

# Trend of STEM Research on Scientific Literacy Skills: A Bibliometric Analysis Using Scopus Database

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**Abstract:** The aim of this research is to identify trends in STEM research related to scientific literacy skills over the years, visualize the research trends in STEM and its impact on scientific literacy skills, and analyze the contribution of STEM research and scientific literacy skills to education in Indonesia. The research data was collected in September 2023 using the Scopus database. The search keywords used in the Scopus database were "STEM Education" OR "STEM Learning" OR stem OR "STEM research" AND "literacy scientific skill" OR "literacy scientific" OR "scientific literacy" OR "science literacy" in multiyears. The data obtained included a total of 267 documents. After analyzing the data, 105 relevant documents were identified. These documents were analyzed using VOSViewer and Biblioshiny. The research findings indicate a strong connection between STEM education and scientific literacy skills. In terms of document types, articles from education science journal and the Jurnal Pendidikan IPA Indonesia were the most prominent sources compared to other document sources. Furthermore, in terms of countries, the United States made the most significant contributions to this topic, with Indonesia ranking second. The University of Alabama at Birmingham was the most prolific affiliate in producing documents on this topic. An intriguing discovery is that STEM education and scientific literacy skills have a substantial impact on education in Indonesia, suggesting the need for further research on this topic.

**Keywords:** STEM, scientific literacy skill, bibliometric

## Introduction

*Science, Technology, Engineering, and Mathematics (STEM)* are becoming increasingly important in the world of education and have garnered broad attention from educators and stakeholders (Gui et al., 2023; Kayan-Fadlelmula et al., 2022). STEM education has been around for over two decades (Timms et al., 2018) and originated in the United States in the 1990s (Gavari-Starkie et al., 2022). STEM education has evolved to include the integration of art, leading to the term STEAM (K.-C. Li & Wong, 2020). STEM education has a broad meaning, as Bybee states that it can be a subject, interdisciplinary, interdisciplinarity, or a specific field of science (Bybee, 2013). Another explanation suggests that STEM is interdisciplinary learning that integrates science, technology, engineering,

and mathematics (Koul et al., 2018; Thibaut et al., 2018). STEM is a teaching and learning process that emphasizes solving real-world problems by integrating multiple disciplines and skills, such as science, technology, mathematics, and engineering (Wahono, Lin, et al., 2020). STEM education aims to equip students by combining interdisciplinary skills and knowledge (Nguyen et al., 2020). Therefore, STEM education requires analysis from various perspectives, skills, and knowledge conducted productively (Reynante et al., 2020).

Bardoe et al. explain that STEM makes a significant contribution to education. Through science, students can gain profound knowledge about their environment. Through technology, students can acquire better skills. Through engineering, students can solve problems, and mathematics helps students develop their

analytical capacities, reduce errors, and critically review the solutions they choose (Bardoe et al., 2023). STEM education combines rigorous academic concepts with real-world learning (Samsudin et al., 2017) and allows students to explore their creativity in solving problems across various disciplines (Wahono, Chang, et al., 2020).

STEM education offers some advantages of training 21st-century skills such as critical thinking, creativity, and technology (Y. Li et al., 2016; Wahono, Lin, et al., 2020). Furthermore, applied STEM learning can develop scientific thinking skills, motivate learners, enhance concept understanding, and aid in communication and collaboration (Chittum et al., 2017; Gede Sandi, 2021; Han et al., 2016). Research also demonstrates that STEM supports creativity in solving challenging problems, emphasizes innovation, creativity, and higher-order thinking skills, and improves critical thinking and problem-solving abilities (Astuti et al., 2021; Barry et al., 2018; Kurup et al., 2019; Yunian Putra & Indriani, 2017). With STEM, students can apply concepts and relate learning to real-life situations (Estapa & Tank, 2017; Sutaphan & Yuenyong, 2019). STEM also has an impact on students' literacy skills (Susanta et al., 2023).

Scientific literacy is one of the essential skills, and it is crucial for the 21st century (OECD, 2018). OECD emphasizes that developing competencies in the 21st century involves scientific literacy. The 4C skills and scientific literacy serve as the foundation for addressing 21st-century challenges (UNEP, 2012). Scientific literacy is vital because it is a key component in addressing various 21st-century challenges and is a fundamental form of literacy needed to support the achievement of 21st-century skills (Kemdikbud, 2019). Scientific literacy is an individual's scientific ability to use their knowledge in identifying problems, acquiring new knowledge, explaining scientific phenomena, and drawing conclusions based on evidence related to scientific issues. Scientific literacy is a person's ability to use scientific knowledge, analyze questions, and draw conclusions based on evidence, in order to understand and make decisions related to the natural world and human activities (Novili et al., 2017; Rini et al., 2021).

Pertiwi et al. outline the importance of scientific literacy, which includes enhancing knowledge and understanding of scientific concepts and processes necessary to participate in a digital-era society. It involves the ability to seek or determine answers to questions stemming from curiosity about everyday experiences, the capacity to explain and predict phenomena, the ability to read and understand scientific articles, the capacity to identify scientific and information technology problems, the ability to evaluate scientific information based on sources and methods used, and the ability to draw conclusions and arguments and assess arguments based on evidence (Pertiwi et al., 2018).

Considering the numerous advantages of STEM education for scientific literacy, many researchers around the world have studied the impact of STEM learning on scientific literacy skills. For example, in Indonesia, studies by Astuti et al. in 2023, Subali et al. in 2023, Kahar et al. in 2022, and Sari et al. in 2021. In the USA, researchers such as Zarestky & Vilen in 2023, in Italy, researchers like Costa et al. in 2023. In Taiwan, there are studies by Nagatomo & Wei in 2023. In Vietnam, researchers include Nguyen & Bui in 2023.

#### *Research Questions*

This research focuses on the trends in STEM research regarding scientific literacy skills in multiyears and presents five research questions:

- a. To what extent is the profile of STEM publication outputs related to scientific literacy skills in multi years?
- b. To what extent is the distribution of STEM publications related to scientific literacy skills among countries and affiliations worldwide?
- c. Who are the primary/most productive authors in STEM research related to scientific literacy skills worldwide?
- d. What are the visual representations of the trends in STEM research related to scientific literacy skills?
- e. To what extent does STEM research on scientific literacy skills contribute to education in Indonesia?

### Materials and Methods

#### Research Tools

This research utilized the assistance of the Bibliometrix software with R programming and VOSviewer. Quantitative methods and techniques were adopted to review the literature published in multi years.

#### Data Collection

Literature data was collected using the Scopus database, known for its quality data. The data selection was performed using the PRISMA method. This systematic review employs bibliometrics, adapted from Kulakli & Osmanaj, Yang et al., Bonilla-Chaves & Palos-Sánchez, Wei et al. (Bonilla-Chaves & Palos-Sánchez, 2023; Kulakli & Osmanaj, 2020; Wei et al., 2023; Yang et al., 2017).

#### Method

Literature search was conducted in September-October 2023 using the Scopus database. This research used three search terms in titles, abstracts, and keywords: "STEM Education" OR "STEM Learning" OR stem OR "STEM research" AND "literacy scientific skill" OR "literacy scientific" OR "scientific literacy" OR " science literacy." The researcher considered only scholarly articles published in multi years and did not restrict the source of publication. Initial data analysis yielded a total of 267 documents, of which 105 were relevant to the search criteria. These documents were analyzed using VOSViewer and Biblioshiny, and the data was documented in .csv format. Subsequently, this data was processed and analyzed using the VOSViewer and Biblioshiny applications to investigate research trends regarding STEM and scientific literacy skills.

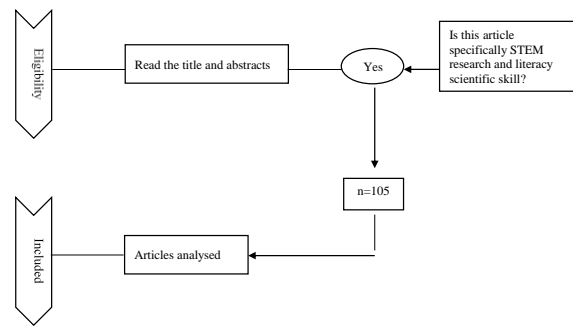
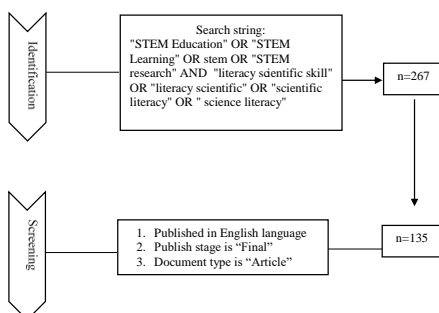


Figure 1. Document Search Steps for Bibliometric Analysis

### Results and Discussion

#### Results

##### Profile of STEM Publication Outputs Related to Scientific Literacy Skills in Multi Years

The search for relevant scholarly articles related to STEM research on scientific literacy skills in the Scopus database resulted in 105 documents. The publication profile over the years is displayed in Figure 1, indicating that research on STEM and scientific literacy skills has experienced fluctuations. However, STEM research on scientific literacy skills has shown an upward trend starting in 2018, and this trend is likely to continue in 2023. It can be seen that 2022 had the highest production of articles on this topic, with a total of 17 (see Figure 2).

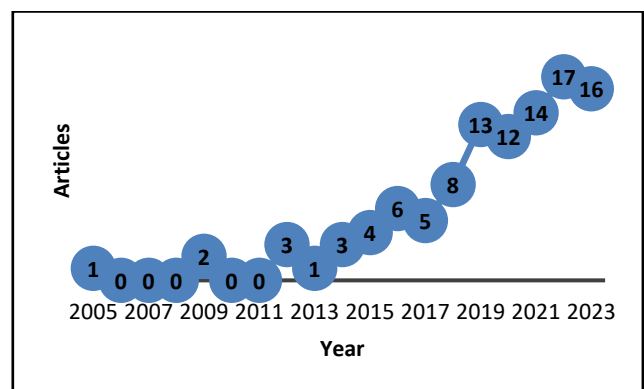


Figure 2. Number of STEM Research Documents on Scientific Literacy Skills

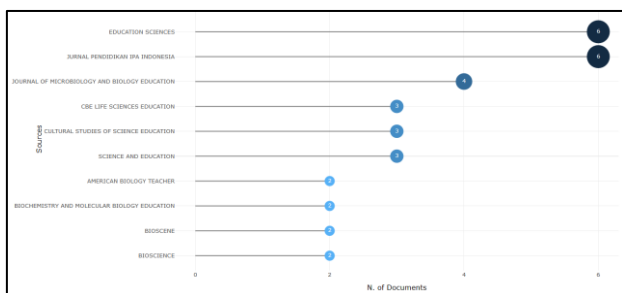


Figure 3. Top 10 Most Relevant Sources for STEM and Scientific Literacy Skills

Figure 3 shows that research on STEM and scientific literacy skills is most commonly published in education science and the Jurnal Pendidikan IPA Indonesia, with a total of 6 documents. It is followed by the Journal of Microbiology and Biology Education with 4 documents.

*Distribution of STEM and Scientific Literacy Skills Publications Among Countries and Affiliations Worldwide*

Based on the number of documents per country, it is evident that the United States is the top-ranking country and has consistently increased its research production in this field, followed by Indonesia in second place, which has also shown a rising trend in this area. This is followed by Australia, China, and Spain. Figure 4 visualizes the most productive countries in producing research on STEM and scientific literacy skills.

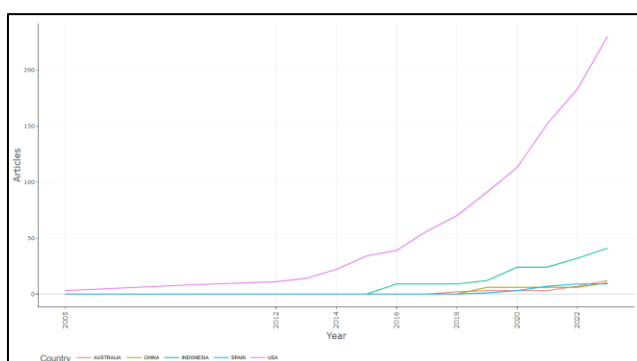


Figure 4. Most Productive Countries in Researching STEM and Scientific Literacy Skills

Research on STEM and scientific literacy skills also involves collaborative publications among countries. It is shown that researchers conduct collaborative research across multiple countries (MCP) and collaborate with a single country (SCP). It is observed that researchers who engage in collaborative research across countries include the

USA, Indonesia, Spain, Germany, Canada, Malaysia, Sweden, and Switzerland. While Italy, China, Georgia, Australia, Colombia, Estonia, Greece, Israel, Singapore, Slovakia, and South Africa maintain collaborations within their own countries, including the USA, Indonesia, Spain, and Germany, where some authors collaborate within their respective countries.

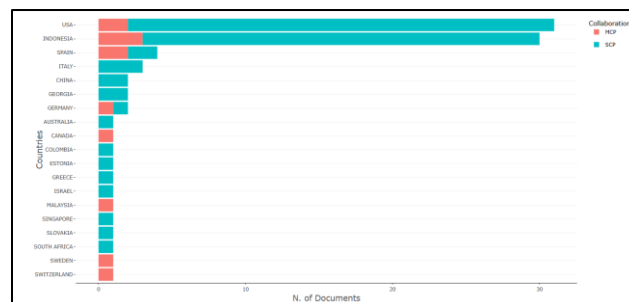


Figure 5. Number of STEM and Scientific Literacy Skills Research Documents by Country

Table 1. Distribution of Collaborative Research Among Countries

Country	Articles	SCP	MCP
USA	31	29	2
INDONESIA	30	27	3
SPAIN	4	2	2
GERMANY	2	1	1
CANADA	1	0	1
MALAYSIA	1	0	1
SWEDEN	1	0	1
SWITZERLAND	1	0	1

According to Table 1, collaborative research between countries is led by Indonesia, with a total of 3 published documents. The United States and Spain are next in line, both having 2 documents of collaborative research. Germany, Canada, Malaysia, Sweden, and Switzerland each have 1 document of collaborative research in the field of STEM and scientific literacy skills.

Based on the number of documents analyzed across institutions, the top institutions are shown in Figure 6. It can be observed that the University of Alabama at Birmingham is the institution that

has produced the most research on STEM and scientific literacy skills, with a total of 12 documents. Following closely, Universitas Negeri Semarang and the University of California San Diego rank second, with 11 publications each. The next position is occupied by the University of Nebraska Medical Center, with a total of 8 publications.

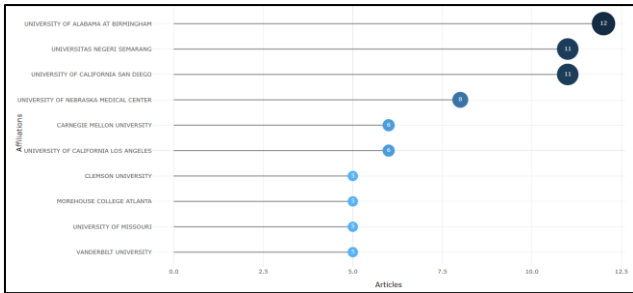


Figure 6. Top 10 Dominant Institutions in Researching STEM and Scientific Literacy Skills

Table 2. Top 10 Institutions with the Most Research Outputs on STEM and Scientific Literacy Skills

No	Affiliation	Articles
1	UNIVERSITY OF ALABAMA AT BIRMINGHAM	12
2	UNIVERSITAS NEGERI SEMARANG	11
3	UNIVERSITY OF CALIFORNIA SAN DIEGO	11
4	UNIVERSITY OF NEBRASKA MEDICAL CENTER	8
5	CARNEGIE MELLON UNIVERSITY	6
6	UNIVERSITY OF CALIFORNIA LOS ANGELES	6
7	CLEMSON UNIVERSITY	5
8	MOREHOUSE COLLEGE ATLANTA	5
9	UNIVERSITY OF MISSOURI	5
10	VANDERBILT UNIVERSITY	5

Primary/Most Productive Authors in Worldwide Research on STEM and Scientific Literacy Skills

In terms of the most productive authors in researching STEM and scientific literacy skills,

Figure 7 displays the number of authors who have produced the most work on this topic. The blue dots represent the number of publications, with larger circles indicating more publications. Meanwhile, the color intensity indicates the number of citations, with darker colors signifying more citations. Booth is the most productive author in generating research on STEM and scientific literacy skills, with a total of 4 documents. Following closely are Haden, Permanasari, and Shavlik, each with 3 publications.

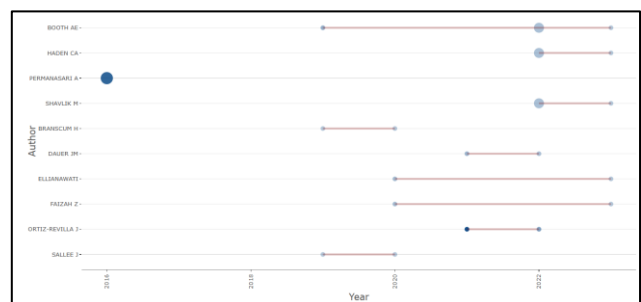


Figure 7. Most Productive Authors in Research on STEM and Scientific Literacy Skills

When considering the authors with the most citations, Permanasari, A. stands out with 119 citations, followed by Ortiz-Revilla in second place with 67 citations. Booth is third with 21 citations. Each cited publication originates from various journals. Table 3 Top citation of article/document in Multi years.

Table 3. Top citation of article/document

No	Author	Jumlah Sitasi
1	Permanasari, A	119
2	Ortiz-Revilla	67
3	Booth	21
4	Dauer	10
5	Faizah	7
6	Allianawati	7

Visualizing the Trends in STEM and Scientific Literacy Skills Research

Based on the analysis of 105 articles related to STEM research and scientific literacy skills in the Scopus database, findings were used to create a

tree map using the Biblioshiny application. The visualization in Figure 8 depicts the distribution of publication categories in the Scopus database that align with research on scientific literacy skills in STEM. Of the 105 documents, there were 50 categories discussing this topic. It is noteworthy that 5 articles addressed scientific literacy skills, and 6 documents covered STEM. This indicates that the themes of STEM and scientific literacy skills continue to be research areas that need further development and deeper examination.



Figure 8. Tree map

Based on the data above, further analysis was conducted using the VOSViewer application to confirm the results from Biblioshiny regarding the novelty of research in this domain. Figure 9 provides an overview of the entire body of research on STEM and scientific literacy skills. Researchers worldwide have formed three clusters (red, green, and blue). The first cluster (red) encompasses research on STEM and scientific literacy skills across various fields, such as education, environment, and society. The second cluster (green) relates to STEM learning and scientific literacy skills, including assessment, instruments, classrooms, questions, and learning. The third cluster (blue) represents STEM learning and scientific literacy skills associated with strategies in STEM education, involving experiences, mathematics, and participation.

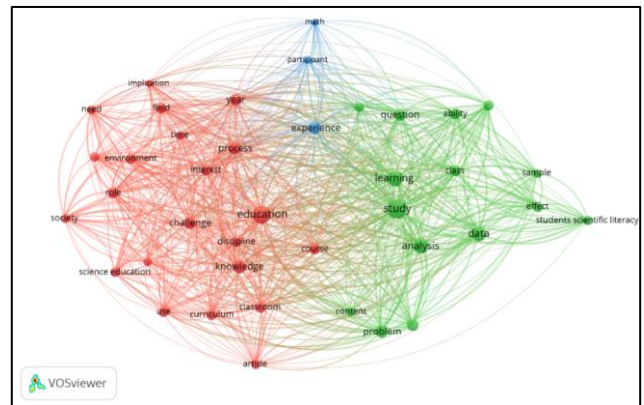


Figure 9. The whole picture of research on scientific literacy skills in STEM education

to determine the novelty of research in STEM education and scientific literacy skills, specific relationships between variables were analyzed, as shown in Figure 10.

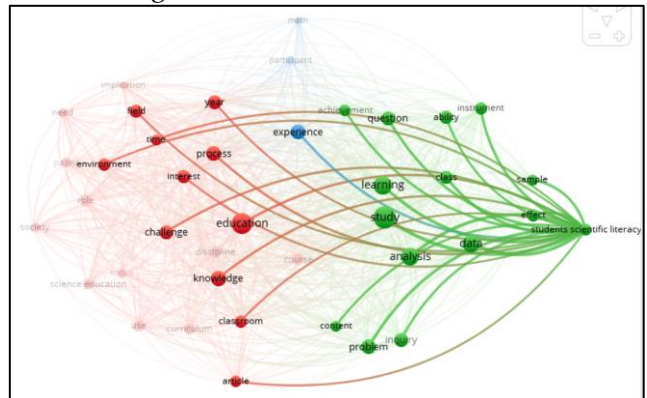


Figure 10. Interconnectedness of STEM Education and Scientific Literacy with Other Domains

Figure 10 illustrates that research on STEM and scientific literacy skills is interconnected with learning, issues, inquiry, content, instruments, and more.

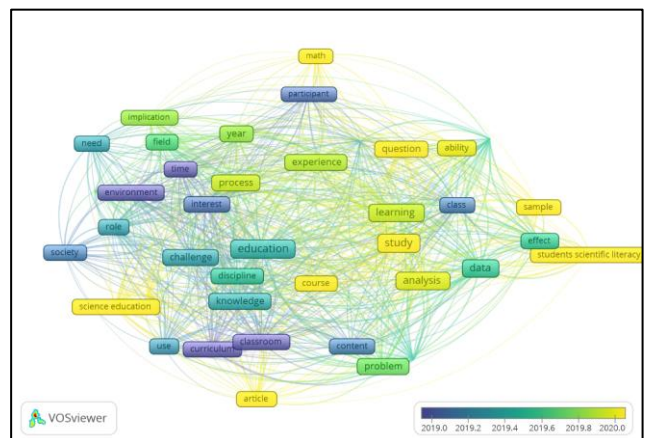


Figure 11. Thematic Map VOSViewer

Figure 11 shows that keywords related to STEM and scientific literacy skills are widely used by researchers. Although there has been extensive research, in 2023 (highlighted in yellow), there are

still several themes that remain interesting issues for investigation. Future research can follow the latest topic trends, one of which is examining STEM and scientific literacy skills in science education.

*Contribution of STEM and Scientific Literacy Research to Education in Indonesia*

Based on the number of research documents related to STEM and scientific literacy skills, there are 12 relevant articles in the context of education in Indonesia. The remaining articles are from countries such as Australia, Italy, the United States, and Spain. The extent of the contribution of STEM and scientific literacy skills in Indonesia is an area that can be further developed. Table 4 provides an overview of STEM education and scientific literacy skills research in Indonesia based on the Scopus database in multiyears.

**Table 4.** Some Examples of Research on STEM Education and Scientific Literacy Skills in Indonesia

No	Author	Year	Title	Result
1	Permanasari, dkk	2016	<b>Project Based Learning Integrated To Stem To Enhance Elementary School's Students Scientific Literacy</b>	PjBL-STEM has been proven to improve students' scientific literacy through t-test and N-Gain analysis. Another implication of this research is the ability to increase motivation and interest in learning science.
2	Permanasari, dkk	2016	Stem Virtual Lab: An Alternative Practical	The development of STEM Virtual Lab

No	Author	Year	Title	Result
			Media To Enhance Student's Scientific Literacy	learning through N-Gain analysis can enhance scientific literacy skills.
3	Yuliati, dkk	2020	A Case Study On Comparison Of High School Students' Scientific Literacy Competencie s Domain In Physics With Different Methods: PBL-STEM Education, PBL, and Conventional Learning	PBL-STEM results in better improvement of scientific literacy skills compared to PBL and control classes. The integration of PBL and STEM through ANOVA, Tuket post hoc test, N-Gain, and Cohen's effect has been proven to enhance scientific literacy skills more effectively.

Table 3 provides some examples of articles on STEM and scientific literacy skills that are cited the most. Research analysis results show that STEM significantly contributes to the development of students' scientific literacy skills in Indonesia. In addition to scientific literacy, STEM education is also proven to impact students' motivation and interest in science learning. The results also indicate that integrated STEM learning models, such as projects, inquiry-based learning, problem-based learning (PBL), and artificial intelligence,

produce more effective outcomes, particularly in terms of scientific literacy skills.

Among all the articles discussing the importance of STEM education and scientific literacy skills, there is still a significant opportunity for researchers to explore and develop this topic. One approach is to integrate STEM education with other teaching methods, techniques, or media. In summary, research results on STEM education make a significant contribution to education in Indonesia.

### Discussion

Research on scientific literacy skills in STEM, based on the Scopus database, began in 2005. STEM education has been present for over two decades (Timms et al., 2018). STEM education originated in the United States in the 1990s (Gavari-Starkie et al., 2022). This is supported by document analysis, which reveals that the United States is the most productive country in developing research on scientific literacy skills in STEM.

STEM makes a significant contribution to education. Through science, students can gain profound knowledge about their environment. Through technology, students can acquire better skills. Through engineering, students can solve problems. Mathematics helps students develop their capacity to analyze information, reduce errors, and critically review the solutions taken (Bardoe et al., 2023). STEM education combines rigorous academic concepts with real-world learning (Samsudin et al., 2017). STEM education offers students the opportunity to explore their creativity in problem-solving across various disciplines (Wahono, Chang, et al., 2020). Considering the numerous benefits of STEM in education, based on document analysis results, many researchers have explored STEM education involving scientific literacy skills. In this regard, Booth has been the most productive author in developing this research, followed by Haden, Permanasari, and Shavlik.

Among the top 10 most productive authors, Permanasari from Indonesia is the most frequently cited author. This indicates that articles written by Permanasari have had a significant impact on researchers worldwide in advancing research in

this field. Citation is an important aspect to determine whether published articles have an impact on others. Research analysis results show that STEM significantly contributes to the development of students' scientific literacy skills in Indonesia (Afriana et al., 2016; Parno et al., 2020). In addition to scientific literacy, STEM education is also proven to impact students' motivation and interest in science learning. The results also mention that integrated STEM education models yield better outcomes, particularly in terms of scientific literacy skills, such as STEM integrated with projects, inquiry-based learning, PBL, and artificial intelligence (Chien et al., 2023; Kim et al., 2023; Santhosh et al., 2023).

### Conclusions

The research results indicate that STEM education is strongly related to scientific literacy skills. In terms of document types, articles from education science and Indonesian science education journals are the most prevalent sources compared to other document sources. Furthermore, in terms of countries, the United States contributes the most to this topic, followed by Indonesia in the second position. The University of Alabama at Birmingham is the most prolific affiliation for this topic. An interesting finding is that STEM education and scientific literacy skills have a significant impact on education in Indonesia, indicating a need for further research on this topic. Recommendations for further research could include exploring other aspects, such as cultural factors.

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