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Mapping research trends on development of scientific literacy assessment: A bibliometric analysis

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Abstract: This study conducts a bibliometric analysis to map the research trends and intellectual landscape surrounding the development of scientific literacy assessments in educational contexts from 2019 to 2023. Scientific literacy, which encompasses the ability to comprehend, evaluate, and apply scientific knowledge, has emerged as a crucial competency in science education. However, existing assessment tools often prioritize factual recall over deeper conceptual understanding and critical thinking abilities. To address this gap, there is a need for innovative assessment approaches that holistically evaluate students' scientific literacy across multiple dimensions. Through a systematic analysis of 185 relevant publications from the Scopus database, this study investigates the numerical distribution of literature by year, document type, journal, author, institution, and country. Additionally, it explores the prominent themes, evolving topic trends, and emerging clusters within the scientific literacy assessment research domain. Bibliometric techniques, including citation analysis, co-authorship networks, and keyword co-occurrence mapping, are employed to provide a comprehensive perspective. The findings reveal a steady increase in publications focused on scientific literacy assessments, reflecting the growing recognition of this research area. The analysis identifies highly influential journals, articles, authors, and institutions actively shaping the field. Furthermore, it highlights key research themes, such as secondary education, teacher professional development, and information literacy. However, the integration of scientific literacy assessments with artificial intelligence remains an underexplored area, presenting opportunities for future research.

Keyword: assessment development; bibliometric analysis; critical thinking; science education; scientific literacy assessment

Introduction

Scientific literacy encompasses the ability to comprehend, evaluate, and apply scientific knowledge to address the multifaceted challenges of our rapidly evolving world. In recent years, heightened awareness of the pivotal role of science education and literacy has underscored the need to equip students with the skills necessary to navigate the complexities of the 21st century (Pratiwi et al., 2019). To gauge students' scientific literacy, a plethora of assessment tools have been developed. These tools serve as compasses, guiding educators in assessing students' proficiency from the outset of a course to their progress during instruction. Notable contributions include the works of Facione, (2020); Facione, (1991); Lawson, (1978); Sundre, (2003); Miller & Sundre, (2008), Lemke et al., (2004); Stein et al., (2007); Quitadamo et al., (2008); Stein & Haynes, (2011); Nuhfer et al., (2016); and Stanhope et al., (2017).

However, despite these commendable efforts, systemic gaps persist in science literacy assessment. Current methodologies of assessment often prioritize factual recall, potentially overshadowing deeper conceptual understanding. As Hidayah et al., (2020) rightly pointed out, current assessment tools tend to focus on specific aspects of students' learning, neglecting their overall capacity to independently analyze, interpret, and draw conclusions about the topic. Standardized tests, while valuable, may fall short in capturing the multifaceted dimensions of scientific literacy, emphasizing rote memorization over critical thinking. These limitations have sparked diverse perspectives among researchers and educators regarding the most effective assessment strategies for measuring scientific literacy. In this context, teachers grapple with mounting pressure, as the trend toward data-driven decision-making

places accountability squarely on their shoulders (Schildkamp & Lai, 2013; Stiggins, 2017).

To address these challenges, a recent study by Aria et al., (2021) sheds light on promising practices. Their findings reveal that many teachers embrace assessment for learning, a pedagogical approach where assessments serve not only as evaluative tools but also as catalysts for student growth. By leveraging assessment results as feedback, teachers continuously refine their teaching methods. This observation underscores the need for a more holistic approach to assessment that encapsulates the full spectrum of students' learning capabilities. By broadening the scope of assessment, we can ensure a more accurate and comprehensive evaluation of students' understanding and application of science concepts. This diversity cannot be accurately gauged through a single type of assessment. To address this challenge, a new assessment system and concept is needed (Neina & Qomariyah, 2021).

Scientific literacy assessments, as a comprehensive approach to evaluation, are instrumental in determining student learning outcomes in science education. They provide a holistic view of students' knowledge and skills, capturing the breadth and depth of their understanding in various scientific domains (Coppi et al., 2023; Fisher, M. R. & Bandy, 2019). Moreover, science literacy assessments serve as a development indicator, offering valuable insights into students' progress over time. They allow educators to track and analyze changes in students' scientific knowledge and skills, thereby facilitating targeted instruction and intervention strategies (Allen et al., 2017). This dynamic use of assessment data underscores its importance in promoting student learning and achievement in science education.

In recent years, bibliometric analysis has surged in popularity within the realm of research (Khan et al., 2021). Its ascendancy can be attributed to its adeptness in managing vast volumes of scientific data and its potential to catalyze significant research impact (Donthu, Kumar, Mukherjee, et al., 2021). As we reflect on the past to shape the future, systematic reviews of scholarly journals have become a customary practice in academic circles (Rialp et al., 2019). Bibliometric analysis, a powerful tool, enables researchers to extract meaning from unwieldy and unstructured datasets. By providing a consolidated perspective, it lays the groundwork for advancing fields in distinctive and meaningful ways (Donthu, Kumar, Pandey, et al., 2021). This method hinges on quantitative techniques, including citation analysis, applied to bibliometric data such as publications and citation units (Broadus, 1987).

Although scientific literacy assessment practices remain a topic in many academic studies with their merits and limitations, research aimed at providing an overview of research on various scientific literacy assessments and to create a general map of research trends is still very limited. Most articles discuss the process of developing science literacy assessment instruments such as the one conducted by Kriswantoro et al., (2021) who developed a critical thinking ability assessment model integrated with science process skills. Nazhifah et al., (2022) have also developed a science literacy instrument integrated with local wisdom as an effort to measure and train students' ability to engage in activities related to science, technology and the environment. There are no bibliometric studies in the literature that would that reveals a map of studies that examined assessments in all aspects of the science literacy dimensions in an education context.

This study uses scientific mapping and bibliometric analysis to shed light on research trends regarding the development of scientific literacy assessments in the domain of educational science. Specifically, this study seeks to answer the following interrelated research questions about the numerical distribution of relevant publications by year, type, journal, author, institution and country of origin that are most cited in the literature. In addition, it will also explore the main themes that characterize research on scientific literacy multiple assessment, topic trends that have evolved over time, and clusters that emerge from text analysis of titles, keywords and abstracts across the literature. By rigorously mapping the intellectual landscape, this investigation provides a comprehensive perspective on the state of an issue that has profound educational significance in adequately developing scientific literacy among diverse student populations. The findings in this article can serve as a reference for future research agendas, such as curriculum evaluation materials, and policy interventions aimed at strengthening scientific literacy through innovative assessment approaches.

Method

Bibliometric analyses evaluate citation performance within specific fields through synthesis. Bibliometric analysis took a more innovative approach by examining the realm of professional literacy. It delved into article titles, author, keyword, and abstracts (Wong et al., 2017; Zhang, 2020). Bibliometric analysis utilizes the keywords within scientific literature to reveal how different publications on a specific topic are interconnected and how the research area has evolved over time (Zupic & Čater, 2015). This methodology is considered well-suited for examining publication trends and growth trajectories on particular subjects, as well as for mapping out networks and connections between authors, their affiliated institutions, and their countries of origin (Suhaimi et al., 2022).

This article will apply bibliometric analysis to evaluate literature about scientific literacy assessment that has been published in scientific journals and periodic conference proceedings (Pham et al., 2021;

Wirzal, Halim, et al., 2022; Wirzal, Nordin, et al., 2022). Scopus database was used for the selection of the papers to be examined in the scope of this research. Scopus is an indexing service and prominent database that compiles metadata from reputable, peer-reviewed scientific journals across disciplines. As stated by Wirzal, Halim, et al., (2022), Scopus consolidates abstracts and citations from highly regarded journals spanning various fields, making it an authoritative source for bibliometric research data. Scopus database has been commonly used for bibliometric analyzes and scientometric visualization (Donthu, Kumar, Pandey, et al., 2021).

This bibliometric analysis was conducted using three primary software tools - Publish or Perish 8 (PoP 8), VOSviewer, and Microsoft Excel to visualize research trends of scientific literacy assessment (Eck & Waltman, 2014). The analysis is to identify publication trends and research trends in terms of scientific literacy assessment in the last five years Wirzal, Nordin, et al., (2022) using VOSviewer. Publish or Perish 8 (PoP 8) was used because it has the ability to quickly collect relevant bibliographic data. VOSViewer is used because it can create a research network through citations, bibliographic merging, co-citations, or co-authorship relationships (Donthu, Kumar, Mukherjee, et al., 2021). This network can also contain journals, researchers, or individual articles, for example. To create and display co-occurrence networks of important phrases extracted from a corpus of scientific literature, VOSviewer also provides text mining features.

This study followed a five-step research framework: (1) research design, (2) data collection, (3) data analysis, (4) data visualization, and (5) discussion (Hernández-Torrano & Ho, 2021) as seen in Figure 1. Network analysis was conducted by examining co-authorship relationships, citation patterns, and keyword co-occurrences (Thu et al., 2021). Co-authorship analysis looked at the connections between authors, countries, and institutions publishing research related to scientific literacy assessment. Citation analysis involved identifying the journals that received the most citations for articles on scientific literacy assessment, in order to gauge the relevance of scientific literacy assessment to various scientific fields. Keyword analysis aimed to uncover the main topics, emerging subfields, and research problems in the area of scientific literacy assessment. This was done by analyzing the co-occurrence of all keywords in the titles, abstracts, and metadata of the scientific journals.

Figure 1. Research Framework

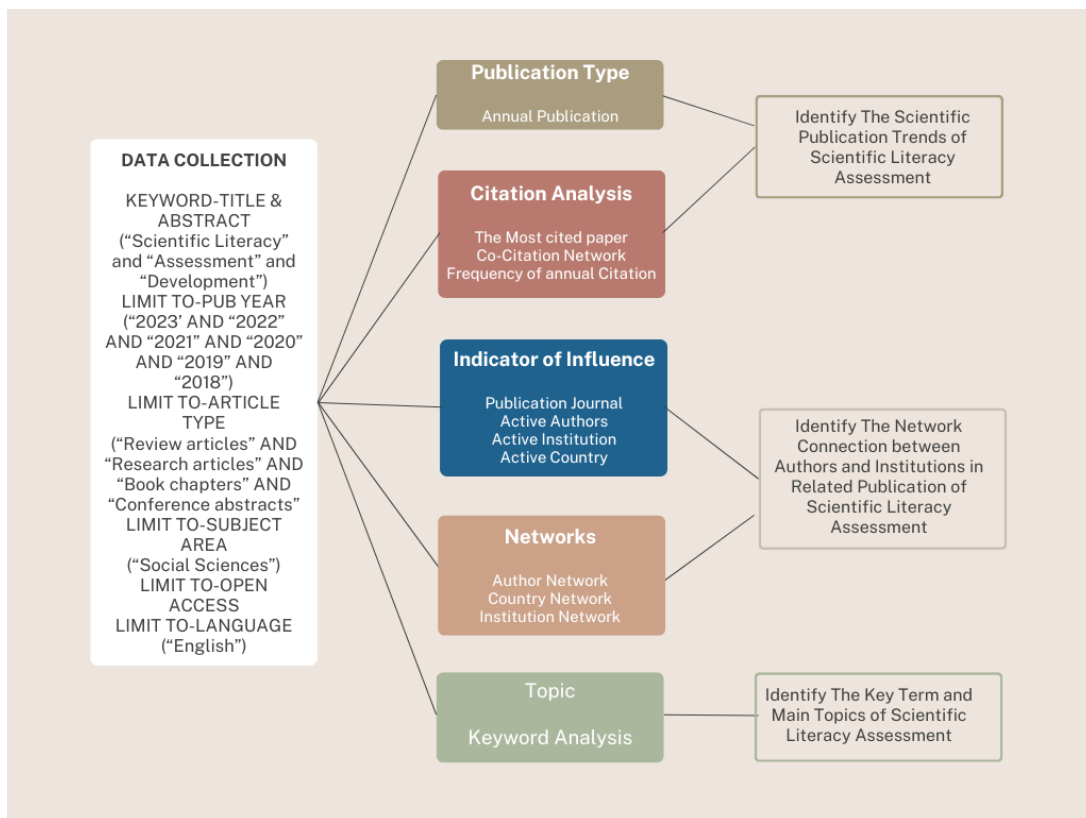Table 1, outlines the keywords used to search for literature pertaining to scientific literacy scientific literacy assessment. The initial search using the terms "scientific literacy" AND "assessment" AND "development" yielded 16.361 documents. This was then refined by limiting the publication years to the last five years (2019-2023), which produced 5.757 documents in English and publication types such as

review articles, research articles, books chapter, and conference abstracts. However, since the subject areas were still quite broad, an additional filter was applied to focus solely on documents classified under the SOCIAL SCIENCES discipline and open access documents. After this final filtering step, the analysis proceeded with a total of 660 relevant documents.

Table 1. The Refinement Process

Query string	Total Documents
KEYWORD-TITLE & ABSTRACT ("scientific literacy" AND "assessment" AND "development")	16.361
Refine I	
KEYWORD-TITLE & ABSTRACT ("scientific literacy" AND "assessment" AND "development") LIMIT-TO-PUB YEAR ("2023" AND "2022" AND "2021" AND "2020" AND "2019") LIMIT-TO-LANGUAGE ("English")	5.757
Refine II	
KEYWORD-TITLE & ABSTRACT ("scientific literacy" AND "assessment" AND "development") LIMIT-TO-PUB YEAR ("2023" AND "2022" AND "2021" AND "2020" AND "2019") LIMIT-TO-LANGUAGE ("English") LIMIT-TO-ARTICLE TYPE ("Review Article" AND "Research Article" AND "Book Chapters" AND "Conference Abstract") LIMIT-TO-SUBJECT AREA ("Social Science"	185

Result and Discussion

Trends on Scientific Literacy Assessment

Scopus is widely regarded as the most esteemed and influential databases globally (Zhu & Liu, 2020). These databases encompass published documents as well as citation data spanning all scientific disciplines, making them invaluable resources for bibliometric analysis (Baas et al., 2020). A comparative study by Si et al., (2019) found that Scopus offers approximately 20% more comprehensive coverage than Web of Science. Consequently, for the purposes of this study, the literature was sourced from the Scopus database.
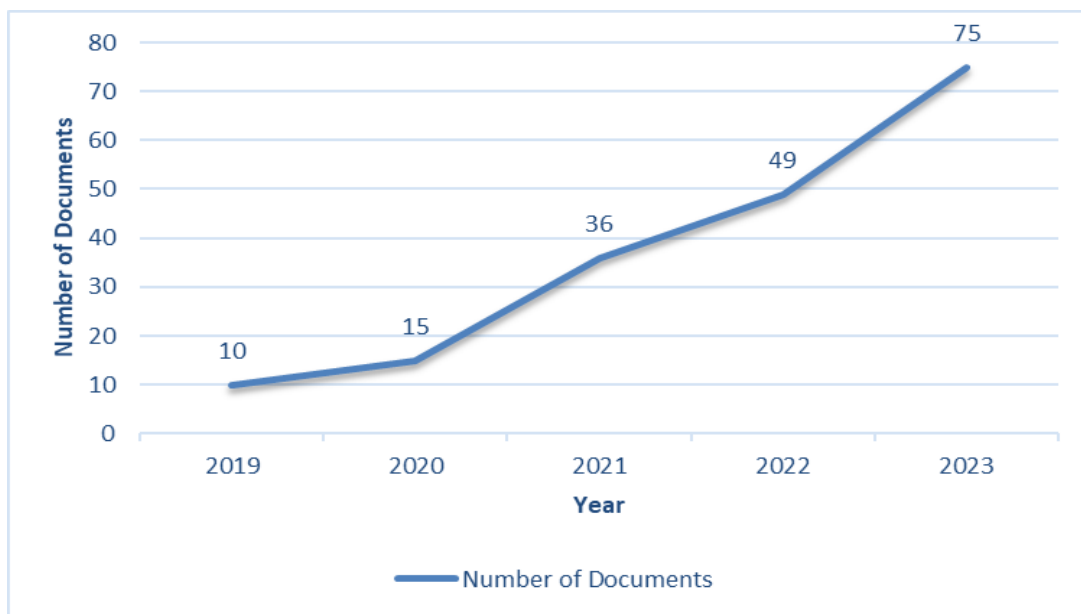

Figure 2. Research Trends in scientific literacy assessment publications for the past five years

The aim of this article was to examine publication trends to depict the trends of research related to scientific literacy assessment over the past five years from 2019 to 2023. Figure 2, illustrates the

development number of publications on the science literacy assessment topic within 2019 to 2023 period. A total of 185 documents published in research article, review article, book chapter, and conference proceedings were selected for the bibliometric analysis. There was a steady rise from 10 publications in 2019 to 185 in 2023. These findings underscore that scientific literacy assessment is an important research area and core competency within science education. The rapid technological advancements have facilitated easier access to information and knowledge transfer (Hsu et al., 2019). However, the validity and reliability of this disseminated information and knowledge need to be critically evaluated (Haug & Mork, 2021) to prevent students from developing misconceptions or flawed conceptual understandings (Spector & Ma, 2019). This necessity aligns with the increasing number of publications and emphasis on scientific literacy assessment for training students to assess the quality of information, arguments, and knowledge they possess for problem-solving (Aristeidou & Herodotou, 2020). Research on the scientific literacy assessment be said to be developing, this can be seen from the initial data which produced 988 citations from 185 publications, with an average of 197,60 citations per year and 4,94 citations per article. Table 2 shows the full results of the metric data after final refine.

Tabel 2. Comparison Metric

Metric Data	Final Refine
Keyword	"scientific literacy" AND "assessment" AND "development"
Publication Years	2019 - 2023
Citation Years	5 years
Papers	185
Citation	988
Cites/year	197,60
Cites/articles	4,94
Cites/author	988
Papers/author	197,99
Author/paper	0,99
h_index	15
g_index	25
hI_annual	3,00
hA_index	8
hI_norm	15

Journal Citation Analysis

Table 3, highlights the top ten scientific journals that have made the most significant contributions to the field of scientific literacy assessment over the past five years, from 2019 to 2023. The table presents data on the number of documents published, the total citations received, the journal quartile rankings, the 2022 CiteScore metrics, and the impact factor values for each of these ten journals. This information is provided to facilitate a comparative ranking and assess the relative influence of these journals within the specified research domain.

Table 3. Productive Journal that Published Article of Scientific Literacy Assessment

No	Journal	Number of Article	Citation	Quartile	Cite Score 2022	SJR
1.	Computers and Education: Artificial Intelligence	35	75	Q1	7,7	1,7
2.	International Journal of Educational Research Open	25	92	Q1	6.5	1,4
3.	Computer & Education	20	93	Q1	23,8	3,7
4.	Educational Research Review	16	83	Q1	17,4	3,3
5.	Teaching and Teacher Education	15	92	Q1	6,5	1,6
6.	International Journal of Educational Research	14	85	Q1	4,9	1,0
7.	International Journal of Educational Development	11	83	Q1	3,9	0,8
8.	Studies in Educational Evaluation	11	82	Q1	5	0,8
9.	Thinking Skills and Creativity	11	91	Q1	6,4	1,1
10.	Learning and Instruction	9	98	Q1	11,2	2,4

The analysis reveals that Computers and Education: Artificial Intelligence has been the most influential journal in the field of scientific literacy assessment over the last five years, having published 35 articles that garnered a total of 75 citations. Following closely is the International Journal of Educational Research Open, with 25 published articles and 92 citations. Computer & Education are tied for the third position, each contributing 20 papers and accumulating 93 citations. The remaining journals can be seen on Table 3. These findings demonstrate the existence of several high-quality, highly-cited articles by researchers exploring the topic of scientific literacy assessment (Djeki et al., 2022).

Data on Table 3 reveals that the publications featuring research on scientific literacy assessment are predominantly found in high-ranking journals, Q1 in the Scopus database. The results indicate that all of these journals hold a Q1 ranking. The journal Computers & Education provides a platform for research at the intersection of artificial intelligence (AI) and education. Its aims are well-aligned with developing and evaluating the tools and methods for assessing scientific literacy. Additionally, research on analyzing educational data, like learning behavioral analysis and emotion detection, could inform the design of scientific literacy assessments that capture the cognitive and affective dimensions involved. These scientific journals demonstrate high relevance to the research topic and are categorized as having a substantial impact factor over the past five years. Notably, the Computer & Education boasts the highest CiteScore of 23,8 among the top 10 journals, followed by Educational Research Review (17.4) and Learning and Instruction (11,2). These three journals hold a Q1 ranking, suggesting a strong correlation between a journal's CiteScore and its positioning in the highest quartile on Scopus (Suhaimi et al., 2022).

The Most Influential Publication

Table 4 highlights the top 10 most cited articles from the total of 185 documents published over the last five years from 2019 to 2023, along with their respective citation counts during this period. Leading the list is an article titled " Developing a short assessment instrument for Technological Pedagogical Content Knowledge (TPACK.xs) and comparing the factor structure of an integrative and a transformative model" by Schmid et al. (2020) from Switzerland which has garnered 96 citations, the highest among the articles analyzed. This article is about developing and validating a concise questionnaire (called TPACK.xs) to measure pre-service teachers' technological pedagogical content knowledge (TPACK). TPACK refers to the knowledge teachers need to effectively integrate technology into their teaching. Notably, the article was published in a Q1 journal (SJR = 3.7), underscoring its credibility and recognition as a highly relevant reference source for research on scientific literacy assessment.

Tabel 4. Most Influential Papers

No	Published Year	First Author	Title	Affiliation	Country	Citation
1.	2020	Mirjam Schmid	Developing a short assessment instrument for Technological Pedagogical Content Knowledge (TPACK.xs) and comparing the factor structure of an integrative and a transformative model	University of Zurich	Switzerland	96
2.	2020	Kim Schildkamp	Formative assessment: A systematic review of critical teacher prerequisites for classroom practice	University of Twente	Netherlands	67
3.	2022	Matthias Carl Laupichler	Artificial intelligence literacy in higher and adult education: A scoping literature review	University Hospital Bonn	Germany	43

No	Published Year	First Author	Title	Affiliation	Country	Citation
4.	2021	Kiomi Matsumoto-Royo	Core practices in practice-based teacher education: A systematic literature review of its teaching and assessment process	Universidad del Desarrollo	Chile	26
5.	2019	Pirjo Aunio	Multi-factorial approach to early numeracy—The effects of cognitive skills, language factors and kindergarten attendance on early numeracy performance of South African first graders	University of Helsinki	Finland	15
6.	2023	Ramazan Yilmaz	The effect of generative artificial intelligence (AI)-based tool use on students' computational thinking skills, programming self-efficacy and motivation	Bartin University	Turkey	15
7.	2020	Sung-Pei Chien	Examining influences of science teachers' practices and beliefs about technology-based assessment on students' performances: A hierarchical linear modeling approach	National Changhua University of Education	Taiwan	11
8.	2020	Matthias Carl Laupichler	Delphi study for the development and preliminary validation of an item set for the assessment of non-experts' AI literacy	University Hospital Bonn	Germany	9
9.	2022	Jonna Pulkkinen	The correspondence between PISA performance and school achievement in Finland	University of Jyväskylä	Finland	9
10.	2020	Timo Ehmke	Measuring mathematics competence in international and national large scale assessments: Linking PISA and the national educational panel study in Germany	Leuphana Universität Lüneburg	Germany	8

Institution' Contribution

Table 5 presents the top 10 institutions or organizations that have published research related to scientific literacy in science education. The analysis of the 185 published documents revealed that they originated from 75 distinct institutions or organizations worldwide. Among these, The University of Hong Kong in China secured the top rank with eight publications. University of Oslo in Norway followed closely with four published articles on this topic. University of Twente in Netherlands took the third

position with four articles. Notably, two institutions from the United Kingdom – University of Cambridge and University of Oxford each contributed three articles. The remaining institutions on the list also had three published documents each. These findings underscore the active involvement of China institutions in developing and researching emerging topics (Djeki et al., 2022), reflecting the country's dominant position in scientific literacy assessment research.

Table 5. Most Contributed Institution based on The Number of Articles

No.	Institution	Country	Number of Article	Citation
1.	The University of Hong Kong	China	8	114
2.	University of Oslo	Norway	4	164
3.	University of Twente	Netherlands	4	66
4.	Queen's University Belfast	United Kingdom	4	9
5.	University of Cambridge	United Kingdom	3	195
6.	University of Zurich	Switzerland	3	111
7.	National Taiwan Normal University	Taiwan	3	31
8.	University of Tübingen	Germany	3	22
9.	University of Oxford	United Kingdom	3	14
10.	University of Teacher Education	Switzerland	3	9

Author' Contribution

Table 6 presents information on the top 10 authors, including the number of documents they have published, and the citations received. The analysis reveals that authors affiliated with institutions in Norway, Germany, and United Kingdom are in the top three positions in terms of productivity on the topic of scientific literacy assessment. Apart from this top three, the remaining authors on the list exhibit relatively minor variations, having published 2 papers each, with comparable citation number ranging from 12 to 51.

Table 6. The Rank of Authors in Scientific Literacy Assessment.

Rank	Author	Institution	Country	Publication Number	Citation Number
1.	Scherer, R.	University of Oslo	Norway	4	202
2.	Húbner, N.	University of Tübingen	Germany	3	13
3.	Mackenzie, A.	Queen's University Belfast	United Kingdom	3	7
4.	Laupichler, M.C.	University Hospital Bonn	Germany	2	51
5.	Aster, A	University Hospital Bonn	Germany	2	51
6.	Raupach, T.	University Hospital Bonn	Germany	2	51
7.	Su, J.	The University of Hong Kong	China	2	31
8.	Segers, E.	University of Curaçao	Curacao	2	28
9.	Nagengast, B.	University of Tübingen	Germany	2	12
10.	Trautwein, U.	University of Tübingen	Germany	2	12

According to the data presented in Table 5, Scherer, R from Norway occupy the top rank with four published documents and 202 citations. He is followed by Húbner, N. from Germany, with three documents and 13 citations. The third position is held by Mackenzie, A. from the United Kingdom, contributing three documents and garnering 7 citations. Seven authors have authored two documents each, consists of Laupichler, M.C., Aster, A, and Raupach, T. from Germany with each 51 citations; Su, J. from China with 31 citations; Segers, E. from Curacao with 28 citations; Nagengast, B. and Trautwein, U. from Germany with 12 citations. All of these authors are established researchers specializing in the topic of scientific literacy assessment. Furthermore, Figure 3 illustrates the collaboration networks between authors with at least two published works, revealing four interrelated research groups. The analysis underscores the strong collaborative relationships among researchers investigating scientific literacy within the field of science education.
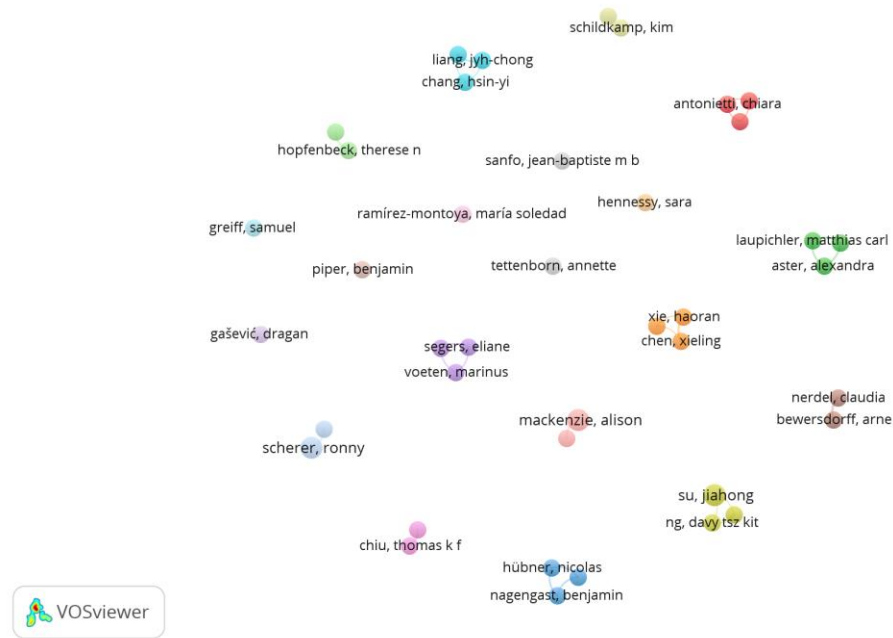
Figure 3. Co-authorship network of authors with at least two documents published

Keyword Analysis

Keyword analysis provides insights into the research topics based on the keywords used in published documents (Goksu, 2021). The network map in Figure 4 was obtained from co-occurrence of keywords from the bibliography data using the full counting, which resulted in 699 relevant keywords. The minimum number of occurrences of keywords was then determined 5 times and obtained 17 keywords that often appear. Each of these keywords is then calculated for its relevance to the topic of development to be carried out. There were 16 keywords whose relevance was more than 60% which were then grouped into 3 clusters. Keywords contained in the same cluster show the relationship between keywords used in different publications.
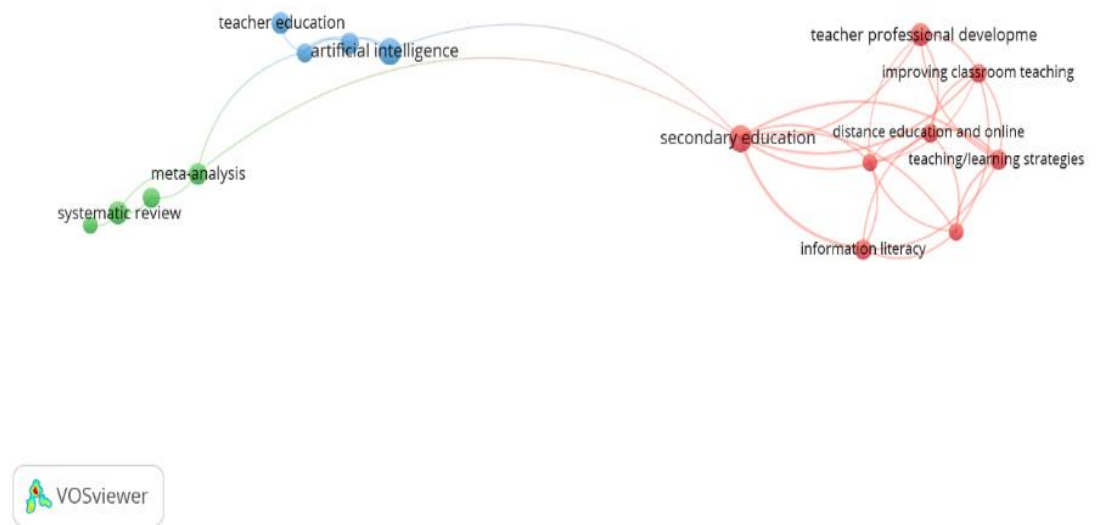

Figure 4. Co-occurrence of 699 keywords in scientific literacy assessment

From the resulting map in Figure 4, it can be seen that research on "scientific literacy assessment" is closely related to the keywords of secondary education, teacher professional development, information literacy, improvement classroom teaching, teaching learning strategies, distance education and online. Based on the visualization, it can be observed that scientific literacy assessment primarily focuses on integrating scientific literacy assessment into secondary education, with teacher professional development emerging as the dominant subject area. However, a research gap is evident in the lack of integration or implementation of scientific literacy assessment with the artificial intelligence. Additionally, emphasis on fostering specific aspects of teacher education appears to be an underexplored area. The more evenly distributed a keyword is, the more frequently it is used in the research subject. On the other hand, the more uneven the distribution of keywords, the less frequent the research topic is. This depiction is very important to identify research that has not been done so that a research update can be carried out.

Conclusion

This bibliometric analysis provides a comprehensive overview of the intellectual landscape surrounding scientific literacy assessment research from 2019 to 2023. The study reveals an increasing trend in the number of publications focused on developing and evaluating assessment tools to measure students' scientific literacy and critical thinking abilities. This growth underscores the rising significance of scientific literacy as a core competency in science education, particularly in the context of the rapidly evolving technological landscape and the need to critically evaluate information. The analysis highlights that a substantial portion of the highly cited literature on this topic is published in reputable, high-impact journals, primarily in the Q1 category according to Scopus rankings. This finding reflects the academic rigor and relevance of the research conducted in this domain. Furthermore, the study identifies leading institutions, authors, and countries actively contributing to the advancement of scientific literacy assessment, with notable contributions from institutions in China, Norway, Germany, and the United Kingdom.Through keyword analysis, the study reveals that current research on scientific literacy assessment is closely linked to themes such as secondary education, teacher professional development, information literacy, and teaching-learning strategies. However, the integration of scientific literacy assessment with artificial intelligence appears to be an underexplored area, presenting opportunities for future research.

Conflict of Interest

All authors state that there is no 'Conflict of Interest' relate with the publication of this article.

Authors Contribution

Y. Hadiastriani: writing original draft preparation; **P. Djarot:** review, feedback, and revision.

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