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Empowering Scientific Literacy of Science Teachers: Systematic Literature Review (SLR)

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Abstract

Scientific literacy plays an essential role in developing and strengthening teacher knowledge in line with the development of student knowledge. The study aims to identify the challenges and obstacles faced by science teachers in strengthening scientific literacy, what strategies and interventions can be used to improve teachers' scientific literacy and the effects of teachers' scientific literacy on student learning and achievement. This study used the PRISMA model, and 26 articles were selected to be analyzed to answer the research questions. This study focuses on empirical studies in 2019-2023 using two databases: Scopus and Web of Science (WOS). Five themes have been identified in the study: content knowledge, professional development, approaches, pedagogical content knowledge, and student knowledge.

Keywords: Scientific Literacy, Challenges, Strategies, Science Teachers, Effects

Introduction

Along with the development of increasingly advanced times, education plays a vital role in forming a knowledgeable and skilled society in line with technological advances. Teachers play an essential role in advancing individuals and communities as facilitators in education. To realize the following, teachers must build a solid scientific literacy foundation to help students develop their knowledge. Literacy refers to an individual's ability to read, write, understand, and use information effectively. In contrast, scientific refers to an approach or method based on scientific principles and processes.

The scientific approach involves observation, data collection, conclusions based on evidence, and scientific processes. The Organisation for Economic Cooperation and Development (OECD) (1998) states that scientific literacy is the ability of individuals to apply knowledge and processes not only to understand science and its concepts but also to participate in making decisions and using them in life. The National Science Teacher Association and the Science-Teaching-Technology (STS) Movement (1991) suggest that someone scientifically and technologically literate requires intellectual skills and other attributes. According to the study, there are four components in scientific literacy: attitude, society, intellect, and inter-disciplinarity. The Program for International Student Assessment (PISA) in 2000 and 2003 has set 3 domains to assess scientific literacy: science process competence, science content or knowledge, and Science application context. Then, in 2012, PISA added another domain, student attitudes towards science. From 2022 to 2025, PISA added another domain, namely measuring students' thinking skills and learning in the digital world.

Three levels of scientific literacy have also been established (Bybee et al., 2009). The first level is cultural scientific literacy, which is understanding the context for accessible communication. The second level is also known as functional scientific literacy. It refers to a person's ability to interact, read, and write consistently in non-technical contexts while being fluent in science terminology. The last level is true scientific literacy, where the individual knows the leading scientific conceptual framework.

Bacanak and Gökdere (2009) explain that scientific literacy is the ability to understand and make judgments about nature and its changes due to human activities by using scientific knowledge, asking questions, and making judgments based on evidence. Holbrook and Rannikmae (2009) explained that scientific literacy is understanding the social impact on science and technology and the nature of science, or the Nature of Science (NOS). Costa et al. (2021) point out that scientific literacy reflects a deictic construct shaped by the social, political, cultural, and scientific context in the society concerned. In conclusion, PISA describes scientific literacy as an individual's ability to understand, use, and apply scientific knowledge and concepts in everyday life. It involves critical skills in reading, writing, speaking, and thinking scientifically, as well as understanding scientific processes and how to access, assess, and use scientific information effectively.

Curriculum Development Division (CDD) of the Ministry of Education Malaysia (2015) in the PISA National Report shows that the percentage of students who reached level five in scientific literacy is deficient at 0.6 percent compared to students who reached level two at 36.4 percent. The cognitive load of students who reached the high level in 2015 also showed the lowest percentage of 8 percent. The various aspects that can be explored to identify the cause of Malaysian students' rank are lower than in other countries. Perera and Asadullah (2019) have identified various factors that cause Malaysia's position in PISA to be low compared to Korea and Singapore. Among the factors discussed in the study are school-related factors such as teacher qualifications, teacher shortages, content autonomy, and others. The study explains that Malaysia is facing an insufficient number of qualified teachers. In addition, the eligibility for teacher recruitment in education is very low, which only reaches a minimum of 3A in the examination. In addition, training to improve teacher quality is at a low level. Korea and Singapore emphasize teacher quality by providing adequate training and robust professional development to enhance teacher knowledge (Perera & Asdullah, 2019).

It provides a clear picture that teachers' scientific literacy levels play an essential role in shaping teachers' content knowledge, pedagogical skills, confidence levels, and teaching strategies. Hardinata and Putri (2019) interviewed six science teachers. The results found that the teachers had misconceptions about scientific literacy, and they did not know the definition of scientific literacy itself. This study shows that more science teachers still have no exposure to scientific literacy. Teachers without exposure need attention to improve their literacy levels to produce interactive methods or strategies. Septiawati et al (2020); Wibowo et al (2020) stated that teachers still practice traditional methods, such as textbooks and worksheets, and use less technology.

Septiawati et al (2020) explained that the pedagogical level of teachers is deficient in implementing teaching methods that use technology, such as electronic worksheets for students. This study is supported by Adam Stefanile (2020), who states that teachers lack proficiency in pedagogy and strategies to integrate technology into teaching. Furthermore, Prasetyo et al (2019) explained that teachers in a Central Java school lacked professional cooperation, peer support, and confidence. In addition, his study found that teachers had a low knowledge of science topics and in making assessments. Teachers also needed to have contextualized science activities. In addition, teachers lack ability to share of views and missions (Prasetyo et al., 2019). A study by Walag et al (2022) found that teachers' confidence levels influence teachers' content knowledge in teaching science subjects. It will affect the development of educational quality, including the improvement of scientific literacy.

Based on the issues raised in the previous study, a Systematic Literature Review (SLR) was conducted to identify the challenges and obstacles science teachers face in strengthening scientific literacy. Other than that, this review also focuses on strategies and interventions that can be used to improve scientific literacy and identify the impact of teachers' scientific literacy on student learning and achievement. This study is critical for informing educational policies and practices, addressing the challenges faced by science teachers, and proposing effective strategies. The significance extends beyond the classroom, influencing the development of a scientifically literate citizenry capable of addressing global challenges and contributing to scientific advancements. By fostering a deeper understanding of the importance of scientific literacy in teachers, this research contributes to the broader goal of creating informed and empowered individuals for the future.

Research Questions

1. What are the challenges and obstacles faced by science teachers to strengthen scientific literacy?
2. What are the strategies and interventions that can be used to improve science teachers' scientific literacy?
3. What are the effects of science teachers' scientific literacy on student learning and achievement?

Methodology

Review Protocol

This SLR uses the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) flow diagram in determining article selection based on the stated research questions. McInnes et al (2018) stated that PRISMA is a guide that can help make judgments in validity and usability and produce a more precise and valuable literature highlight. There are several phases in the selection of related articles, namely the identification, screening, eligibility, and article submission phases in this study. In fact, in this study, several steps are carried out in determining the search systematically: identification, screening, eligibility, quality appraisal, data extraction, and analyses.

Systematic Searching Strategies

Identification

The first phase used in this systematic literature review is the identification phase, which refers to the PRISMA guidelines. Based on the search used on the internet to get keywords, the authors have used a site such as thesaurus.com to get synonymous meanings based on the study to be carried out. Not only that, the authors also get keywords from previous studies and asks for opinions from experts on the terms used to get reasonable keywords.

As a result of the search, several terms were used by the authors to search for keywords, such as science literacy, scientific literacy, science knowledge, scientific knowledge, science teacher, STEM teacher, science educator, and STEM educator. To combine the known terms, the authors used search functions such as field code function, phrase search, free card, truncation, and Boolean control to get more focused articles. (Refer to Table 1)

Table 1

Database	**Keywords**
Scopus	TITLE-ABS-KEY((science literacy* OR scientific literacy* OR scientific knowledge* OR science knowledge*) AND (science teacher* OR STEM teacher* OR science educator* OR STEM educator*))
Web of Science (WOS)	TS=((science literacy* OR scientific literacy* OR scientific knowledge* OR science knowledge*) AND (science teacher* OR STEM teacher* OR science educator* OR STEM educator*))

The authors used databases from Scopus and Web of Science (WOS) to obtain the articles in this study. The article search in the identification phase identified 415 articles from Scopus and 19508 articles from WOS.

Screening

The next phase in this study is the screening phase. This phase is aimed at selecting articles based on predefined criteria. Table 2 shows that a set of criteria has been used to determine whether the article is included or excluded in this study. The authors have set four criteria required in this screening phase: year of publication, document type, language, and subject. For the year of publication criteria, the authors select articles from 2019 to 2023 only. Articles from 2018 and before have been excluded. The second criterion is the type of document. The authors selected articles that had empirical data only. The authors have excluded such things as reviewed articles, chapters in books, books, systematic literature highlights, and others. For the third criterion, the authors selected articles that used English only. The authors make an exclusion of articles that use articles other than English. The last criterion is the subject. The authors select articles based on the subject of Social Science only. The authors have excluded the other subject of Social Science.

Table 2
Eligibility

Criteria	**Eligibility**	**Exclusion**
Publication year	2019 - 2023	2018 and before
Document Types	Articles (empirical data)	Reviewed articles, Chapters in books, Books, Systematic Literature Reviews, and others
Language	English	Languages other than English
Subject	Subjects related to Social Science	Medicine, Engineering, Health Science, and other subjects related to Social Science

For the eligibility phase, a total of 48 articles were fully accessible. The authors have made a quality appraisal by re-reading the article's title, abstract, and content that fulfills the study. Based on the quality appraisal that has been carried out, a total of 26 articles fulfills the set criteria.

Quality Appraisal

A quality appraisal was conducted to ensure that the methodology and analysis of the selected articles fulfilled satisfactory criteria. The Mixed-Method Appraisal Tool (MMAT) provided by Hong et al (2018) was used at the quality appraisal stage. MMAT provides a systematic framework to help researchers assess the quality of studies and the strengths and weaknesses of the studies they review. MMAT focuses on several study methods: qualitative, quantitative randomized controlled trials, quantitative non-randomized trials, quantitative descriptive, and mixed-methods.

Before the authors make a quality appraisal of each research method, screening questions need to be stated. Once the screening questions are answered, and the criteria are met, the authors can appraise the article's study method and data analysis. To ensure the selected articles fulfill the criteria, MMAT has provided the required guidelines on each of the stated review methods regarding (Hong et al., 2018). For each article that is quality appraised, the authors have obtained references from experts to avoid bias in selecting articles.

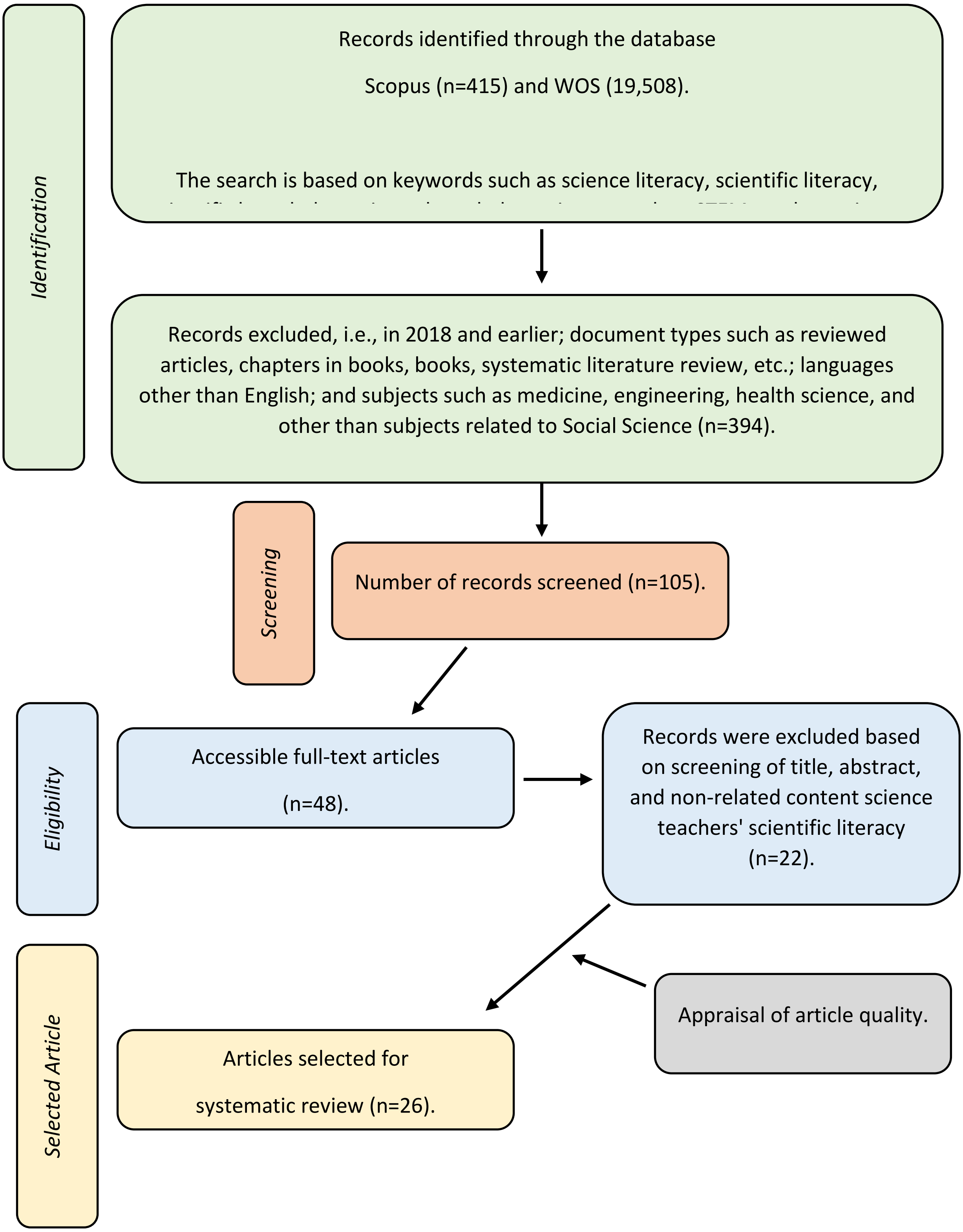

Figure 1 PRISMA flow diagram

Table 3
Data Analysis

Num.	Authors	Research Title
1	Steinwachs & Martens (2022)	Addressing student conceptions in evolution classes: professional vision practices of preservice and in-service biology teachers
2	Poce et al. (2019)	From tinkering to thinkering. Tinkering as critical and creative thinking enhancer
3	Alghamdi et al. (2022)	Epidemiology in Middle School Science Curricula: A COVID-19 Pre–post Intervention
4	Jimenez et al. (2022)	Developing and evaluating a pollination systems knowledge assessment in a multidisciplinary course
5	Schofield et al. (2023)	Early years education teachers' perceptions of nature of science
6	Busch (2023)	Pedagogical Content Knowledge for Informal Science Educators: Development of the ISE-PCK Framework
7	Lilly et al. (2023)	A comparison of elementary teachers' verbal supports for students in inclusive and general classroom contexts during an NGSS-aligned science, engineering, and computer science unit
8	Cooper et al. (2022)	A Reading Group for Science Educators: An Approach for Developing Personal and Collective Pedagogical Content Knowledge in Science Education
9	Rachmatullah et al. (2023)	The Role of Teachers' Self-efficacy Beliefs and Habits in Differentiating Types of K-12 Science Teachers
10	Luft et al. (2022)	The first 5 years of teaching science: The beliefs, knowledge, practices, and opportunities to learn of secondary science teachers
11	Chan & Erduran (2023)	The Impact of Collaboration Between Science and Religious Education Teachers on Their Understanding and Views of Argumentation
12	Peters-Burton et al. (2023)	Student, Teacher, and Scientist Views of the Scientific Enterprise: An Epistemic Network Re-analysis
13	Wulff et al. (2023)	Enhancing writing analytics in science education research with machine learning and natural language processing-Formative assessment of science and non-science preservice teachers' written reflections
14	Fridberg et al. (2023)	Spanish and Swedish teachers' perspective of teaching STEM and robotics in preschool - results from the botSTEM project
15	Davis & Palincsar (2023)	Engagement in high-leverage science teaching practices among novice elementary teachers
16	Nilsson & Lund (2023)	Design for learning - involving teachers in digital didactic design (D-3)
17	Wallace et al. (2022)	Stories That Teachers Tell: Exploring Culturally Responsive Science Teaching

18	Mouza et al. (2022)	A Virtual Professional Development Program for Computer Science Education During COVID-19
19	Abdulbakioglu et al. (2022)	Open Lesson as a Means of Teachers' Learning
20	Zoupidis et. al (2022)	Study of Kindergarten Teachers' Intentions to Choose Content and Teaching Method for Teaching Science
21	Vasconcelos & Paz (2023)	Inquiring children and elementary school teachers to diagnose their conceptions about islands
22	Buma & Sibanda (2022)	In-Service and Pre-Service Science Teachers' Enacted Pedagogical Content Knowledge about the Particulate Nature of Matter
23	Mathis et al. (2023)	How instructors can view knowledge to implement culturally relevant pedagogy
24	Nja et al. (2022)	Mapping SS1-3 chemistry teachers' interest, self-efficacy, and literacy in teaching for creativity using simulation
25	Alghamdi (2023)	Exploring Early Childhood Teachers' Beliefs About STEAM Education in Saudi Arabia
26	Becerra et al. (2023)	Developing an Instrument to Assess Pedagogical Content Knowledge for Evolution

The study was analyzed thematically using several processes, such as fitting into the dataset and managing the initial code to structure the data from general to more specific (Shaffril et al., 2021). Thematic analysis can provide the reviewer with research headings, important information, and the relationships between them (Makkizadeh & Sa'adat, 2017). Based on the thematic data analysis, the authors have recognized some themes to be discussed.

Table 4
Source Hong et al (2018)

Research Design	Assessment Criteria (Quality Appraisal)
Qualitative	• Is the qualitative approach appropriate to answer the research question? (QA1) • Are the qualitative data collection methods adequate to address the research question? (QA2) • Are the findings adequately derived from the data? (QA3) • Is the interpretation of results sufficiently substantiated by data? (QA4) • Is there coherence between qualitative data sources, collection, analysis, and interpretation? (QA5)
Quantitative randomized controlled trials	• Is randomization appropriately performed? (QA1) • Are the groups comparable at baseline? (QA2) • Are there complete outcome data? (QA3) • Are outcome assessors blinded to the intervention provided? (QA4) • Did the participants adhere to the assigned intervention? (QA5)
Quantitative non-randomized	• Are the participants representative of the target population? (QA1)

	• Are measurements appropriate regarding both the outcome and intervention (or exposure)? (QA2) • Are there complete outcome data? (QA3) • Are the confounders accounted for in the design and analysis? (QA4) • During the study period, is the intervention administered (or exposure occurred) as intended? (QA5)
Quantitative descriptive	• Is the sampling strategy relevant to address the research question? (QA1) • Is the sample representative of the target population? (QA2) • Are the measurements appropriate? (QA3) • Is the risk of nonresponse bias low? (QA4) • Is the statistical analysis appropriate to answer the research question? (QA5)
Mixed-method	• Is there an adequate rationale for using a mixed methods design to address the research question? (QA1) • Are the different components of the study effectively integrated to answer the research question? (QA2) • Are the outputs of the integration of qualitative and quantitative components adequately interpreted? (QA3) • Are divergences and inconsistencies between quantitative and qualitative results adequately addressed? (QA4) • Do the different components of the study adhere to the quality criteria of each tradition of the methods involved? (QA5)

Table 5
Result of quality appraisal

Research	**Research Design**	**QA1**	**QA2**	**QA3**	**QA4**	**QA5**	**Number of Criteria Fulfilled**	**Article Inclusion**
Steinwachs & Martens (2022)	Q	√	√	√	√	√	5/5	√
Poce et al. (2019)	QD	x	x	√	x	√	2/5	√
Alghamdi et al. (2022)	MM	√	√	√	√	x	4/5	√
Jimenez et al. (2022)	MM	√	√	√	√	x	4/5	√
Schofield et al. (2023)	QD	√	x	√	x	√	3/5	√

Busch (2023)	MM	√	√	√	√	x	4/5	√
Lilly et al. (2023)	MM	√	√	√	√	x	4/5	√
Cooper et al. (2022)	Q	√	√	√	√	√	5/5	√
Rachmatullah et al. (2023)	QD	√	x	√	x	√	3/5	√
Luft et al. (2022)	MM	√	√	√	√	x	4/5	√
Chan & Erduran (2023)	Q	√	√	√	√	√	5/5	√
Peters-Burton et al. (2023)	MM	√	√	√	√	x	4/5	√
Wulff et al. (2023)	MM	√	√	√	√	x	4/5	√
Fridberg et al. (2023)	MM	√	√	√	√	x	4/5	√
Davis & Palincsar (2023)	MM	√	√	√	x	x	3/5	√
Nilsson & Lund (2023)	MM	√	√	√	√	√	5/5	√
Wallace et al. (2022)	Q	√	√	√	√	√	5/5	√
Mouza et al. (2022)	MM	√	√	√	√	x	4/5	√
Abdulbakioglu et al. (2022)	MM	√	√	√	√	x	4/5	√
Zoupidis et. al (2022)	QD	√	x	√	x	x	2/5	√
Vasconcelos & Paz (2023)	QD	√	x	x	x	√	2/5	√
Buma & Sibanda (2022)	MM	√	√	√	x	√	4/5	√
Mathis et al. (2023)	Q	√	√	√	√	√	5/5	√
Nja et al. (2022)	QD	√	x	√	x	√	3/5	√
Alghamdi (2023)	QD	√	x	√	x	√	3/5	√
Becerra et al. (2023)	MM	√	√	√	√	√	5/5	√

Result and Discussion

Based on Figure 2 below, the country most involved in studies related to the scientific literacy of science teachers is the United States of America, namely 11 articles (Jimenez et al., 2022; Busch et al., 2023; Lilly et al., 2023; Rachmatullah et al., 2023; Luft et al., 2022; Peters-Burton et al., 2023; Davis et al., 2023; Wallace et al., 2022; Mouza et al. 2023 & Mathis et al. 2023). Apart from that, the countries of Saudi Arabia Alghamdi et al (2022); Alghamdi (2023) and Germany Steinwachs & Martens (2022); Wulff et al (2023) have two article numbers. Others have only one article number, namely Nigeria Nja et al (2022), South Africa Buma & Sibanda (2022), Portugal Vasconcelos & Paz (2023), Greece Zoupidis et al (2022), Kazakhstan Abdulbakioglu et al (2022), Sweden Nilsson & Lund (2023), England Chan & Erduran (2023), Australia Cooper et al (2022), UAE Schofield et al (2023) and Italy (Poce et al., 2019). Two articles combine several countries, namely countries from Chile and Germany Becerra et al (2023) and articles from Spain, Sweden, Italy, and Cyprus (Fridberg et al., 2023).

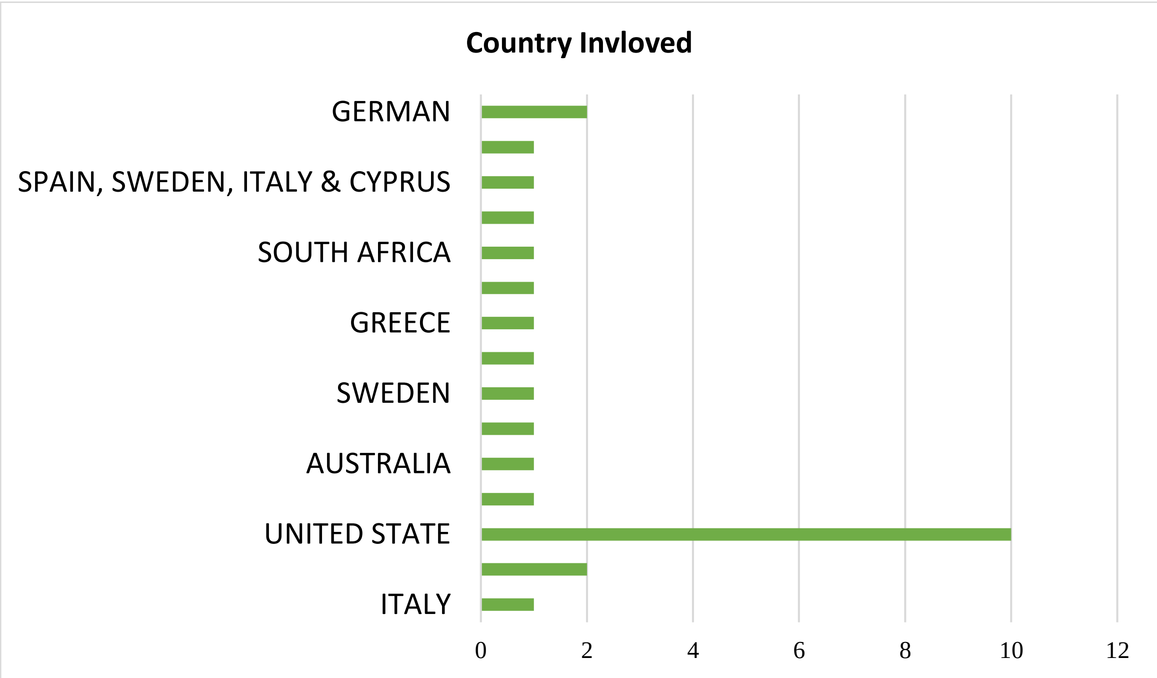

Figure 2: Country involved in the research

The number of articles from the United States recorded was 38.46 percent. Meanwhile, Saudi Arabia recorded 7.69 percent, and Germany recorded 7.69 percent. Not only that, countries such as Nigeria 3.87 percent, South Africa 3.87 percent, Portugal 3.87 percent, Greece 3.87 percent, Kazakhstan 3.87 percent, Sweden 3.87 percent, England 3.87 percent, Australia 3.87 percent, UAE 3.87 percent and Italy 3.87 percent. The percentages shown show that developed countries like the United States make many studies related to the scientific literacy of teachers to ensure progress in the field of education.

For the year of article publication, there is one article from 2019, namely (Poce et al., 2019). The years 2020 and 2021 showed no article publication. The following year, 2022, there were 11 articles (Steinwachs & Martens, 2022; Alghamdi et al., 2022; Jimenez et al., 2022; Cooper et al., 2022; Luft et al., 2022; Chan & Erduran, 2022; Wallace et al., 2022; Abdulbakioglu et al., 2022; Zoupidis et al., 2022; Buma & Sibanda, 2022; Nja et al., 2022). The year 2023 showed the highest number of articles, with 14 articles (Schofield et al., 2023; Busch et al., 2023; Lilly et al., 2023; Rachmatullah et al., 2023; Peters-Burton et al., 2023; Wulff et al., 2023; Fridberg et al., 2023; Davis & Palincsar, 2023; Nilsson & Lund, 2023; Mouza et al., 2023; Vasconcelos & Paz, 2023; Mathis et al., 2023; Alghamdi 2023 & Becerra et al., 2023)

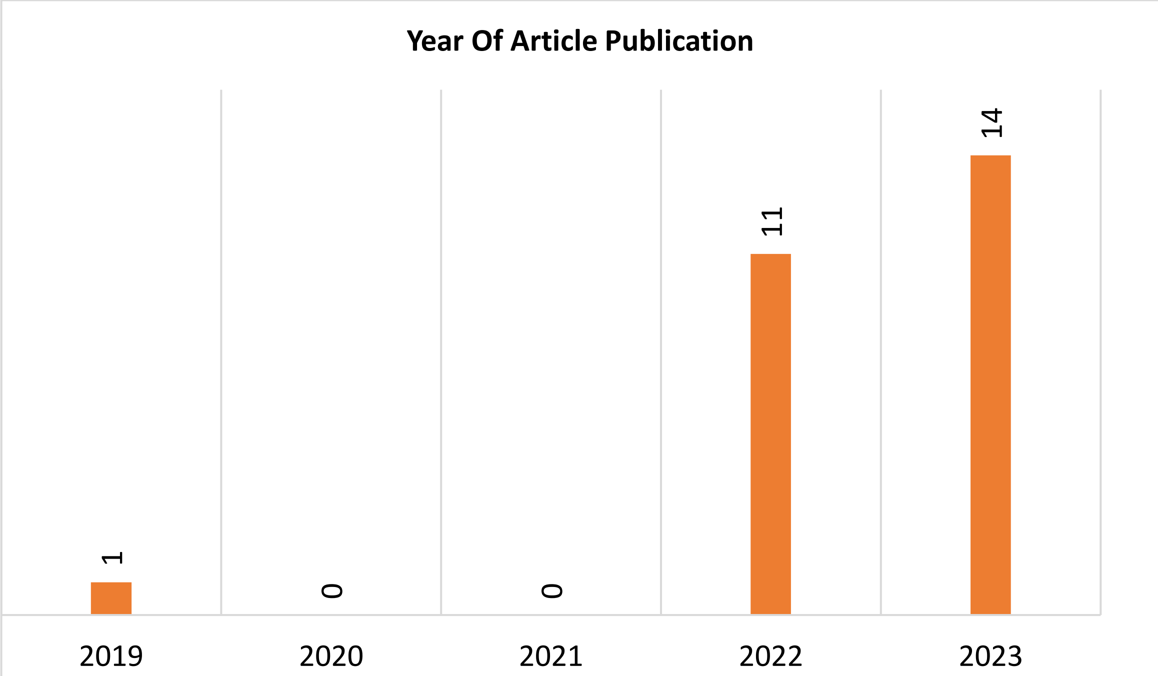

Figure 3: Year of article publication

Therefore, the year of publication in 2023 shows the highest percentage, 53.86 percent. Next, the year of publication in 2022 is 42.31 percent. The years 2021 and 2020 show zero percentages because there are no articles, and 2019 is 3.87 percent. Based on the year of article publication, the year 2023 shows the highest number of articles found because it shows that studies related to scientific literacy need to be given more in-depth attention.

Based on the research design graph shown in Figure 3, mixed methods were most widely used in the articles, namely as many as 14 articles (Alghamdi et al., 2022; Jimenez et al., 2022; Busch et al., 2023; Lilly et al., 2023; Luft et al., 2022; Peters-Burton et al., 2023; Wulff et al., 2023; Fridberg et al., 2023; Davis & Palincsar, 2023; Nilsson & Lund, 2023; Mouza et al., 2023; Abdulbakioglu et al., 2022; Buma & Sibanda 2022; Becerra et al., 2023). Apart from that, quantitative descriptive also has eight articles (Poce et al., 2019; Schofield et al., 2023; Schofield et al., 2023; Rachmatullah et al., 2023; Zoupidis et al., 2022; Vasconcelos & Paz, 2023; Nja et al., 2022; & Alghamdi 2023). Five articles have been identified for the qualitative study design (Steinwachs & Martens, 2022; Cooper et al., 2022; Cooper et al., 2022; Wallace et al., 2022 & Mathis et al., 2023).

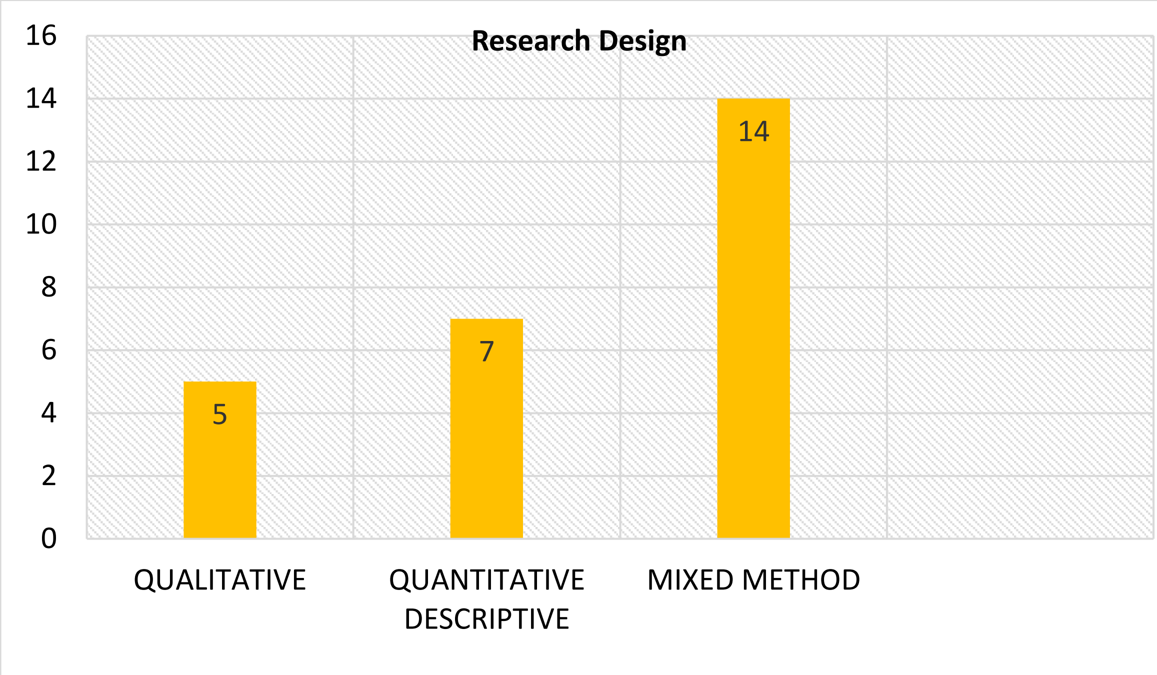

Figure 4: Research design

Thus, the percentage in the study designed for mixed methods shows the highest percentage of 53.85 percent. The quantitative descriptive method also shows a percentage number of 27.00 percent, and the percentage for the qualitative method is 19.23 percent. Based on the analysis of the 26 articles identified, the authors recognize that six themes have been formed (Table 6) to answer the study questions stated earlier. The themes formed based on the first research questions are content knowledge, professional development, and approaches; the second is pedagogical content knowledge and self-competence; and the third is student knowledge.

Table 6

Research	Research Design	Country	Themes					
			CK	PD	A	PCK	SC	SK
Steinwachs & Martens (2022)	Q	German		X	X			
Poce et al. (2019)	QD	Italy			X			X
Alghamdi et al. (2022)	MM	Saudi Arabia			X			X
Jimenez et al. (2022)	MM	United States						X
Schofield et al. (2023)	QD	UAE	X	X				
Busch (2023)	MM	United States			X			
Lilly et al. (2023)	MM	United States						X

Cooper et al. (2022)	Q	Australia		X				
Rachmatullah et al. (2023)	QD	United States		X				
Luft et al. (2022)	MM	United States		X		X		
Chan & Erduran (2023)	Q	England		X				
Peters-Burton et al. (2023)	MM	United States			X			
Wulff et al. (2023)	MM	German		X				
Fridberg et al. (2023)	MM	Spain, Sweden, Italy, & Cyprus			X			X
Davis & Palincsar (2023)	MM	United States						X
Nilsson & Lund (2023)	MM	Sweden			X			
Wallace et al. (2022)	Q	United States						X
Mouza et al. (2022)	MM	United States		X	X			
Abdulbakioglu et al. (2022)	MM	Kazakhstan		X				
Zoupidis et. al (2022)	QD	Greece		X				
Vasconcelos & Paz (2023)	QD	Portugal	X					X
Buma & Sibanda (2022)	MM	Afrika Selatan				X		
Mathis et al. (2023)	Q	United States			X			
Nja et al. (2022)	QD	Nigeria					X	X
Alghamdi (2023)	QD	Saudi Arabia	X	X				
Becerra et al. (2023)	MM	Chile & German		X	X			

Note: CK (Content Knowledge); PD (Professional Development); A (Approaches); PCK (Pedagogical Content Knowledge); SC (Self-Competence); SK (Student Knowledge); Q (Qualitative); QD (Quantitative Descriptive); MM (Mixed-Method)

1. ***What are the challenges and obstacles faced by science teachers to strengthen scientific literacy?***

a) Content Knowledge

The first challenge to strengthen teachers' scientific literacy is from teachers' content knowledge. Science teachers have misconceptions about subject content due to low scientific knowledge (Schofield et al., 2023; Vasconcelos & Paz, 2023). The study conducted by Vasconcelos & Paz (2023) states that teachers have misconceptions about teaching content, for example, in Geosciences. Not only that, science teachers at the beginning of the service also have misconceptions about distinguishing scientific laws and theories in teaching Science (Schofield et al., 2023). Teachers' misconceptions of the content indicate that teachers do not comprehensively understand the lesson's content. Apart from misconceptions, teachers' content knowledge level is also low due to not having a background in a field (Alghamdi, 2023). The study conducted by Alghamdi (2023) explains that teachers have limited knowledge to integrate STEAM due to a lack of skills and strategies to implement STEAM in teaching. Teachers need to find suitable alternatives to ensure they can increase their level of knowledge.

Teachers' misconceptions of teaching content are an issue that needs to be given due attention because misconceptions will affect teachers' scientific literacy. In addition, misconceptions will also impact students because the dissemination of information by teachers to students must be based on correct facts. Not only misconceptions but the level of teacher content knowledge is also essential to ensure teachers have a high level of knowledge in implementing various strategies and approaches to teaching and learning.

b) Pedagogical Content Knowledge

The next challenge is from the aspect of Pedagogical Content Knowledge (PCK) of science teachers in improving scientific literacy. Studies from Luft et al. (2022) and Buma and Sibanda (2022) discuss implementing PCK practices in teaching. Teachers need to practice PCK to ensure their scientific literacy levels increase. All teachers need to realize this fact regardless of their teaching experience. A study conducted by Buma and Sibanda (2022) stated that in-service science teachers are less likely to integrate PCK elements in teaching than trainee teachers. It will have an impact on the PCK of in-service teachers. Luft et al (2022) explained that science teachers who implemented PCK elements in teaching showed significant changes. According to Luft et al (2022), again, this change is in line with the increase in teachers' teaching experience. It implies that teachers who have more teaching experience will show significant changes if they implement PCK elements in teaching. Teachers need to improve PCK as it plays a vital role in effective teaching and learning. PCK allows teachers to design and deliver instruction that meets the needs of different students. It will help teachers actively engage students, facilitate conceptual understanding, and address misconceptions in teaching and learning.

c) Self-Competence

The next challenge is related to self-competence in improving scientific literacy. Self-competence of teachers plays an essential role in improving scientific literacy. Various factors such as self-confidence, interest, and belief will determine self-competency. Some teachers have low competence because they have less experience in teaching. For example, teachers are at the beginning of the service. The study conducted by Nja et al (2022) compared experienced chemistry teachers with less experienced teachers. Nja et al (2022) found that chemistry teachers with experience showed high interest, literacy, and confidence in teaching chemistry concepts compared to the new teachers in the teaching field. According to Nja et al (2022), experienced teachers also provide high cooperation in teaching. Teachers not only need to understand scientific concepts and processes but also need to have confidence in expressing scientific ideas and practices. High self-competence allows teachers to ask questions, explore complex scientific phenomena, and build a deep understanding of scientific concepts. It also allows teachers to communicate effectively and contribute to students' scientific progress.

2. What are the strategies and interventions that can be used to improve science teachers' scientific literacy?

a) Professional Development

Strategies and interventions play a role in improving scientific literacy among science teachers. The interface between strategies and interventions is regarding teachers' professional development. Teachers can have discussions and reflections after teaching to increase scientific literacy and improve teaching practices in order to make judgments on teaching (Steinwachs & Martens, 2022; Wulff et al., 2022; Cooper et al., 2022 & Chan & Erduran, 2023). The study conducted by Steinwachs and Martens (2022) on science teachers stated that discussion and reflection with other teachers is a critical task in teacher practice. Wulff et al (2022) made a written analysis to assess teachers in teaching so that teacher literacy can develop. Cooper et al (2022) explained that group discussions could help other teachers develop pedagogical content knowledge and increase teacher content knowledge in science and science education. In addition, teachers can also make discussions and reflections, such as interdisciplinary cooperation among teachers outside the field to improve teacher practice. Interdisciplinary cooperation will strengthen the understanding of the pedagogical concepts of science teachers (Chan & Erduran, 2023).

Apart from that, providing training to teachers is also a strategy and intervention that can be used to improve scientific literacy among science teachers (Schofield et al., 2023; Rachmatullah et al.; 2023; Mouza et al., 2022; Zoupidis et al., 2022; Alghamdil, 2023; Becerra et al., 2023; Luft et al., 2022 & Abdulbakiogle et al., 2022). The study conducted by Alghamdi (2023) explained that teachers need professional development, such as training because teachers have limited knowledge in STEAM fields. Zoupidis et al (2023) also explained that training for teachers is needed to improve teacher practices, such as teaching approaches used by teachers. According to Zoupidis et al (2023), again, there are groups of teachers who only teach students using specific content and teaching methods, which depend on their level of knowledge and their assessment of students only.

According to Luft et al (2022), an effective induction program needs to be implemented for teachers at the beginning of their service because they showed no significant changes in their beliefs, pedagogical content knowledge, and instructional practices even though they had five years of teaching experience. Abdulbakiogle et al (2022) explained that teachers and students showed a weak positive relationship when open lesson practice. It is because teachers have low pedagogical content knowledge, causing them to be uncomfortable when realizing open lesson practice. Exercises that provide skills can add to teachers' scientific knowledge, especially in the Nature of Science (NOS) (Schofield et al., 2023). According to Rachmatullah et al (2023); Mouza et al (2023), teachers who accompany training in professional development will increase their confidence to teach science and add knowledge. The study conducted by Becerra et al (2023) also explained that teachers who participated in training in professional development showed significant differences compared to teachers who did not participate in involved training.

b) Approaches

Apart from using professional development, some approaches can be applied to enhance teachers' scientific literacy. For example, video lessons, tinkering activities, intervention workshops, coaching frameworks, instruments, instructional approaches, and project generation (Steinwachs & Martens, 2022; Poce et al., 2019; Alghamdi et al., 2022; Nilsson & Lund, 2023; Busch et al., 2023; Peters-Burton et al., 2023; Mouza et al., 2022; Mathis et al., 2023; Beccera et al., 2023; Luft et al., 2022; Davis & Palincsar, 2023; Albdulbakioglu et al., 2022; Fridberg et al., 2023). Steinwachs et al (2022) explained in their study that teachers can also use video lessons to improve their scientific literacy in dealing with challenges in the world of education. The study conducted by Poce et al (2019) explains that tinkering activities can improve creative and critical thinking skills and positively impact fluency and flexibility in thinking skills. Such activities will contribute to improving the level of teacher knowledge.

Not only that, strategies such as creating intervention workshops can further strengthen teachers' scientific knowledge and literacy (Alghamdi et al., 2022; Nilsson & Lund 2023). According to Alghamdi et al (2022), the workshops conducted can strengthen teachers' skills in teaching in addition to improving teachers' knowledge, understanding, and application of medical terminology and disease epidemiology. It is supported by a study from Nilsson and Lund (2023) stating that intervention workshops can develop teacher views and teacher knowledge. The development of a framework is also one of the approaches that can be used to improve teachers' scientific literacy (Busch et al., 2023; Peters-Burton et al., 2023; Mouza et al., 2022; Mathis et al., 2023 & Becerra et al., 2023). The development of this framework will help in understanding the goals, programs, contexts, linkage strategies, and assessment of teachers in improving their scientific literacy (Busch et al., 2023).

In addition, framework coaching also helps teachers explore their views on NOS as they have fewer ideas on NOS (Peters-Burton et al., 2023) and helps teachers integrate their knowledge of students and communities (Mouza et al., 2022; Mathis et al., 2023). Instrument coaching is also one of the strategies that help teachers to improve their scientific literacy. Becerra et al (2023) explained that the instrument built for the Evolution title could help teachers assess the level of their knowledge in the teaching field and understanding related to the teaching title. Apart from that, project coaching can also improve teachers' confidence levels (Fridberg et al., 2023). The study by Fridberg et al (2023) showed that teachers who used bot-STEM projects had more confidence in teaching.

3. What are the effects of science teachers' scientific literacy on student learning and achievement?

a) Student Knowledge

Teachers with high scientific literacy will have a positive impact on student learning and achievement. Poce et al (2019) suggest that the activities that teachers carry out give students an impression of STEM subjects and, at the same time, improve student development in 21st-century thinking skills. Alghamdi et al (2022) also stated that student engagement concerning curriculum and community increased. Jimenez et al (2022) Fridberg et al (2023), Vasconcelos and Paz (2023); Nja et al (2023); Lilly et al (2023); Wallace et al (2022) stated that the instruments tools and materials used by teachers could improve students' level of knowledge. It shows that teachers with high scientific literacy will always strive to ensure student learning and achievement have a good impact.

A study by Nja et al (2022) states that teachers who use simulation in their teaching concepts can help students improve in chemistry. Whereas teachers who use verbal support and storytelling techniques can also positively impact student achievement and learning (Lilly et al., 2023 & Wallace et al., 2022). However, to ensure that students' knowledge levels increase, teachers need to develop relevant resources for teaching and student learning (Vasconcelos & Paz, 2023). For example, the development of instruments or tools that allow students to assess their conceptual understanding and also help students connect to learning, such as STEM and robotics learning (Jimenez et al., 2022; Fridberg et al., 2023).

Conclusion

This study was conducted by focusing on three main focuses: identifying the challenges and obstacles faced by science teachers to strengthen scientific literacy. The second focus is on what strategies and interventions can be used to improve the scientific literacy of science teachers. Furthermore, the third focus is on the impact of teachers' scientific literacy on student learning and achievement. Based on the main focus of this study, the authors have identified the issues that need to be given attention so that the scientific literacy of science teachers is robust to ensure that teachers can help students develop their knowledge. Based on the first focus, which is related to challenges and obstacles, the authors have identified two main themes: content knowledge and pedagogical content knowledge. Teachers have misconceptions about teaching content and have a low level of knowledge, and this causes challenges in improving teachers' scientific literacy. In addition, teachers also have a low level of pedagogical content knowledge, causing them to have less solid scientific literacy.

For the second focus of the study, the authors have recognized two themes discussed, namely professional development and approaches used by teachers. These themes have been identified to explain strategies and interventions to improve teachers' scientific literacy. Teachers can use various strategies and interventions such as group discussions, reflections, providing exercises, tinkering activities, workshops, frameworks, intervention workshops and others. These strategies allow teachers to improve their scientific literacy. The third focus of the study is that the authors have recognized that teachers' scientific literacy impacts student learning and achievement. Students will show positive responses, such as actively involving themselves in learning. Thus, a further research proposal for this study is to examine other factors that may influence teachers' scientific literacy. In addition, the authors also suggested that a more comprehensive study should be conducted on the development of appropriate instruments to measure teachers' scientific literacy.

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