attention to digital literacy capabilities in facing digital information challenges. The yellow cluster, with topics such as "digital literacies," "technology," and "theoretical perspectives," shows the conceptual and theoretical dimensions of digital literacy. The interconnection between clusters indicates that these topics are interrelated and mutually reinforcing in forming a comprehensive understanding of digital literacy and education in the modern era.

Overall, the bibliometric analysis reveals that research on digital literacy and online learning has evolved around three dominant clusters: (1) educational technology and learning outcomes, (2) media and information literacy, and (3) psychosocial and motivational aspects of online learning. These clusters align closely with the key findings of the SLR, which emphasize the positive impact of digital literacy on student engagement, motivation, and performance. The convergence of both methods demonstrates that bibliometric mapping provides the structural overview, while the SLR offers evidence-based depth, together forming a coherent understanding of how digital literacy enhances online learning effectiveness globally.

4.4. SLR Study

Among the 266 records collected, 211 are identified as journal articles, which constitute the primary focus of this analysis.

Table 9. Data distribution.

No	Types	Sum
1	Article	211
2	Conference Paper	42
3	Review	13
Total		266

4.5. Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA)

The process of selecting articles in this systematic review is carried out by referring to the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines, which systematically

describe the identification, screening, feasibility assessment, and inclusion of studies in a Systematic Literature Review (SLR) analysis, as seen in Figure 16.

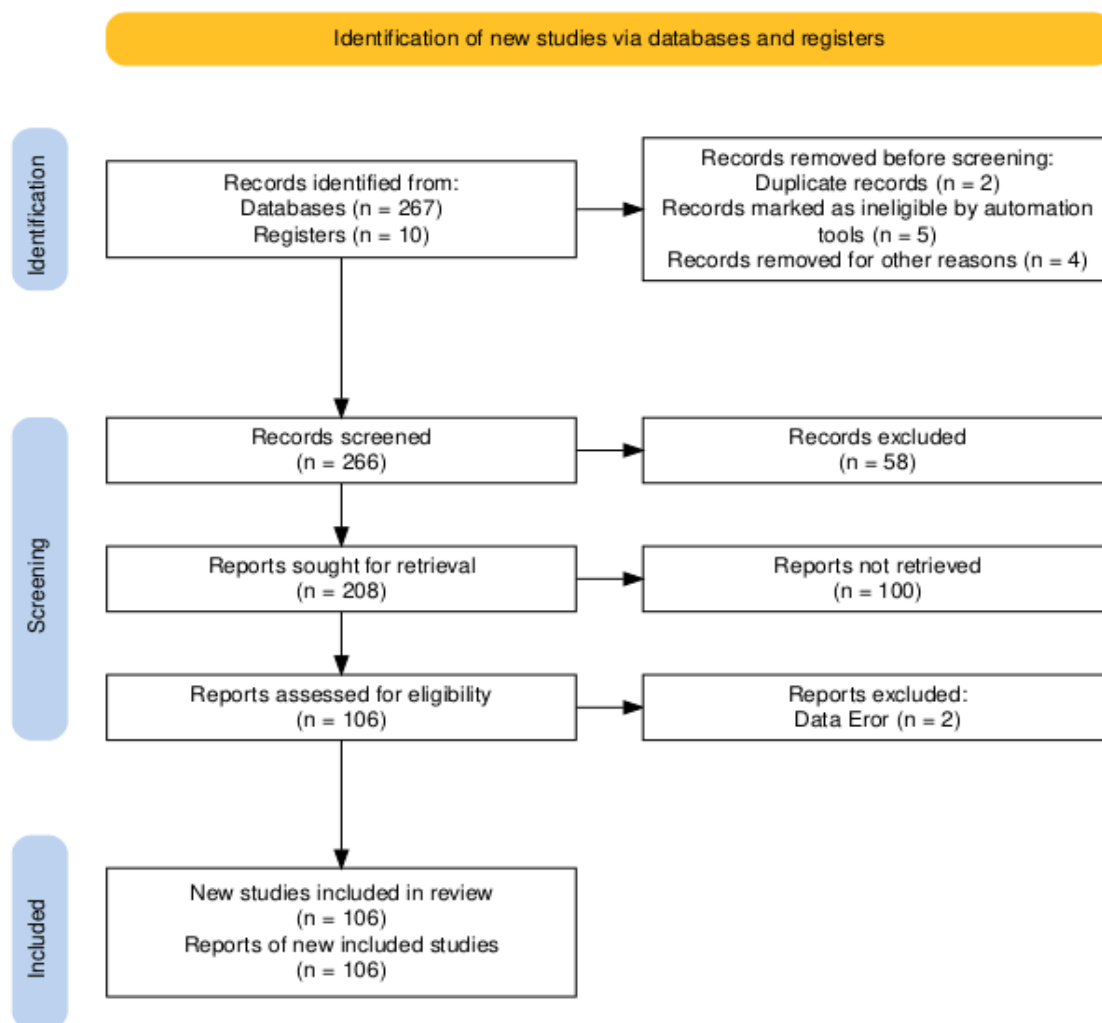


Figure 16. Results of the PRISMA method.

At the identification stage, a total of 277 data were successfully collected by researchers, consisting of 267 data from databases and 10 data from other registrations. Before the screening process, records that do not meet the criteria are deleted early. A total of 11 data were deleted for specific reasons; two duplicates, five automatically deleted by the tool for not meeting criteria, and four deleted for other unstated reasons (e.g., incomplete or irrelevant records). Thus, 266 data points entered the screening stage. At this stage, a selection was made based on titles and abstracts, excluding 58 records judged irrelevant. Furthermore, a total of 208 reports were sought for further analysis, but 100 of them were not obtained due to limited access or other technical issues. Of the 108 successfully obtained reports, 106 were deemed worthy of further analysis through a full-text reading. Even so, two reports were excluded because data errors were found. Finally, a total of 106 studies that met all selection criteria were included in the systematic review. This process shows careful and transparent selection, ensuring that only relevant and valid studies are included in the final study.

Table 10. Classification of research methods.

Category Methodology	Number of Papers	Percentage ($\pm$)	Example Methodology
Quantitative	28	~40%	Surveys, controlled experiments, SEM, regression analysis
Qualitative	18	~25%	Interviews, case studies, text analysis, grounded theory
Mix (Mixed Method)	12	~17%	Combined survey + interview, pre-test/post-test with qualitative analysis
Literature/Document Studies	7	~10%	Systematic review, bibliometrics, policy analysis
Technology Experiments	5	~7%	Trial of digital platforms (e.g., gamification, blockchain)

Table 10 presents data on the categories of research methodologies used in a number of scientific papers, including method types, number of papers, percentage use, and examples of methodologies applied. Quantitative methods dominated with 28 papers or about 40%, using techniques such as surveys, controlled experiments, Structural Equation Modeling (SEM), and regression analysis. Qualitative methods include 18 papers, or 25%, using interviews, case studies, text analysis, and grounded theory. Mixed methods (combined quantitative and qualitative) were used in 12 papers (17%), combining surveys, interviews, and pre-test/post-test analysis. Literature or document studies include 7 papers (10%), focusing on systematic insights, bibliometrics, and policy analysis. Technological experiments are recorded in 5 papers (7%), with applications on digital platforms such as gamification and blockchain. This data indicates that research in the primary field employs a quantitative approach but demonstrates diversity in methods to achieve comprehensive results.

Table 11. Classification of Mind Finding.

Discovery Categories	Number of Papers	Percentage	Sample Findings
Effectiveness of Digital Interventions	22	~30%	Improved misinformation detection capabilities, improved learning scores through digital tools
The Impact of Online Learning	18	~25%	Online vs in-person comparison, student preference, technical challenges
Media/Digital Literacy	15	~20%	Competency gaps, teacher roles, integrative curriculum
Psychosocial Factors	10	~14%	Motivation, student involvement, well-being (well-being)
Policy & Curriculum	5	~7%	Education policy recommendations, digital literacy standards
Educational Technology Innovation	3	~4%	Blockchain, gamification, AI in education

Table 11 shows the distribution of research findings categories based on the number of papers, percentages, and examples of relevant findings. The effectiveness of digital interventions is the most dominant category of findings, recorded in 22 papers, or around 30%, focusing on improving information

detection capabilities and improving learning scores through digital tools. The impact of online learning ranks second place with 18 papers (25%), discussing the comparison between online and face-to-face learning, student preferences, and technical challenges faced. Media/digital literacy reveals in 15 papers (20%), highlighting the role of teachers and integrative criteria. Psychosocial factors are discussed in 10 papers (14%) covering motivation, student engagement, and well-being. Policies and curriculum, as well as educational technology innovations, are recorded in 5 papers (7%) and 3 papers (4%), respectively, with findings that include education policy recommendations, digital literacy standards, and the use of innovative technologies such as blockchain, gamification, and AI in education. This data shows that the effectiveness of digital technology and online learning is the focus in the study.

Table 12. Classification study design.

Categories Design	Number of Papers	Percentage	Sample Study	Key Characteristics
Experimental	19	~26%	"Combating fake news through media literacy education"	Control group vs experimental, controlled intervention
Quasi-Experimental	15	~21%	"The impact of blended learning on medical students"	Non-random, pre-test/post-test assignments
Observational (Cross-sectional)	14	~19%	"Social media literacy among oil palm farmers"	One-time survey, correlation analysis
Qualitative	12	~16%	"Teachers' perspectives on media literacy"	Interviews, case studies, and content analysis
Mixed Method	8	~11%	"Digital literacy practice in Yogyakarta schools"	Quantitative & qualitative combination
Literary/Systematic Studies	5	~7%	"Digital transformation and literacy: SLR"	Literature review, meta-analysis

Table 12 shows the distribution of research design categories by number of papers, percentages, research examples, and key characteristics. Experimental design was the most dominant category, with 19 papers or about 26%, characterized by control groups and interventions, such as research on educational media literacy to counter fake news. Quasi-experimental design follows with 15 papers (21%), involving non-random assignments and pre-post testing, e.g., a study on the impact of blended learning on medical students. Observational (cross-sectional) research includes 14 papers (19%), generally using one-time surveys and correlation analysis, such as a study of social media literacy among oil palm farmers. Qualitative approaches include 12 papers (16%), relying on interviews, case studies, and content analysis to explore perspectives, e.g., teachers' views on media literacy. Mixed methods appear in 8 papers (11%), investigating literacy practices in schools.

Finally, a literary or systematic study involving meta-analysis is found in 5 papers (7%). Generally, experimental and quasi-experimental methods are more widely used to analyze the effectiveness of interventions in digital literacy and education.

Table 13. Future research classification.

Recommended Categories	Number of Papers	Percentage	Example Recommendations	Implication
Validation & Replication	24	~33%	"Further studies are needed with a larger and more diverse sample."	Reinforcing key findings
Long-Term Interventions	18	~25%	"Longitudinal research to look at sustainable effects"	Sustainability impact
Technological Innovation	12	~16%	"Exploration of AI and blockchain in education"	Digital transformation
Contextualization	10	~14%	"Studies in rural areas & cross-cultural"	Global relevance
Curriculum Integration	6	~8%	"Development of national digital literacy standards"	Education policy
Methodology	4	~5%	"Mixed method approach with in-depth qualitative data"	In-depth analysis

Table 13 displays data on the categories of research recommendations, complete with the number of papers, percentages, examples of recommendations, and their application. Validation and replication are the most dominant recommendations, with 24 papers (~33%), demonstrating the importance of conducting follow-up studies with a larger and more diverse sample to reinforce key findings. Long-term interventions were recommended in 18 papers (~25%), recommending longitudinal studies to assess the ongoing effects of the interventions—which sometimes resulted in the discontinuation of the study results. Technological innovations were noted in 12 papers (~16%), focusing on exploring new technologies such as AI and blockchain in education, leading to digital transformation. Contextualization is suggested in 10 papers (~14%) with recommendations to conduct studies in rural and cross-cultural areas to increase the relevance of global research. Curriculum integration appears in 6 papers (~8%), encouraging the development of national digital literacy standards, which have implications for education policy. Finally, the methodology is discussed in 4 papers (~5%), recommending a mixed-methods approach with in-depth qualitative data for a more comprehensive analysis. These data underscore the importance of strengthening research with validation, expanding the scope of the context, and encouraging technological innovation in education.

Table 14. Classification summary.

Category Summary	Number of Papers	Percentage	Sample Summary	Key Implications
Effectiveness of Interventions	31	~42%	"Digital literacy interventions increase misinformation detection capabilities by 21%"	Empirical evidence of a successful approach
Comparison of Learning Methods	18	~25%	"Hybrid learning is more effective than full online learning for STEM subjects."	Impact of learning models
Digital Literacy Competencies	12	~16%	"Journalism students were able to identify 78% of fake news after training"	Balance of competence
Psychosocial Impact	7	~10%	"Gamification increases motivation to learn but has no effect on achievement."	Non-academic factors
Technological Innovation	5	~7%	"Blockchain reduces diploma verification costs by up to 60%"	Technical solutions

Table 14 summarizes research findings categories, number of papers, percentages, examples of summary findings, and key strengthening. The Intervention Effectiveness category dominated with 31

papers (~42%), showing empirical evidence that digital literacy intervention approaches effectively improve misinformation detection capabilities. Learning Methods was recorded in 18 papers (~25%), highlighting that the hybrid learning model is more effective than full online, which impacts the selection of learning models. Digital Literacy Competency appeared in 12 papers (~16%), with the important finding that training can improve students' ability to identify fake news, thus highlighting the need for a balance of digital competencies. Psychosocial impacts are discussed in 7 papers (~10%), revealing that gamification increases learning motivation but does not directly impact academic achievement, emphasizing the importance of non-academic factors. Finally, Technological Innovation is recorded in 5 papers (~7%), including blockchain applications reducing diploma verification costs, offering innovative solutions in education. This data illustrates the focus of the study: intervention effectiveness, learning methods, digital literacy, psychosocial factors, and technology application.

The main finding is that digital literacy significantly increases student engagement, motivation, and academic achievement in online learning, in line with the results of a previous study by Bughrara et al. [18] and Irhandayaningsih [8], which emphasizes the role of digital skills in the adaptation and success of online learning. However, the study also uncovered significant challenges that have not been addressed in depth, such as technology access gaps and lack of educator training, which are also important findings in the UNESCO report [9] and research by Rizal et al. [10]. Thus, this study strengthens the argument that digital literacy is not only a technical aspect but also requires attention to social and policy factors to ensure equitable access and quality of digital education. Theoretically, these results strengthen the framework of digital literacy as a multidimensional ability that includes cognitive, technical, and social-emotional aspects. This study expands the understanding that digital literacy should be considered the foundation of an effective and inclusive online learning ecosystem, supporting constructivist learning theories that place students as active actors in the learning process. This concept is also relevant to the 21st-century educational paradigm that demands critical thinking, collaboration, and creativity skills integrated with mastery of digital technology. Integrating bibliometric results with the SLR findings strengthens the argument that digital literacy acts as both a prerequisite and a catalyst for effective online learning. The high publication density in journals focusing on education and media studies mirrors the growing recognition that digital literacy is not purely technical but socio-cognitive in nature. The consistent emphasis on teacher competence, learner autonomy, and ethical use of digital tools across reviewed studies confirms the necessity of embedding digital literacy within pedagogical design and national curricula.

In terms of practical implications, these findings provide concrete direction for educational institutions and policymakers to prioritize the development of digital literacy through intensive training for educators and improving technological infrastructure [35]. An adaptive and technology-based approach to learning must be supported by a curriculum that integrates digital literacy comprehensively so that students

are not only able to operate devices but also able to assess, utilize, and participate critically in the digital environment. In addition, collaboration between stakeholders, including governments, schools, and communities, is indispensable to address access gaps and expand digital inclusion. However, implementing these recommendations must consider different socio-cultural contexts and infrastructure conditions, especially in developing countries. This demands more contextual and longitudinal follow-up research to understand the long-term impact of digital literacy interventions. In addition, technological innovations such as artificial intelligence and blockchain offer great potential to support learning, personalization, and data security. Still, they need to be empirically tested to be implemented effectively and ethically in online education. Overall, this study enriches the literature with empirical data and bibliometric analysis and opens up a space for discussion on how digital literacy can be the key to sustainable and inclusive educational transformation amid the acceleration of global digitalization. The integration of these bibliometric insights with SLR findings provides both macro-level trends and micro-level evidence, strengthening the conclusion that digital literacy serves as a bridge between technology adoption and effective learning outcomes.

5. Conclusion

This study concludes that the integration of bibliometric analysis and systematic literature review (SLR) provides a comprehensive understanding of digital literacy's impact on online learning and educational outcomes. Key findings reveal that digital literacy significantly enhances student engagement, motivation, and academic performance. However, challenges such as technology access gaps, insufficient educator training, and inadequate curriculum integration persist. The novelty of this study lies in combining two methodological approaches, offering a global map of research trends while addressing critical gaps and implementation challenges that have often been overlooked in existing studies. For policymakers, it is recommended to prioritize investments in improving digital infrastructure, particularly in developing countries, and to ensure equitable access to technology for all students. Educators should receive ongoing professional development in digital tools and teaching methods, emphasizing the integration of digital literacy into all levels of the curriculum. Furthermore, a concerted effort should be made to incorporate digital literacy standards into national education policies. Future research should focus on longitudinal studies in diverse local contexts, examining the long-term effects of digital literacy interventions and exploring the role of technological innovations like AI and blockchain in enhancing the adaptability and sustainability of education. In summary, this study demonstrates that digital literacy functions not only as a technical competence but as a transformative capacity that fosters inclusive and adaptive education in the digital era. The findings provide a strong evidence base for future policies and research aimed at reducing digital divides and promoting equitable learning opportunities worldwide.

This study concludes that the integration of bibliometric analysis and systematic literature review

provides a comprehensive understanding of digital literacy's influence on online learning. Digital literacy is shown to enhance student engagement, motivation, and academic performance, although issues such as unequal technological access, limited teacher training, and insufficient curriculum integration remain challenges. This study contributes by offering a holistic view of global research trends while identifying practical gaps that require further attention.

While the analysis is broad, it is limited by variations in research contexts and reliance on secondary data, meaning the findings should be interpreted with caution. Future studies are encouraged to incorporate primary empirical evidence and examine long-term effects in diverse educational settings. Strengthening digital infrastructure, expanding teacher professional development, and embedding digital literacy more deeply into learning design are essential steps to support more inclusive and sustainable online education.

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