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Review Article

The Evolution of Scientific Literacy Research in Science Education: A Bibliometric Analysis of Trends, Themes, and Collaboration (2016-2025)

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ABSTRACT

Purpose of the study: This study aims to map the development of scientific literacy research within the field of science education by examining publication trends, influential contributors, thematic structures, and collaboration patterns based on Scopus-indexed literature published between 2016 and 2025.

Methodology: A bibliometric analysis was conducted using the Scopus database. Relevant journal and review articles were retrieved using the keywords "scientific literacy" and "science education." Bibliographic data were analyzed and visualized using the Bibliometrix package (R software) to examine publication growth, source impact, thematic evolution, and collaboration networks.

Main Findings: The results reveal a steady increase in research output on scientific literacy in science education over the past decade, with contributions concentrated among a limited number of authors, journals, institutions, and countries. Core research themes include scientific literacy, science education, and nature of science, while emerging topics such as misinformation, climate literacy, digital literacy, and citizenship have gained prominence in recent years. Collaboration patterns indicate stable yet selective networks at both author and country levels.

Novelty/Originality of this study: This study provides a comprehensive decade-long bibliometric mapping that integrates trends, contributor impact, thematic structures, and collaboration patterns in scientific literacy research within science education. The findings offer an updated multidimensional overview of the field, support clearer positioning of future research agendas, and highlight underexplored themes and opportunities for broader international collaboration.

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1. INTRODUCTION

Scientific literacy has increasingly been recognized as an essential competence in twenty-first-century education, particularly in response to the growing complexity of global challenges related to science, technology, the environment, and health [1]-[5]. Rather than being limited to the acquisition of scientific concepts and factual

knowledge, scientific literacy encompasses individuals' abilities to understand science-based information, critically evaluate scientific evidence, and apply such knowledge in informed and responsible decision-making in everyday life [6]-[8]. Within this context, science education plays a strategic role in fostering scientific literacy that is aligned with the demands of contemporary society, positioning scientific literacy as a central objective of science education and an important indicator of instructional quality across educational systems [9]-[11].

In educational practice, scientific literacy functions as a bridge between scientific knowledge and its application in real-world contexts [12]. Science learning that is oriented toward scientific literacy is expected to support the development of critical thinking skills, problem-solving abilities, and informed understanding of contextual scientific issues, including those related to environmental sustainability, public health, and technological advancement [13]–[15]. As scholarly interest in scientific literacy has grown, research in science education has expanded considerably, encompassing a wide range of topics such as curriculum and instructional design, assessment of scientific literacy, integration of STEM approaches, utilization of digital technologies, and the incorporation of social, cultural, and environmental contexts into science learning [16]-[18].

The substantial growth of publications addressing scientific literacy in science education has resulted in an increasingly broad and fragmented research landscape [19], [20]. Studies in this field are distributed across numerous journals, disciplinary perspectives, and geographical regions, making it challenging to obtain a comprehensive overview of the knowledge structure, research trajectories, and contributions of authors, institutions, and countries [21]. Conventional literature reviews, whether narrative or systematic, can provide in-depth insights into specific topics; however, they often have limitations in capturing large-scale research patterns and data-driven trends when the volume of publications continues to increase [22]–[24].

In this regard, bibliometric analysis offers a quantitative approach to mapping the structure and dynamics of research fields through the analysis of bibliographic metadata. This approach enables the identification of publication growth trends, influential authors and journals, institutional and national research contributions, collaboration patterns, and the evolution of research themes based on keyword analysis [25]. Although bibliometric methods have been widely applied across various disciplines, comprehensive bibliometric studies that specifically examine scientific literacy within the context of science education remain relatively limited and dispersed [10], [26]. Existing bibliometric research tends to focus either on science education more broadly or on scientific literacy without explicitly situating it within the science education domain.

Therefore, there is a need for a comprehensive and up-to-date bibliometric mapping that integrates publication trends, influential contributors, thematic structures, and collaboration patterns in scientific literacy research within science education. Addressing this gap is essential for clarifying the current knowledge structure of the field, identifying emerging research directions, and supporting the formulation of future research agendas in science education.

Accordingly, this study aims to systematically map the development of scientific literacy research in science education through a bibliometric analysis of Scopus-indexed publications published between 2016 and 2025. To achieve this aim, the study addresses the following research questions: How have publication trends and growth patterns in scientific literacy research within science education evolved over time?; 2) Which authors, journals, institutions, and countries have made the most influential contributions to scientific literacy research in science education?; 3) What are the major research themes and emerging topics in studies of scientific literacy within science education?; 4) How do collaboration patterns among authors and countries shape research on scientific literacy in science education?

2. RESEARCH METHOD

This study employed a bibliometric review design to systematically examine the development of research on scientific literacy within the field of science education. Bibliometric analysis is a quantitative approach used to map the structure, trends, and dynamics of a research field through the analysis of bibliographic metadata, allowing for the identification of publication growth, influential contributors, thematic evolution, and collaboration patterns. The unit of analysis in this study was bibliographic records rather than human participants. Therefore, no research sample or sampling technique involving respondents was applied. The dataset consisted of journal articles and review articles indexed in the Scopus database that met predefined inclusion criteria. Scopus was selected as the data source due to its extensive coverage of peer-reviewed international journals and its widespread use in bibliometric studies.

Data collection procedures were conducted in December 2025 using the Scopus database. The search strategy applied the keyword combination "scientific literacy" AND "science education" to titles, abstracts, and author keywords. The search was limited to publications written in English and published between 2016 and 2025 to capture recent and contemporary research trends in the field. Only journal articles and review articles were included in the dataset, while conference proceedings, books, book chapters, editorial materials, and documents with incomplete bibliographic information were excluded to ensure data consistency and relevance.

This study did not employ survey instruments, questionnaires, or psychometric measurement tools. Consequently, reliability indicators such as Cronbach's alpha are not applicable. Instead, the reliability and validity of the study were ensured through the use of standardized bibliographic data obtained from the Scopus database and the application of established bibliometric analysis procedures, which are commonly used and recognized in science education research. Data analysis procedures were carried out using the Bibliometrix package implemented in R software. The analysis included descriptive bibliometric indicators to examine publication trends and growth patterns, citation-based metrics to identify influential authors, journals, institutions, and countries, and network-based analyses to explore collaboration patterns among authors and countries. In addition, keyword co-occurrence and thematic mapping analyses were conducted to identify major research themes and emerging topics in scientific literacy research within science education. The results of these analyses were visualized using bibliometric maps and network graphs to facilitate interpretation and address the research questions of this study.

3. RESULTS AND DISCUSSION

Publication Trends and Growth of Scientific Literacy Research

To address RQ1, this subsection examines publication trends and growth patterns in scientific literacy research within science education based on descriptive bibliometric indicators.

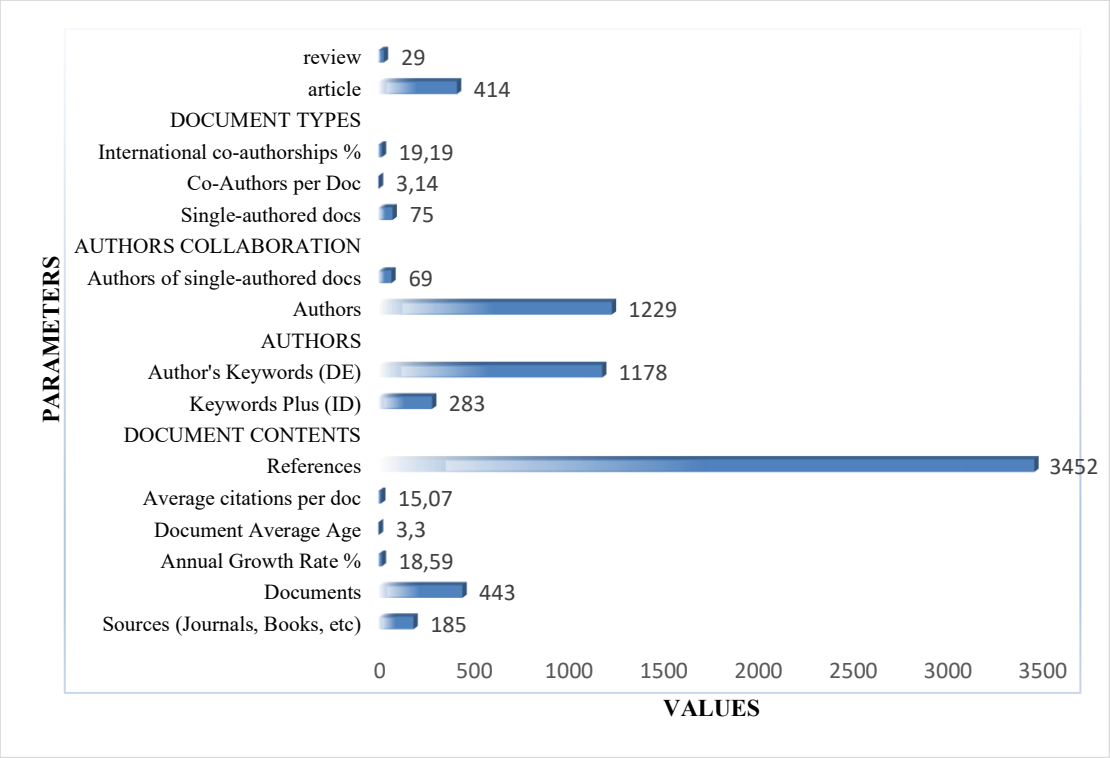

Figure 1. Summary of the dataset

Figure 1 presents a summary of the bibliographic dataset analyzed in this study. A total of 443 publications indexed in the Scopus database between 2016 and 2025 were identified, with an annual growth rate of 18.59%. The relatively recent average document age of 3.3 years indicates that research on scientific literacy within science education has experienced substantial recent activity, suggesting that the field remains dynamic and continues to attract scholarly attention. These findings indicate a sustained increase in research output over the past decade, reflecting growing academic interest in scientific literacy as a central focus of science education research.

Following the overview of the dataset characteristics, the analysis proceeds to examine the temporal distribution of publication in order to identify publication trends and growth patterns in scientific literacy research within science education.

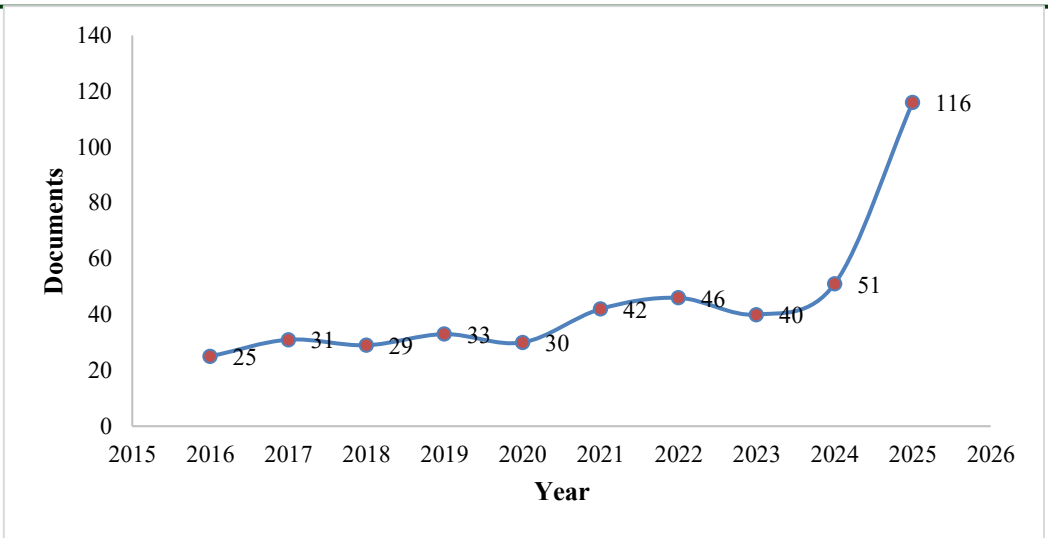

Figure 2. Annual Scientific Production

Figure 2 illustrates the annual scientific production on scientific literacy in science education from 2016 to 2025. This results show a generally increasing trend in the number of publications over the study period, with a more pronounced rise observed after 2020 [11], [20]. While minor fluctuations are evident in creatin years, the overall patterm indicates a gradual expansion of reswarch output in this area. This trend may reflect broader developments in science education research, including increased attention to science-related societal issues and the growing emphasis on scientific literacy in educational policy and assessment frameworks. However, this pattern should be interpreted as an indication of changing research attention rather than a direct causal relationship.

Overall, the publication trend suggests a steady increase in scholarly output on scientific literacy in science education over the past decade, providing a quantitative context for subsequent analyses of research contributions, themes, and collaboration patterns.

Influential Authors, Journals, Institutions, and Countries

In response to RQ2, this subsection identifies the most influential authors, journals, institutions, and countries contributing to scientific literacy research in science education using citation-based bibliometric indicators. The analysis draws on publication productivity, citation impact, and collaboration patterns to evaluate scholarly influence and dissemination.

Table 1 presents the top 20 authors based on citation indicators, including h-index, g-index, total citations (TC), and number of publications (NP). The results show that a relatively small group of authors has made substantial contributions to the field, indicating concentration of scholarly influence. Authors such as Archila Pa and De Mejía A-M demonstrate high h-index and total citation values, reflecting both sustained productivity and strong scholarly impact. Several other authors, including Zeidler, Sadler, and Sjöström, also appear prominently, suggesting that research on scientific literacy is closely connected to broader theoretical discussions on socioscientific issues, nature of science, and citizenship-oriented science education.

Table 1. Top 20 Author's impact

Author	h_index	g_index	m_index	TC	NP
Archila Pa	8	11	1	128	11
De Mejía A-M	8	11	1	128	11
Molina J	5	7	0.625	87	7
Restrepo S	5	5	1,25	48	5
Eilks I	4	4	0.444	198	4
Lederman Ng	4	4	0.5	69	4
Lin J	4	4	0.444	120	4
Develaki M	3	3	0.333	76	3
García-Carmona A	3	5	0.375	60	5
Guerrero G	3	4	0.75	53	4
Holbrook J	3	3	0.5	54	3
Lavonen J	3	4	0.429	45	4
Li Y	3	4	0.6	40	4
Ortiz Bt	3	4	0.75	23	4

Author	h_index	g_index	m_index	TC	NP
Ramnarain U	3	3	0.5	33	3
Rannikmäe M	3	3	0.5	54	3
Sadler Td	3	3	0.429	364	3
Sjöström J	3	3	0.333	177	3
Vieira Rm	3	3	0.3	147	3
Zeidler	3	4	0.3	538	4

Figure 3 illustrates author productivity over time. Several influential authors have contributed consistently across multiple years, rather than concentrating their publications within a short time span. This pattern directly addresses RQ2 by highlighting which authors maintain long-term engagement and influence in the field.

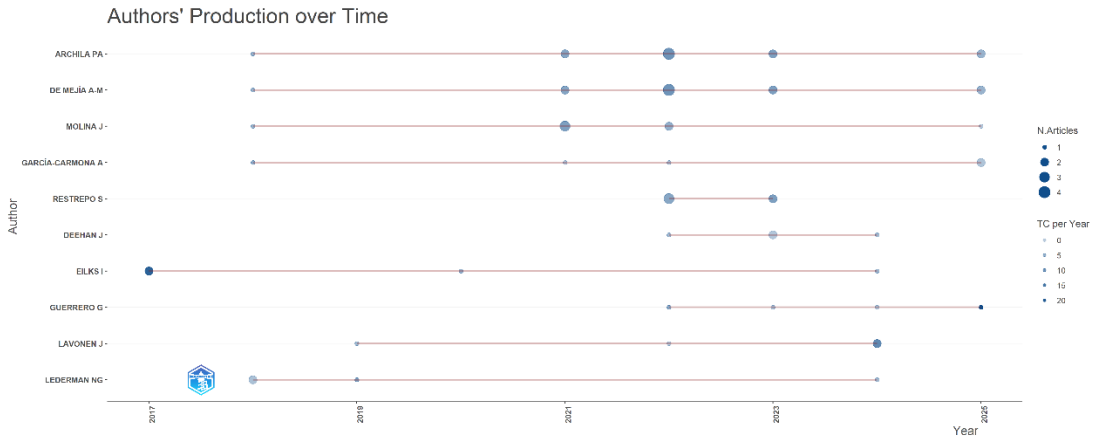

Figure 3. Author Production over time

Building on the analysis of authors, the examination of publication venues provides insight into how research on scientific literacy is disseminated. The influence of journals was analyzed using Bradford's Law to identify core publication sources. Figure 4 presents the source distribution. Publications are concentrated in a small number of core journals, followed by a broader distribution across secondary and peripheral sources. This confirms RQ2 by identifying key journals that shape discourse and scholarly communication in scientific literacy research.

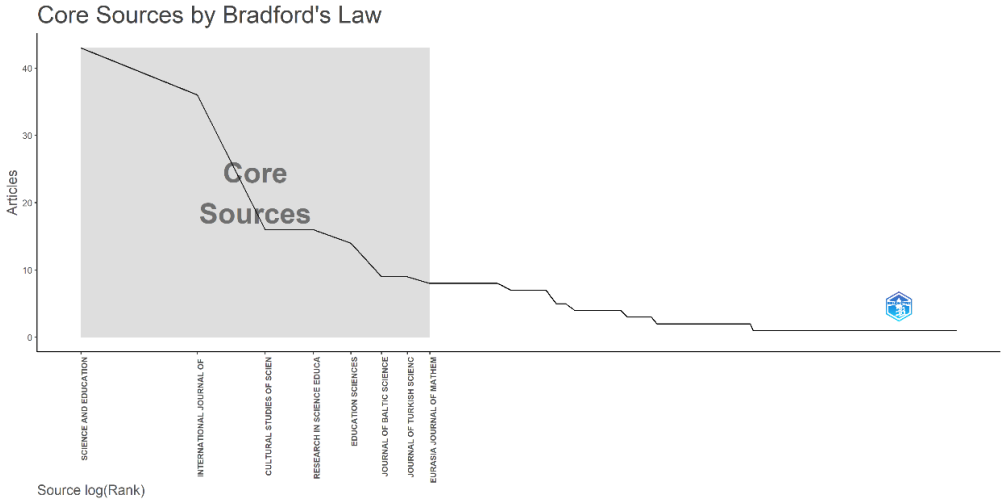

Figure 4. Source distribution according to Bradford law

Figure 5 and Table 2 summarize journal performance in terms of h-index, total citations, and publication output. Journals such as *Science & Education* and *International Journal of Science Education* demonstrate high citation impact alongside consistent publication output, reflecting their central role in shaping the research field. These findings suggest that research dissemination is concentrated among well-established journals, which contributes to the cohesion and visibility of the scientific literacy research community.

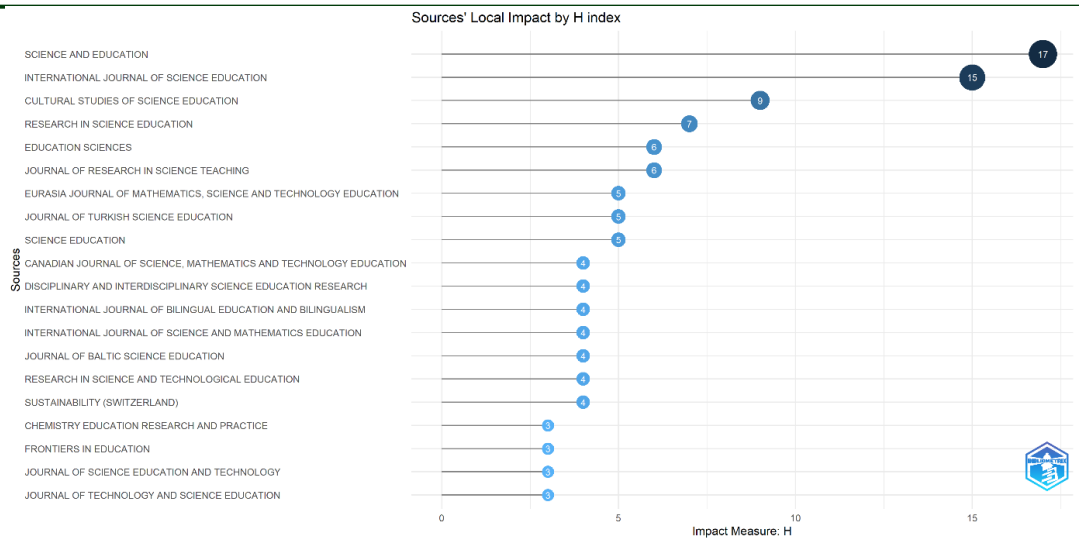

Figure 5. Journal Impact

Table 2. Source Impact

Source	h_index	g_index	m_index	TC	NP	PY_start
Science and Education	17	31	1.7	973	43	2016
International Journal of Science Education	15	24	1.667	605	36	2017
Cultural Studies of Science Education	9	16	0.9	416	16	2016
Research in Science Education	7	13	0.7	170	16	2016
Education Sciences	6	8	0.667	80	14	2017
Journal of Research In Science Teaching	6	7	0.6	244	7	2016
Eurasia Journal of Mathematics, Science And Technology Education	5	7	0.556	53	8	2017
Journal of Turkish Science Education	5	9	0.556	91	9	2017
Science Education	5	7	0.5	316	7	2016
Canadian Journal of Science, Mathematics and Technology Education	4	5	0.444	96	5	2017
Disciplinary and Interdisciplinary Science Education Research	4	7	0.571	320	7	2019
International Journal of Bilingual Education and Bilingualism	4	4	0.8	47	4	2021
International Journal of Science and Mathematics Education	4	8	0.4	212	8	2016
Journal of Baltic Science Education	4	6	0.4	39	9	2016
Research in Science and Technological Education	4	8	0.5	83	8	2018
Sustainability (Switzerland)	4	7	0.667	59	8	2020
Chemistry Education Research and Practice	3	4	0.333	95	4	2017
Frontiers in Education	3	7	0.75	60	8	2022
Journal of Science Education and Technology	3	5	0.333	67	5	2017
Journal of Technology and Science Education	3	3	0.375	35	3	2018

Institutional analysis was conducted to identify organizations with substantial research output. Figure 6 illustrates affiliation production over time, showing that output is concentrated in a limited number of institutions with stable publication patterns. This sustained contribution underscores institutional leadership in advancing scientific literacy research, aligning with RQ2 by identifying where influential research originates.

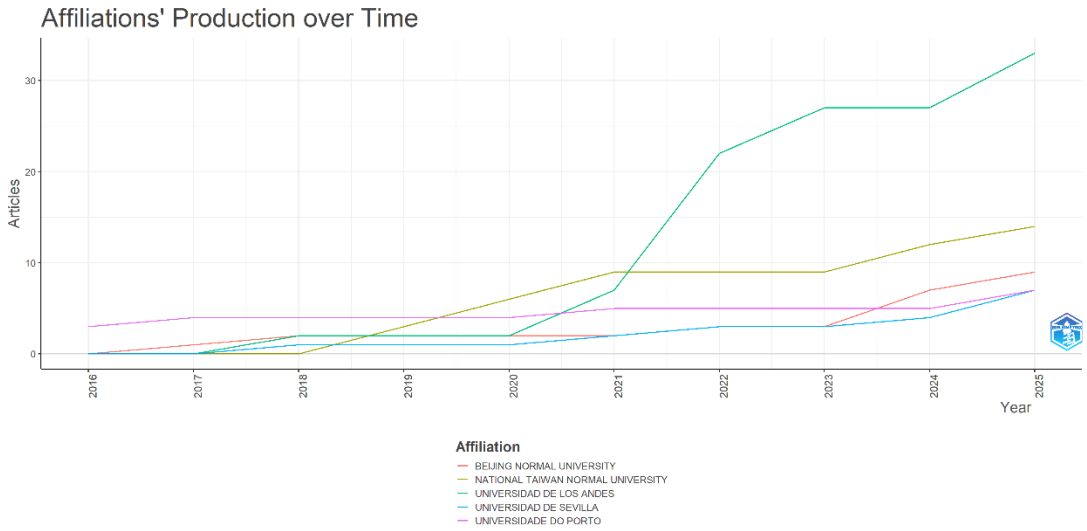

Figure 6. Affiliation Production over time

At the national level, research output was analyzed to assess the geographical distribution of publications. Figures 7 and 8 show that a small number of countries dominate research output, particularly those with well-developed research infrastructures. Figure 9 displays corresponding authors' countries, highlighting the leadership positions of nations that consistently contribute high-volume and highly cited publications. These results address RQ2 by identifying countries that drive research influence and indicate opportunities for broader international collaboration.

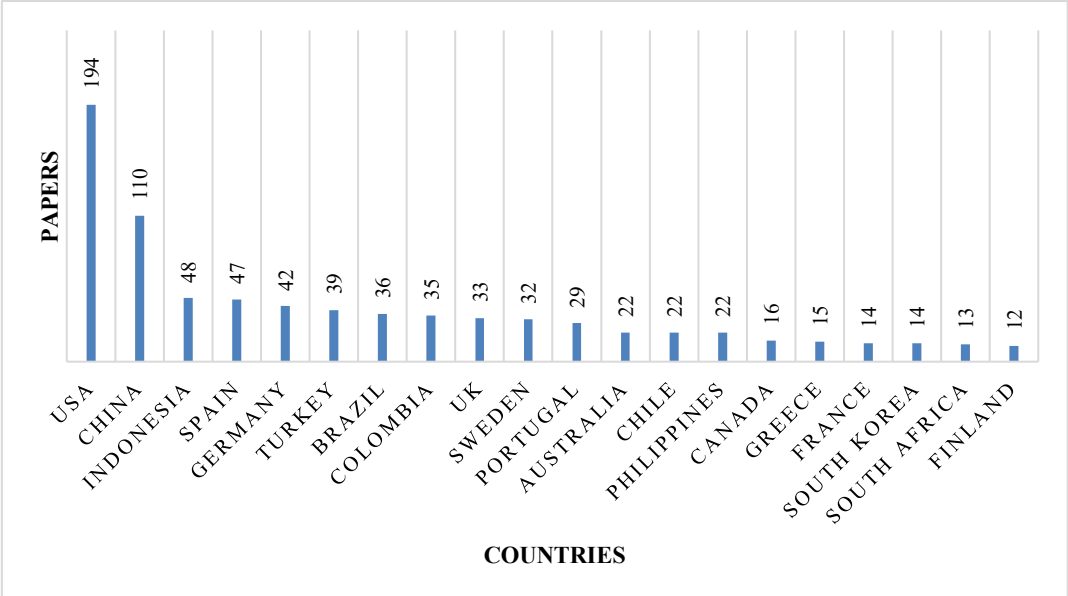

Figure 7. Countries Production over time

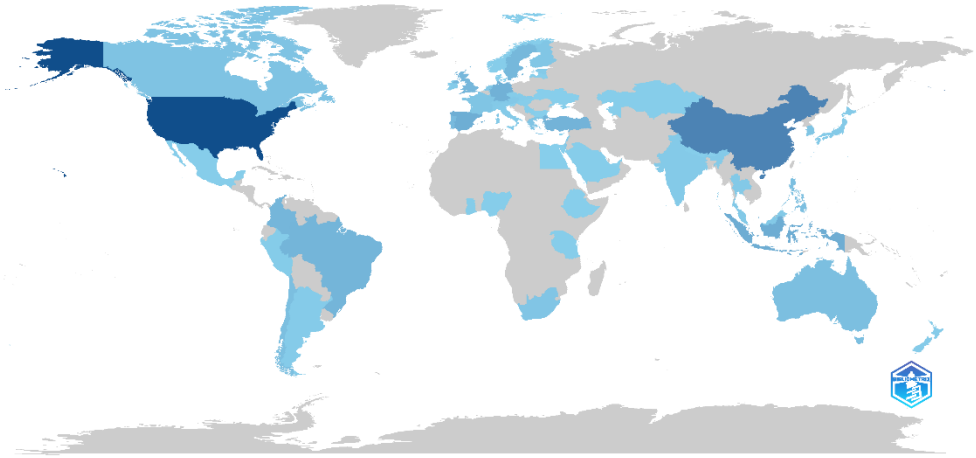

Figure 8. Country paper distribution

To further examine national research leadership, Figure 9 displays the distribution of corresponding authors' countries. The results suggest that leadership roles in scientific literacy research are largely concentrated in the same countries that demonstrate high overall publication output. This pattern highlights an uneven global distribution of research activity and points to opportunities for broader international participation and increased representation of diverse educational contexts in future research.

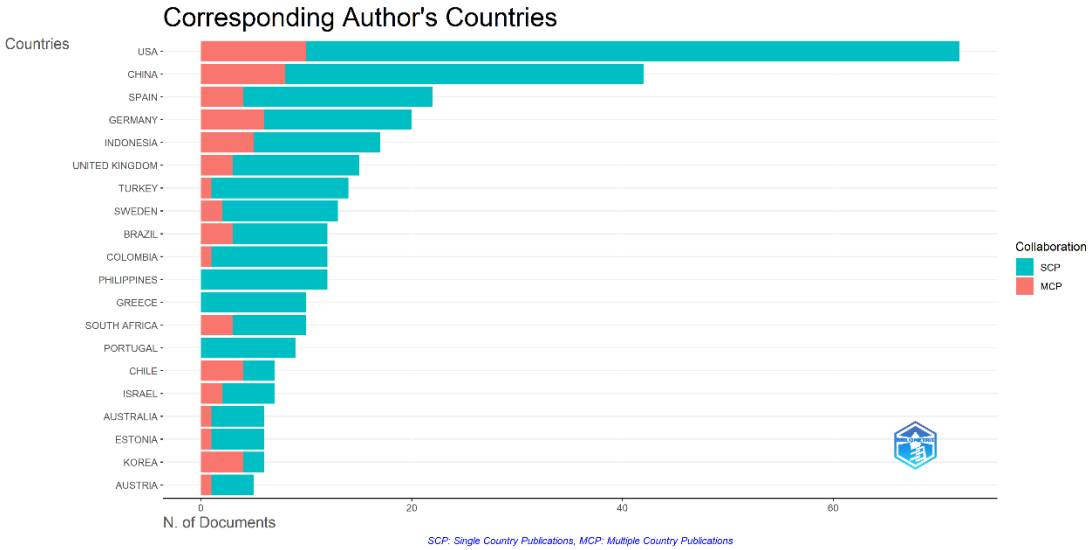

Figure 9. Corresponding Author's Countries

Overall, the analysis shows that research on scientific literacy in science education is highly concentrated among specific authors, journals, institutions, and countries, providing a clear picture of the influential contributors in the field. This bibliometric mapping not only answers RQ2 but also offers insights into the structural patterns of scholarly influence, potential collaboration opportunities, and emerging hubs of research activity, which can guide future research planning and policy development.

Research Themes and Emerging Topics in Scientific Literacy

In response to RQ3, this subsection examines the major research themes and emerging topics in studies on scientific literacy within science education. Keyword-based bibliometric analyses were employed to identify dominant conceptual areas, thematic structures, and evolving research interests over time.

Figure 10 presents the thematic map of scientific literacy research in science education, illustrating the relationships between themes based on centrality and density. The map reveals several well-developed and central themes that form the conceptual core of the field. Notably, themes related to scientific literacy, science education, and nature of science occupy central positions, indicating their foundational role in structuring research within this domain. These themes reflect long-standing scholarly efforts to conceptualize scientific literacy as a key educational outcome linked to students' understanding of scientific knowledge, practices, and

epistemology [27]–[30]. Their central position addresses RQ3 by highlighting core research concepts that dominate the field.

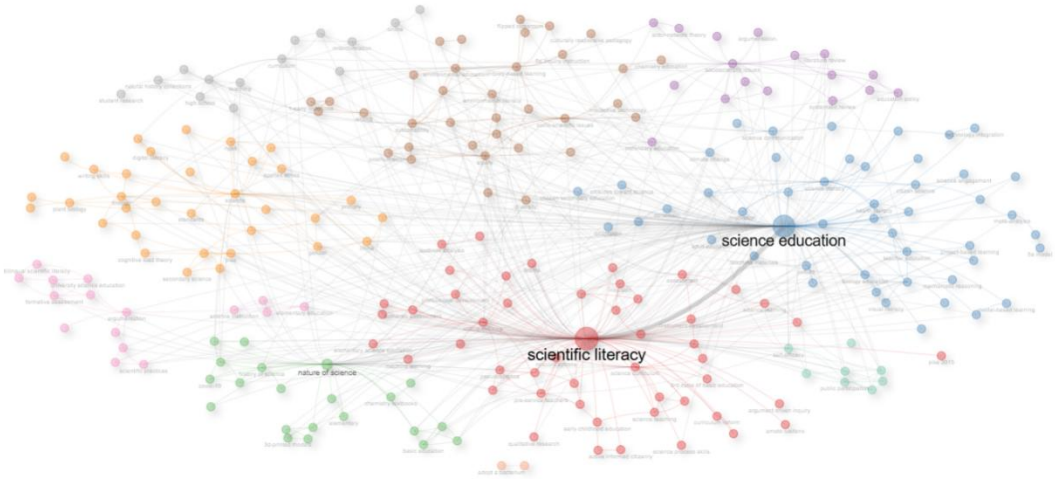

Figure 10. Thematic Map

Complementing the thematic map, Figure 11 displays the most frequently occurring keywords across the dataset. The prominence of keywords such as scientific literacy, science education, nature of science, and socioscientific issues further confirms the centrality of these concepts in the literature [31]–[34]. The recurring appearance of socioscientific issues suggests a sustained interest in connecting scientific literacy with real-world contexts, ethical considerations, and decision-making processes in science education, providing novel insights into emerging educational priorities.

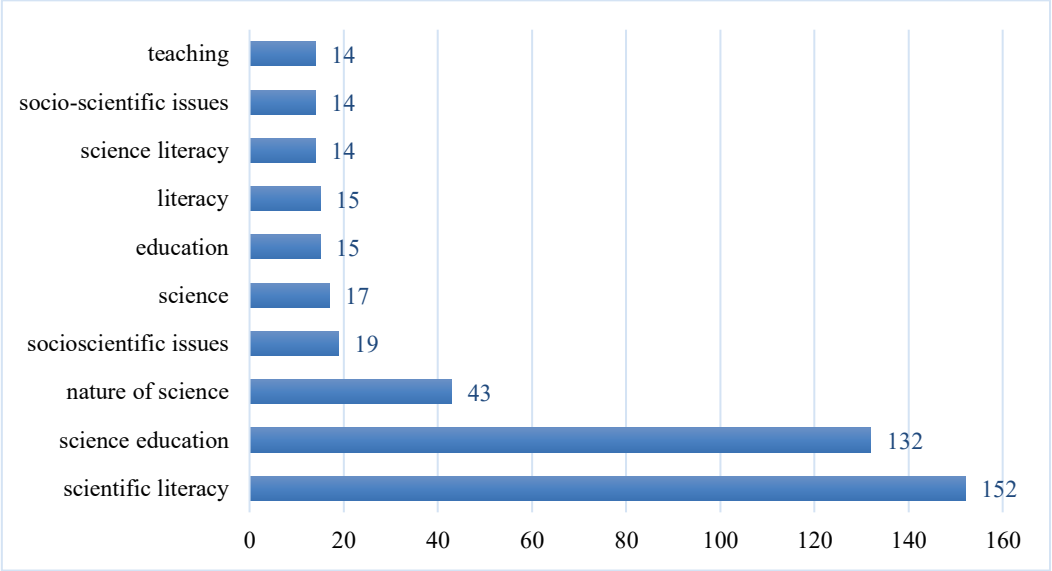

Figure 11. Keyword Occurance

Figure 12 presents the keyword frequency distribution. The results indicate that a relatively small number of keywords account for a substantial proportion of occurrences, while a wider range of terms appears less frequently. This pattern demonstrates that scientific literacy research is organized around a set of core concepts alongside a diverse array of complementary topics, highlighting the multidisciplinary nature of science education research and confirming the evolving thematic landscape addressed in RQ3.

Figure 12. Keyword Count

Emerging research trends are illustrated in Figure 13, showing the evolution of prominent topics over time. Foundational themes such as scientific literacy and nature of science remain consistently present, while newer topics misinformation, climate literacy, digital and media literacy, and citizenship have gained visibility in recent years. This indicates a gradual shift toward addressing contemporary societal challenges, reflecting the role of scientific literacy in navigating complex science-related issues [35], [36]. These findings provide novelty by identifying emerging themes that extend existing research and suggest implications for future research directions and curriculum development.

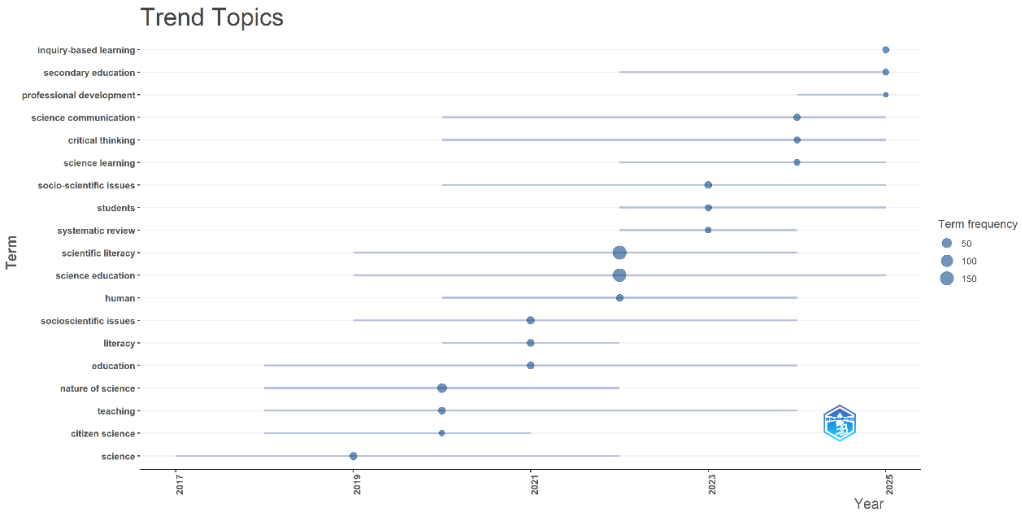

Figure 13. Trend Topics

Overall, the thematic and keyword analyses indicate that research on scientific literacy in science education is characterized by a stable conceptual core combined with evolving research interests. While foundational themes anchor the field, emerging topics demonstrate ongoing efforts to align scientific literacy with current social, technological, and environmental contexts. These results not only answer RQ3 but also offer insight into underexplored research areas, informing future studies, policy, and educational practice.

Collaboration Patterns in Science Literacy Research

In response to RQ4, this subsection examines collaboration patterns among authors and countries in research on scientific literacy within science education. Collaboration was analyzed through co-authorship networks and international collaboration maps to reveal the structure, intensity, and dynamics of scholarly interactions in the field.

Figure 14 presents the author collaboration network, illustrating co-authorship relationships among researchers. The network shows that scientific literacy research is characterized by several interconnected clusters, each representing groups of authors who frequently collaborate. Within these clusters, a small number of authors occupy more central positions, indicating their roles as recurring collaborators or connectors across multiple studies. This pattern directly addresses RQ4 by highlighting the structure of author-level collaboration and identifying central contributors in the field.

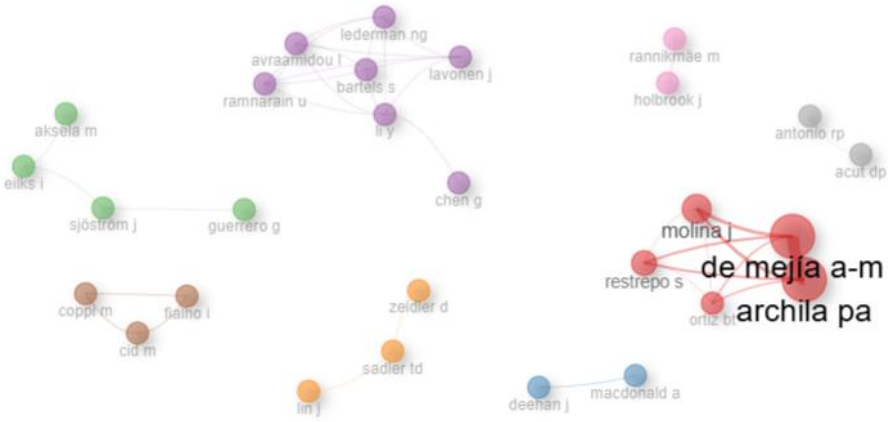

Figure 14. Author collaboration network in scientific literacy research

The network structure indicates that collaboration is moderately fragmented, with limited connections between some clusters. This implies that while collaborative research practices are present, cross-group integration remains selective. Such a structure reflects typical patterns in education research, where collaboration is shaped by shared theoretical frameworks, institutional affiliations, or long-term research agendas.

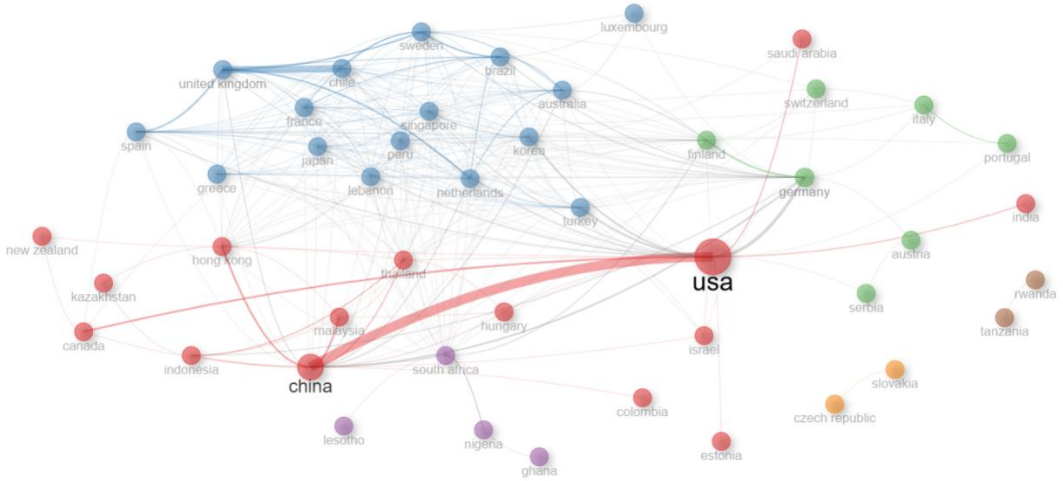

Figure 15. International Collaboration Network by Country

Figure 15 illustrates the international collaboration network among countries. International collaboration is present but unevenly distributed. A small number of countries form the core of the collaboration network, maintaining multiple international linkages, while many other countries participate primarily through domestic collaborations. These patterns highlight RQ4 by showing which countries drive global research collaboration and which regions have potential for increased cross-national engagement.

Countries with higher publication output occupy more central positions, suggesting that research leadership is often associated with stronger international connectivity [37]–[39]. However, cross-national links across different regions indicate ongoing efforts to engage diverse educational contexts. This has practical implications for fostering broader international collaboration, supporting inclusion of diverse perspectives, and enhancing the comparative understanding of scientific literacy across educational systems.

Table 3 presents the most cited papers in the dataset. The citation patterns show that highly cited works are distributed across multiple authors and publication years, rather than concentrated in a single group or country. This demonstrates that influential contributions in scientific literacy research often emerge from studies addressing conceptual frameworks, socioscientific issues, and broader educational implications, providing a sustained knowledge base for the field.

Table 3. Most cited papers in scientific literacy research

Paper	Total Citations	TC per Year	Normalized TC
[40]	730	73.00	11.56
[41]	242	24.20	3.83
[42]	214	30.57	6.18
[9]	181	30.17	7.76
[43]	170	34.00	7.98
[44]	133	13.30	2.11
[45]	126	14.00	6.13
[46]	123	12.30	1.95
[47]	109	21.80	5.12
[48]	92	11.50	4.38
[49]	91	13.00	2,63
[50]	89	17.80	4,18
[51]	88	12.57	2.54
[52]	81	11.57	2.34
[53]	71	23.67	8.43
[54]	70	7.78	3.41
[55]	68	7.56	3.31
[56]	62	8.86	1.79
[57]	61	12.20	2.86
[58]	59	7.38	2.81

Overall, the collaboration analysis indicates that research on scientific literacy in science education is supported by stable yet selective collaborative structures at both author and country levels. Established research groups play a central role, but international connections reveal opportunities for expanding collaborative engagement. These findings not only answer RQ4 but also provide novel insights into collaboration patterns, highlight potential hubs for future research, and inform strategies to strengthen cross-regional cooperation in science education scholarship.

4. CONCLUSION

This study provides a comprehensive bibliometric analysis of scientific literacy research in science education from 2016 to 2025, revealing several key insights. The results show steady growth in publications, reflecting sustained scholarly interest, with a concentrated core of influential authors, journals, and institutions shaping the field. Thematic analyses indicate a stable conceptual foundation around scientific literacy, science education, and the nature of science, alongside emerging topics such as misinformation, climate literacy, digital literacy, and citizenship, highlighting both continuity and innovation. Collaboration networks at the author and country levels are structured but selective, with opportunities to strengthen cross-regional partnerships. By integrating trends, contributor impact, thematic evolution, and collaboration structures, this study provides practical insights for educators, policymakers, and researchers, while also identifying areas for future research. Limitations include reliance on Scopus-indexed publications, suggesting that future studies could expand to other databases and explore broader international collaborations. Overall, the study delivers actionable insights into the development, structure, and emerging directions of scientific literacy research, contributing both conceptually and practically to the field.

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AUTHOR CONTRIBUTIONS

Ahmad Saputra contributed to the conceptualization of the study, data collection, bibliometric analysis, data visualization, and the drafting of the original manuscript. Insih Wilujeng contributed to the research design, methodological supervision, interpretation of results, and critical revision of the manuscript for intellectual content. Antuni Wiyarsi contributed to the conceptual refinement of the study, validation of the analysis, and critical review and editing of the manuscript. All authors have read and approved the final version of the manuscript.

CONFLICTS OF INTEREST

The author(s) declare no conflict of interest.

USE OF ARTIFICIAL INTELLIGENCE (AI)-ASSISTED TECHNOLOGY

The authors declare that no artificial intelligence (AI) tools were used in the generation, analysis, or writing of this manuscript. All aspects of the research, including data collection, interpretation, and manuscript preparation, were carried out entirely by the authors without the assistance of AI-based technologies.

REFERENCES

[1] OECD, *PISA 2018 Results (Volume I): What Students Know and Can Do*, vol. I. Paris, 2019. doi: 10.1787/5f07c754-en.

[2] P. Sarini, W. Widodo, S. Sutoyo, and I. N. Suardana, "Scientific literacy profile of prospective science teacher students," *IJORER Int. J. Recent Educ. Res.*, vol. 5, no. 4, pp. 1026–1039, 2024, doi: 10.46245/ijorer.v5i4.627.

[3] G. Roy, S. Sikder, and L. Danaia, "Adopting scientific literacy in early years from empirical studies on formal education: A systematic review of the literature," *Int. J. STEM Educ.*, vol. 12, no. 1, pp. 1–24, 2025, doi: 10.1186/s40594-025-00547-1.

[4] J. Sjostrom, "Vision III of scientific literacy and science education: an alternative vision for science education emphasising the ethico-socio-political and relational-existential," *Stud. Sci. Educ.*, vol. 61, no. 2, pp. 239–274, 2025, doi: 10.1080/03057267.2024.2405229.

[5] J. Osborne, D. Allchin, and J. Osborne, "Science literacy in the twenty-first century: Informed trust and the competent outsider," *Int. J. Sci. Educ.*, vol. 0693, pp. 2134–2155, 2025, doi: 10.1080/09500693.2024.2331980.

[6] B. C. Herman, M. H. Newton, and D. L. Zeidler, "Impact of place-based socioscientific issues instruction on students' contextualization of socioscientific orientations," *Sci. Educ.*, vol. 105, no. 4, pp. 585–627, 2021, doi: 10.1002/sce.21618.

[7] A. Van Stekelenburg, "Science literacy and the acceptance of scientific facts," *Curr. Opin. Psychol.*, vol. 67, pp. 1–5, 2026, doi: 10.1016/j.copsyc.2025.102183.

[8] D. Wan, Y.-J. Lee, S. Chen, and Q. Yu, "How scientific literacy is conceptualized in tasks from junior secondary physics textbooks," *Int. J. Sci. Educ.*, pp. 1–24, 2024, doi: 10.1080/09500693.2024.2429045.

[9] D. Hottecke and D. Allchin, "Reconceptualizing nature-of-science education in the age of social media," *Sci. Educ.*, vol. 104, no. 4, pp. 641–666, 2020, doi: 10.1002/sce.21575.

[10] M. Dzul, H. Wirzal, N. Abdul, H. Nordin, and M. A. Bustam, "Bibliometric analysis of research on scientific literacy between 2018 and 2022: Science education subject," *Int. J. Essent. Competencies Educ.*, vol. 1, no. 2, pp. 69–83, 2022, doi: 10.36312/ijece.v1i2.1070.

[11] J. A. Lubis, Y. Pantiwati, and A. Rahardjanto, "Students' scientific literacy in critical thinking skills in science learning: A bibliometric analysis from the scopus database," *J. Ilm. Biol.*, vol. 13, no. 2, pp. 1100–1112, 2025, doi: 10.33394/bioscientist.v13i2.15732.

[12] T. Kastorff, S. Moser, J. H. Heine, and A. Kauertz, "Global competence behavior : Exploring the relevance of students' scientific literacy, related attitudes, and values-evidence from PISA 2018 across 52 countries," *Large-scale Assessments Educ.*, vol. 14, no. 3, pp. 1–26, 2026, doi: 10.1186/s40536-025-00278-3.

[13] A. Z. Ilma and H. Kuswanto, "Toward student ' s scientific literacy in science learning : a systematic literature review and bibliometric analysis," *Rev. Mex. F'ısica E*, vol. 22, pp. 1–16, 2025, doi: 10.31349/RevMexFisE.22.020222.

[14] P. N. Putri, F. Rachmadiarti, T. Purnomo, and M. Satriawan, "Measuring scientific literacy of students' through environmental issues based on PISA 2025 science framework," *J. Penelit. Pendidik. IPA*, vol. 11, no. 3, pp. 44–53, 2025, doi: 10.29303/jppipa.v11i3.10413.

[15] D. R. Sari, S. Saputro, U. S. Maret, and U. S. Maret, "A systematic review on integrating SSI into science education," *Educ. Stud. Res. J.*, vol. 2, no. 1, pp. 1–14, 2025, doi: 10.5281/zenodo.14693973.

[16] M. Istyadji and S. Sauqina, "Conception of scientific literacy in the development of scientific literacy assessment tools: A systematic theoretical review," *J. Turkish Sci. Educ.*, vol. 20, no. 2, pp. 281–308, 2023, doi: 10.36681/tused.2023.016.

[17] A. Z. Ilma, I. Wilujeng, A. Widowati, M. Nurtanto, and N. Kholifah, "A systematic literature review of STEM education in Indonesia (2016-2021): Contribution to improving skills in 21st century learning," *Pegem Journal of Education and Instruction*, vol. 13, no. 2. pp. 134–146, 2023. doi: 10.47750/pegegog.13.02.17.

[18] N. Mafarja, H. Zulnaidi, and M. M. Mohamad, "Virtual learning environment to improve scientific literacy: A systematic review," *Res. Sci. Technol. Educ.*, pp. 1–25, 2025, doi: 10.1080/02635143.2025.2547927.

[19] S. E. Program, P. Rd, and N. Ciheuleut, "Mapping research trends on development of scientific literacy assessment: A bibliometric analysis," *JPBI (Jurnal Pendidik. Biol. Indones.*, vol. 10, no. 1, pp. 211–222, 2024, doi: 10.22219/jpbi.v10i1.31136.

[20] A. O. S. Pratama, "Exploring trends and focus of science literacy research bibliometric analysis 2019-2024," *Pendas J. Ilm. Pendidik. Dasar*, vol. 9, no. 4, pp. 1–10, 2024, doi: 10.23969/jp.v9i04.19573.

[21] A. Miller, E. A. Miller, T. Li, I. Chen, J. Krajcik, and S. C. Kelly, "Designing for and investigating elementary students' cognitive flexibility, science, and literacy achievement in project-based science learning," *Discip. Interdiscip. Sci. Educ. Res.*, vol. 1, pp. 1–23, 2025, doi: 10.1186/s43031-025-00131-1.

[22] R. Kumar, "Bibliometric analysis: Comprehensive insights into tools, techniques, applications, and solutions for research excellence," *Spectr. Eng. Manag. Sci.*, vol. 3, no. 1, pp. 45–62, 2025, doi: 10.31181/sems31202535k.

[23] O. Öztürk, R. Kocaman, and D. K. Kanbach, "How to design bibliometric research: An overview and a framework proposal," *Rev. Manag. Sci.*, vol. 18, no. 11, pp. 3333–3361, 2024, doi: 10.1007/s11846-024-00738-0.

[24] M. Linnenluecke, M. Marrone, and A. Singh, "Conducting systematic literature reviews and bibliometric analyses,"

Aust. J. Manag., vol. 45, no. 2, pp. 175–194, 2020, doi: 10.1177/0312896219877678.
[25] M. Cobo, A. G. Herrera-Lopez, E. Viedma-Herrera, and F. Herrera, "Science mapping software tools: Review, analysis, and cooperative study among tools," *J. Am. Soc. Inf. Sci. Technol.*, vol. 62, no. 7, pp. 1382–1402, 2011, doi: 10.1002/asi.21525.
[26] M. K. Kadirhanoğulları, and E. O. Kose, "A bibliometric analysis of articles on bibliometric studies in science education," *Int. J. Res. Educ. Sci.*, vol. 10, no. 2, pp. 315–339, 2024, doi: 10.46328/ijres.3370.
[27] R. A. Leonia, N. Rolina, and E. Suyantri, "A systematic review of scientific literacy in early childhood science learning: approaches, methods, and media," *J. Penelit. Pendidik. IPA*, vol. 11, no. 2, pp. 38–46, 2025, doi: 10.29303/jppipa.v11i2.10576.
[28] L. Z. Wardi, W. Wasis, W. Widodo, M. Satriawan, and K. Nisa, "Trends and development of digital learning research to train science literacy in physics learning: Literature review and bibliometric analysis," *J. Pendidik. MIPA*, vol. 25, no. 3, pp. 1051–1066, 2024, doi: 10.23960/jpmipa/v25i3.pp1051-1066.
[29] N. N. Rediani, "The impact of project-based learning on students' scientific literacy and autonomy," *Indones. J. Educ. Dev.*, vol. 5, no. 1, pp. 67–78, 2024, doi: 10.59672/ijed.v5i1.3747.
[30] I. Yuliana, M. E. Cahyono, W. Widodo, and I. Irwanto, "The effect of ethnoscience-themed picture books embedded within context-based learning on students' scientific literacy," *Eurasian J. Educ. Res.*, vol. 92, pp. 317–334, 2021, doi: 10.14689/ejer.2021.92.16.
[31] C. Viehmann, J. M. F. Cárdenas, and C. G. R. Peña, "The use of socioscientific issues in science lessons: A scoping review," *Sustain.*, vol. 16, no. 14, 2024, doi: 10.3390/su16145827.
[32] N. G. Lederman, A. Antink, and S. Bartos, "Nature of science, scientific inquiry, and socio-scientific issues arising from genetics: A pathway to developing a scientifically literate citizenry," *Sci Educ*, vol. 23, pp. 285–302, 2014, doi: 10.1007/s11191-012-9503-3.
[33] A. G. Carmona, "Learning about the nature of science through the critical and reflective reading of news on the COVID-19 pandemic," *Cult. Stud. Sci. Educ.*, vol. 16, no. 4, pp. 1015–1028, 2021, doi: 10.1007/s11422-021-10092-2.
[34] N. N. Azizah, Y. Herlanti, and E. Muliyah, "The relationship between scientific literacy skills and argumentation skills through discussion of socioscientific issues on the virus concept," *J. Educ. Sci.*, vol. 9, no. 4, pp. 2699–2718, 2025, doi: 10.31258/jes.9.4.p.2699-2718.
[35] W. T. Ummah, "Integrating scientific attitude to realize pancasila learner profile in science learning," *Integr. Sci. Educ. J.*, vol. 6, no. 1, pp. 15–23, 2025, doi: 10.37251/isej.v6i1.1318.
[36] S. M. Utami and A. Subagyo, "The development of electronic students' worksheets (E-LKPD) based on argument driven inquiry learning model to improve scientific argumentation skills," *Integr. Sci. Educ. J.*, vol. 5, no. 2, pp. 65–73, 2024, doi: 10.37251/isej.v5i2.810.
[37] V. A. Ballesteros-ballesteros and R. A. Z, "Mapping the conceptual structure of research on open innovation in university–industry collaborations: A bibliometric analysis," *Front. Res. Mertics Anal.*, vol. 10, pp. 1–25, 2025, doi: 10.3389/frma.2025.1693969.
[38] Z. Lu, W. Li, Y. Wang, and S. Zhou, "Bibliometric analysis of global research on ecological networks in nature conservation from 1990 to 2020," *Sustainability*, vol. 14, pp. 1–20, 2022, doi: 10.3390/ su14094925.
[39] M. Carammia, "A bibliometric analysis of the internationalisation of political science in Europe," *European Political Science*, vol. 21, no. 4, pp. 564-595, 2022, doi: 10.1057/s41304-022-00367-9.
[40] R. Bonney, T. B. Phillips, and J. W. Enck, "Can citizen science enhance public understanding of science?," *Public Underst. Sci.*, vol. 25, no. 1, pp. 2–16, 2016, doi: 10.1177/0963662515607406.
[41] D. L. Zeidler, "STEM education: A deficit framework for the twenty first century? A sociocultural socioscientific response," *Cult. Stud. Sci. Educ.*, vol. 11, pp. 11–26, 2016, doi: 10.1007/s11422-014-9578-z.
[42] D. L. Zeidler, B. C. Herman, and T. D. Sadler, "New directions in socioscientific issues research," *Discip. Interdiscip. Sci. Educ. Res.*, vol. 1, no. 11, pp. 1–9, 2019, doi: 10.1186/s43031-019-0008-7.
[43] L. Valladares, "Scientific literacy and social transformation," *Sci. Educ.*, vol. 30, pp. 557–587, 2021, doi: 10.1007/s11191-021-00205-2.
[44] R. M. Vieira and C. T. Vieira, "Fostering scientific literacy and critical thinking in elementary science education," *Int. J. Sci. Math. Educ.*, vol. 14, pp. 659–680, 2016, doi: 10.1007/s10763-014-9605-2.
[45] J. Sjöström, N. Frerichs, V. G. Zuin, and I. Eilks, "Studies in science education use of the concept of bildung in the international science education literature, its potential, and implications for teaching and learning," *Stud. Sci. Educ.*, vol. 7267, pp. 1–28, 2017, doi: 10.1080/03057267.2017.1384649.
[46] A. Shtulman and K. Harrington, "Tensions between science and intuition across the lifespan," *Top. Cogn. Sci.*, vol. 8, no. 1, pp. 118–137, 2016, doi: 10.1111/tops.12174.
[47] L. Ke, T. D. Sadler, L. Zangori, and P. J. Friedrichsen, "Developing and using multiple models to promote scientific literacy in the context of socio-scientific issues," *Sci. Educ.*, vol. 30, pp. 589–607, 2021, doi: 10.1007/s11191-021-00206-1.
[48] H. A. Yacoubian, "Scientific literacy for democratic decision-making," *Int. J. Sci. Educ.*, vol. 40, no. 3, pp. 308–327, 2018, doi: 10.1080/09500693.2017.1420266.
[49] H. Cofre, P. Nunez, D. Santibanez, J. M. Pavez, M. Valencia, and C. Vergara, "A critical review of students' and teachers' understandings of nature of science," *Sci. Educ.*, vol. 28, pp. 205–248, 2019, doi: 10.1007/s11191-019-00051-3.
[50] L. Chen and S. Xiao, "Perceptions, challenges and coping strategies of science teachers in teaching socioscientific issues: A systematic review," *Educ. Res. Rev.*, vol. 32, pp. 1–14, 2021, doi: 10.1016/j.edurev.2020.100377.
[51] S. Koerber dan C. Osterhaus, "Individual differences in early scientific thinking: Assessment, cognitive influences, and their relevance for science learning," *J. Cogn. Dev.*, vol. 20, no. 4, pp. 510–533, 2019, doi: 10.1080/15248372.2019.1620232.

[52] S. Kahn and D. L. Zeidler, "A conceptual analysis of perspective taking in support of socioscientific reasoning," *Sci. Educ.*, vol. 28, pp. 605–638, 2019, doi: 10.1007/s11191-019-00044-2.
[53] J. Osborne and D. Pimentel, "Science education in an age of misinformation," *Sci. Educ.*, vol. 107, no. 3, pp. 553–571, 2023, doi: 10.1002/sce.21790.
[54] D. Hodson and S. L. Wong, "Going beyond the consensus view: Broadening and enriching the scope of NOS-oriented curricula," *Can. J. Sci. Math. Technol. Educ.*, vol. 17, no. 1, pp. 3–17, 2017, doi: 10.1080/14926156.2016.1271919.
[55] J. Azevedo and M. Marques, "Climate literacy: A systematic review and model integration," *Int. J. Glob. Warm.*, vol. 13, pp. 3–4, 2017, doi: 10.1504/IJGW.2017.084789.
[56] S. Brouwer and L. K. Hessels, "Increasing research impact with citizen science: The influence of recruitment strategies on sample diversity," *Public Underst. Sci.*, vol. 28, no. 5, hal. 606–621, 2019, doi: 10.1177/0963662519840934.
[57] J. A. Greene *et al.*, "Modeling temporal self-regulatory processing in a higher education biology course," *Learn. Instr.*, vol. 72, pp. 1–8, 2021, doi: 10.1016/j.learninstruc.2019.04.002.
[58] J.-X. You and T.-Y. Guo, "Core competences and scientific literacy: The recent reform of the school science curriculum in China," *Int. J. Sci. Educ.*, vol. 40, no. 15, pp. 1913–1933, 2017, doi: 10.1080/09500693.2018.1514544.