Scientific literacy in physics learning: A bibliometric analysis from 1977 until 2023 and its impact on quality education

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Abstract. This study focuses on keyword mapping and exploring research trend topics of scientific literacy in physics education for future research opportunities. The study aims to analyze bibliometrics literature on scientific literacy in physics education and publication trends indexed by the Scopus database. The method used is using bibliometrics analysis in the Scopus database. According to the data, this research shows that scientific literacy publications from 1977-2023 are 287 research papers. The most dominant keywords are scientific literacy skills, physics teacher, and science education. The top author in scientific literacy is Prahan BK. The most published articles in scientific literacy are in the Journal of Physics Conference Series. Scientific literacy can serve as a strong foundation for achieving the SDG for quality education, as it enables individuals and society to understand, encourage, and support efforts to improve the quality of education for all. In conclusion, scientific literacy is still possible to analyze and link with other topics, so scientific literacy for education physics will make the world of education more diverse. There are many future study opportunities, from results analysis to literacy science.

1 Introduction

As a participant in the PISA assessment, Indonesia has shown consistently low rankings in the TIMSS science literacy surveys from 2000 to 2012. Additionally, PISA data highlight several concerns, including low science literacy achievements among students, with an average of 32% across all aspects. This breakdown shows 29% in content, 34% in processes, and 32% in contexts. There is also a notable lack of diversity in science literacy among students from different provinces in Indonesia. Furthermore, Indonesian students’ problem-solving abilities are significantly lower than those in Malaysia, Thailand, and the Philippines [1]. The importance of science literacy in education has been well documented, underscoring its role as a critical measure of educational quality and its international recognition.

Enhancing knowledge and scientific skills has emerged as a pressing need for policy change within the education system. One of the essential skills that students must possess is
scientific literacy. The scientific literacy approach has been chosen to develop students' scientific knowledge and skills worldwide [2]. To this end, various efforts have been undertaken to improve the quality of education in different countries, including research studies. Research on scientific literacy has been extensively conducted across various fields, such as health [3] and geography [4].

However, scientific literacy research in education has already seen widespread application and study by many researchers. A bibliometric analysis study has not been conducted on scientific literacy in physics education. Therefore, this research focuses on mapping out the keywords associated with scientific literacy and identifying trends in topics within physics education to highlight future research opportunities. A comprehensive study is necessary to assist other researchers in planning steps to enhance the quality of education.

Quality education is a central aim of the Sustainable Development Goals (SDGs) for 2030. The sustainable development paradigm has become a new agenda for progress in numerous countries, with development approaches evolving every decade to formulate a vision for a better world. Among the targets of the SDGs, education remains a critical and challenging issue for many nations. Specifically, education falls under SDG 4, which is committed to ensuring inclusive and equitable quality education and promoting lifelong learning opportunities for everyone [5]. SDG4 outlines seven targets and three implementation methods, emphasizing fairness and inclusivity in education, gender equality, and the provision of quality and lifelong learning opportunities [5]. Scientific literacy is crucial in fulfilling the SDG for quality education by empowering individuals and societies to comprehend, encourage, and support initiatives to enhance education quality for all [5].

This article aims to provide a bibliometric analysis of the literature related to scientific literacy studies within physics education and identify trends in studies or publications indexed by the Scopus database from 1977 to 2023. Applying bibliometric methods facilitates the examination of research states in specific knowledge areas [6]. This analysis can reveal major topics within the field that constitute a significant portion of the publications and present research opportunities for scientific literacy in education, particularly in physics.

2 Methods

This study employs bibliometric analysis with the aid of the Scopus database. Data was collected on May 9, 2023, using the "Scientific Literacy in Physics Learning" keyword. The scope of this study is limited to publications from 1977 to 2023. The data obtained were saved in CSV format. Subsequently, the data were analyzed using Vosviewer, Microsoft Excel, and Microsoft Word to create more engaging visualizations and deeper analysis. Bibliometric analysis can be used to identify and verify the current trends in research development [6]-[10]. Figure 1 illustrates the distribution of research topics.

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Fig. 1. Flowchart of the Study
3 Results and Discussion

3.1 Research trends in scientific literacy

The number of documents retrieved from the Scopus database from 1977 to 2023 is displayed in Figure 2.

![Figure 2. Research Publications Trends of Scientific Literacy in Learning Physics from 1977 to 2023.](image)

Figure 2 illustrates the number of published documents in scientific literacy from 1977 to 2023. The data show that in 1977, there was one article published. However, between 1978 and 1986, no articles were published in this field. Furthermore, starting from 2000, there was a noticeable increase in publications, reaching a peak in 2019 and 2021, with 46 articles published yearly. A decline in publications was observed in 2020, a trend that may be attributed to the impact of COVID-19, which significantly affected publication gatherings [11]. The shift in educational practices from in-person to virtual environments also impacted the learning system. As of 2023, only seven documents have been recorded, but this number is expected to change as the year has only progressed for a few months and seven more months remain.

3.2 Bibliometric map in scientific literacy

The visualization in Figure 3 is derived from the database results that have been obtained.

![Figure 3. Visualization Deployment of Scientific Literacy](image)
Figure 3 presents a co-occurrence visualization on a map based on text data related to scientific literacy in physics education. The bibliometric map of scientific literacy in physics education reveals four distinct clusters: red, yellow, green, and blue. The map features 1,068 words, each linked by a network that displays related keywords within scientific literacy. The colors of the clusters correspond to their interrelatedness based on their relationships. The larger the circle, the more frequently that word or text data is utilized in the context of scientific literacy. From this visualization, it is evident that scientific literacy is closely associated with the various words highlighted.

Within the red cluster, there are numerous keywords, including "teaching," "science education," and "communication." Pantiwati's research discusses the vital role of science education in successfully implementing scientific literacy, highlighting that the key to successful learning is the scientific literacy teachers employ with students to achieve educational objectives [12]. This data agrees with Wulan's study, which discusses the importance of the accuracy of evaluations aligned with the literacy methods teachers apply to their students [13]. Additionally, argumentation can be utilized as a form of literacy outcome within the learning context, as demonstrated in recent research studies [14-15].

In the yellow color cluster, the keyword "motivation" appears prominently. Motivation is crucial for development and research across all fields, particularly education. Furthermore, Helwi and Indari's research delves into virtual literacy motivation during the COVID-19 pandemic [16]. The study by Hamzah et al. examines the development of literacy related to motivating children with special needs [17]. Additionally, Sukma et al. explore literacy development as a motivating factor for performing practical physics lessons in high schools [18].

In the green-colored clusters, the keywords include "physics teacher," "test," and "scientific literacy skills." This fact aligns with the findings of a study by Malik [19], which investigates scientific literacy skills about Student Worksheet questions based on scientific literacy in physics learning. The study suggests that Student Worksheet assessments should not solely rely on traditional question models but can also incorporate questions based on scientific literacy. As explored in Setiawan's research, various literacy models are utilized in learning, such as Student Worksheets [20]. Literacy is not limited to using Student Worksheet; it can also be linked to applications like Facebook, which may provide different data, similar to literacy on Student Worksheet. This approach is consistent with the findings of a study by Dewi et al. [21], which utilized the Facebook application for educational purposes.

The keywords "demand" and "researchers" stand out in the blue-colored clusters. The demand for effective assessment systems in scientific literacy is significant, as detailed in Malik's study, which analyzes formative assessments in high school physics using computer-assisted scientific literacy [19]. The findings highlight the importance of evolving assessment systems and tools to keep pace with developments in the field. Regarding tools used for assessing scientific literacy, Cahyanovianty and Wahidin's research explores the development of a practical module created individually to assess scientific and social literacy skills [22]. Additionally, other tools have been developed for conducting authentic assessments using scientific literacy, which can enhance participants' understanding of scientific literacy, as demonstrated in Astuti and Setiawan's research [23]. It was observed that the most influential papers in this area were predominantly research articles, followed by conference papers, with fewer review papers also contributing to the discourse [13].
Figure 4 illustrates variations in word intensity and size, indicating different levels of emphasis within the dataset. Words with brighter intensity and larger size, such as "test," "teaching," "license," and "physics teacher," are highlighted as critical terms. In contrast, words like "scientist," "gain," "stem," "time," "science," "PISA," "profile," and many others appear with lower intensity, suggesting they are of secondary focus. This density visualization reveals novelty in physics teaching and scientific literacy skills, suggesting these are the most frequently used words in research on scientific literacy within physics education. This finding indicates that the words with greater density and size represent the most significant novelties in the research topic of scientific literacy in physics education. Similarly, the learning process and the role of educational participants are underscored as critical to facilitating learning and literacy for assessing student development. Notably, the literacy skills of non-science undergraduate students are relatively low [24], highlighting a potential area for further investigation and improvement.

Several models for developing scientific literacy have been identified, including Student Worksheet scientific literacy [20], representation [25], and projects and alternatives [26]. Setiawan explores the relationship between LKPD science literacy and learning motivation, finding that LKPD as a form of scientific literacy positively affects students' motivation to learn [20]. Another study examines the application of representational literacy in physics education, discovering that representational literacy can enhance students' conceptual understanding [25]. The findings from these studies provide empirical evidence that the abilities of high school students to utilize dual representations in physics, particularly in topics related to heat, require further enhancement [27].

Ali et al. study development processes utilizing project-based literacy, encompassing three phases: investigation, design, and realization [28]. Another study discusses literacy as an alternative approach during emergencies [26]. It is emphasized that science process skills should be cultivated in scientific disciplines and across various knowledge areas [29]. Alternative literacy methods include article reading and self-assessment based on the articles. Visualization studies indicate that Socio Scientific Issues (SSI) significantly impact science learning, particularly in enhancing argumentation skills [30]. There is a noted need for innovative physics learning that incorporates direct application in real-world environments to bolster interest in physics education [31].
Based on Figures 5, 6, and 7, the visualized network maps illustrate the interconnectivity among the keywords "scientific literacy skills," "physics teacher," and "science education." These terms are closely related to scientific literacy within physics learning, with each color in the clusters indicating interrelated groups. In Figure 5, "scientific literacy skills" are
connected to other keywords like "high school student," "license," "society," and more. Figure 6 shows that "physics teacher" is associated with terms such as "teaching," "practice," "observation," among others. Meanwhile, in Figure 7, "science education" links to "nature," "practice," "test," and additional keywords. These connections underscore that scientific literacy skills are deeply intertwined with scientific literacy [15], [32-35].

Prospective teachers' proficiency in primary physics teaching is relatively high, meeting the anticipated standards through multi-model active learning [36]. Therefore, scientific literacy skills are likely to improve significantly when scientific literacy is integrated into every aspect of learning. Furthermore, the keyword "Scientific literacy" plays a crucial role in determining the effectiveness of the learning model employed. This fact aligns with findings from [37-41], which indicate that adopting specific methods tailored to each learning material based on scientific literacy can yield positive outcomes. Enhancing students' abilities to solve physics problems requires using suitable inquiry learning methods (free, guided, and structured) supported by PhET [27]. Trends in physics research, particularly in photography, have been explored through bibliometric studies [15]. Additionally, students often perceive physics as challenging due to insufficient practical work during classroom learning [42].

### 3.3 Authors map in scientific literacy

![Fig. 8. Visualization Network on Documents Writer, and Collaboration Between Writer](image)

Figure 8 presents a visualization of document authors and their collaboration relationships. The metadata includes 708 authors. The visualization indicates collaboration patterns among writers; for example, the red represents the collaboration between writer Prahani BK and writer Roja, HI. In addition, some authors have not collaborated with others, such as Nasrudin D., Kampa N., Defrianti D., and others. This visualization highlights the network of collaborations and individual contributions within the research community.
Figure 9 showcases a network of the ten most prominent authors and their connections within the Scientific Literacy in Physics Learning field, as derived from the Scopus database. The authors include Hariyono E., Prahani BK, Sunarti T., Utari S., Saepuzaman D., Yuberti Y., Watanabe G., Munhaz MG, Rusilowati A., Aminah NS, and Yuliati L. These individuals represent the top contributors to the topic based on their publications and collaborations. For a detailed explanation of the Author's contributions and connections, refer to Table 1.

Table 1. Top 10 Authors on the Topic Literacy Science in Learning Physics

<table>
<thead>
<tr>
<th>Rank</th>
<th>Author</th>
<th>Documents</th>
<th>Citations</th>
<th>Total Link Strength</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Prahani BK</td>
<td>4</td>
<td>11</td>
<td>184</td>
</tr>
<tr>
<td>2</td>
<td>Hariyono E.</td>
<td>3</td>
<td>5</td>
<td>102</td>
</tr>
<tr>
<td>3</td>
<td>Sunarti T.</td>
<td>4</td>
<td>26</td>
<td>85</td>
</tr>
<tr>
<td>4</td>
<td>Utari S.</td>
<td>4</td>
<td>34</td>
<td>66</td>
</tr>
<tr>
<td>5</td>
<td>Saepuzaman D.</td>
<td>3</td>
<td>24</td>
<td>61</td>
</tr>
<tr>
<td>6</td>
<td>Munhaz MG</td>
<td>3</td>
<td>0</td>
<td>57</td>
</tr>
<tr>
<td>7</td>
<td>Watanabe G.</td>
<td>3</td>
<td>0</td>
<td>57</td>
</tr>
<tr>
<td>8</td>
<td>Aminah NS</td>
<td>4</td>
<td>14</td>
<td>25</td>
</tr>
<tr>
<td>9</td>
<td>Rusilowati A.</td>
<td>3</td>
<td>51</td>
<td>14</td>
</tr>
<tr>
<td>10</td>
<td>Yuliati L.</td>
<td>3</td>
<td>18</td>
<td>5</td>
</tr>
</tbody>
</table>

3.4 Origin publication journal

From the analysis conducted using VOSviewer, it is also possible to examine the distribution of journal publications based on the documentation in the observed metadata from the Scopus research database. This database lists 110 journals related to the field under study. Additionally, VOSviewer allows for centralizing journal data according to the researcher's preferences. In this instance, the researcher has focused on the top 5 journals in the field, which can be viewed in Figure 10.
Based on the volume of publications produced by researchers, it is possible to determine the source or origin of the journal publications. The Journal of Physics Conference Series emerges as the journal with the highest number of publications related to physics education, according to Scopus data \[27\]. Table 2 presents the top 5 sources of journals that have published the most articles on scientific literacy in physics education from 1977 to 2023.

<table>
<thead>
<tr>
<th>Origin Journal</th>
<th>Documents</th>
<th>Citations</th>
<th>Total Link Strength</th>
</tr>
</thead>
<tbody>
<tr>
<td>Journal of Physics; Conference Series</td>
<td>102</td>
<td>271</td>
<td>66</td>
</tr>
<tr>
<td>Science and Education</td>
<td>8</td>
<td>63</td>
<td>39</td>
</tr>
<tr>
<td>Aip Conference Proceedings</td>
<td>16</td>
<td>7</td>
<td>32</td>
</tr>
<tr>
<td>Revista Brasileira de Ensino de Fisica</td>
<td>6</td>
<td>2</td>
<td>15</td>
</tr>
<tr>
<td>Physics Teacher</td>
<td>8</td>
<td>30</td>
<td>0</td>
</tr>
</tbody>
</table>

Table 2 displays the journals with the highest number of published articles in scientific literacy in physics education from 1977 to 2023. These data can serve as a valuable reference for researchers seeking literature sources on physics education and scientific literacy. This information aims to facilitate further research by providing a clear direction for sourcing references, conducting research, and identifying current research trends to be explored.

3.5 The impact of scientific literacy research in quality education

Scientific literacy significantly enhances students' understanding of scientific concepts, allowing them to grasp subject matter more effectively and develop robust problem-solving skills. By fostering critical skills such as analysis, evaluation, and critical thinking, science literacy empowers students to assess information better, distinguish between facts and opinions, and make informed decisions based on scientific evidence. Furthermore, science literacy advocates active learning, such as students participating in scientific experiments, observations, and investigations. This hands-on approach enables them to experience scientific concepts directly, deepening their understanding and augmenting their ability to apply acquired knowledge. A common challenge in physics education is that students often perceive physics as difficult, primarily due to inadequate practical application during classroom learning. Thus, there is a pressing need to enhance students' scientific process.
abilities, particularly in applying scientific methods. Additionally, to stimulate motivation for learning physics, it is essential to implement educational strategies that demonstrate the interconnections between concepts, aiming to improve students' mastery of physics material [42]. Scientific literacy lays a solid groundwork for achieving the Sustainable Development Goal (SDG) of quality education. It equips individuals and communities with the ability to comprehend, advocate for, and contribute to enhancing the overall quality of education for everyone [5].

4 Conclusion

This study utilizes bibliometric analysis to explore the evolution of scientific literacy in physics education, revealing an increasing trend in research from 1977 to 2023, with 287 documents identified. Prahani BK is the most prolific author, while the Journal of Physics: Conference Series is the leading publication venue in this field. Keywords like "scientific literacy skills," "physics teacher," and "science education" highlight the significance of these elements in enhancing scientific literacy. The findings indicate a robust potential for future research in integrating scientific literacy with related topics, thereby enriching physics education and supporting the Sustainable Development Goal of quality education.

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