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Scientific Argumentation in Physics Learning and Its Influence on Scientific Literacy: A Systematic Literature Review

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Abstract

This study uses a systematic literature review approach. There are 22 articles that are analyzed in depth and comprehensively using the PRISMA *(Preferred Reporting Items for Systematic Review and Meta-Analysis)* method. The stages of the PRISMA method consist of identification, screening, eligibility, and inclusion. The databases used are Scopus and Google Scholar. This study consists of 3 research questions, namely (1) research trends on scientific argumentation in physics learning; (2) implementation of scientific argumentation in physics learning; and (3) the influence of scientific argumentation on students' scientific literacy. The findings of this study are: (1) research trends on scientific argumentation in physics learning are mostly conducted in Indonesia; the year of most publications is 2025, the most frequently used research method is the quantitative approach, and the research subjects are junior high and senior high school students; (2) this study explains that scientific argumentation in physics learning integrates one or more STEM components and the most widely used Toulmin argumentation pattern; (3) scientific argumentation in physics learning has a positive influence on students' scientific literacy skills.

Keywords: Scientific Argumentation, Physics Learning, Scientific Literacy, STEM.

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INTRODUCTION

Scientific literacy is a crucial competency in the 21st century because it significantly enhances critical and innovative thinking skills (Sanjiartha et al., 2024). Students with scientific literacy skills are able to connect current issues with learning and explain scientific facts (Marwah & Pertiwi, 2024). Furthermore, Mauladhani et al. (2023) stated that scientific literacy can improve understanding of physics concepts and their application in everyday life. Scientific literacy skills support the physics learning process, both in understanding concepts and their application.

Indonesian students' scientific literacy skills are low (Rohmaya, 2022; Yusmar & Fadilah, 2023; Pratama et al., 2024). PISA *(Program for International Student Assessment)* results show that the scientific literacy of Indonesian students has decreased. The scientific literacy score in 2018 was 396 while in 2022 the score was 383, the scientific literacy score dropped by 13 points. Scientific literacy needs to be improved to overcome the decline in PISA results.

Scientific literacy consists of four main aspects: scientific knowledge, scientific process skills, scientific context, and scientific attitudes. Science process skills in physics learning still need to be improved. Poor science process skills can make physics learning difficult (Rizki et al., 2022). Inadequate understanding of physics concepts leads to students' lack of confidence in solving physics problems

(Syahdah & Irvani, 2023), a significant problem in scientific literacy. Students' skills in identifying scientific opinions, understanding and interpreting data, and drawing conclusions are relatively low.

Implementing STEM in physics learning can improve 21st-century skills such as critical thinking skills, creativity, collaboration, and communication (Minarti et al., 2022; Himsar & Harahap, 2024; Tarigan et al., 2024). Several studies state that the integration of STEM in physics learning can improve understanding of concepts, scientific processes, and scientific attitudes (Batrisyia et al., 2024; Isa, 2024; Meraoui et al., 2024; Hikmah et al., 2025). Apart from that, STEM can also improve students' learning outcomes and academic achievements in physics learning (Norlaili et al., 2022; Bingöl & Baran, 2023). The STEM approach is the right strategy to increase scientific literacy in students.

Scientific argumentation is an important skill in physics learning. Critical thinking and scientific argumentation are interrelated and contribute to the learning process (Fauziah et al., 2024). Furthermore, Anshori & Sastromiharjo (2023) suggest that scientific argumentation improves the quality of the learning process. Scientific argumentation improves critical thinking skills and conceptual understanding. Darmaji et al. (2022) and Irawan & Suyono (2024) state that improving scientific literacy can improve students' scientific argumentation skills. Scientific literacy and scientific argumentation skills show a linear relationship. Scientific argumentation skills in physics are influenced by learning approaches and models. Problem-based learning focused on STEM improves scientific argumentation in students (Muspiroh et al., 2024).

Scientific argumentation and scientific literacy are interrelated. Both emphasize critical thinking, logical reasoning, and the use of scientific evidence. Scientific literacy encompasses mastering concepts, explaining phenomena, evaluating information, and making decisions based on scientific evidence. Scientific argumentation, on the other hand, trains students in formulating opinions, communicating them based on data, and critically evaluating them.

In the context of physics, scientific argumentation supports students in developing scientific literacy skills. Aspects of scientific literacy skills in physics learning include data interpretation, scientific communication, problem solving, and information evaluation. Students learn to formulate and express opinions, defend their opinions based on data, critically evaluate information, and deeply understand physics concepts through scientific discussions. Therefore, scientific argumentation plays a significant role in strengthening students' scientific literacy in physics learning, which requires logical reasoning and scientific evidence.

Many studies have been conducted on scientific literacy, physics learning, and scientific argumentation. However, previous studies examined scientific literacy, physics learning, and scientific argumentation separately, without a direct link between the three study themes. Research by Hasanah et al. (2022) demonstrated that cooperative learning tools in STEM-based physics learning can improve scientific literacy. Furthermore, Salsabila et al. (2025) demonstrated that learning models integrated with digital media effectively improve scientific literacy. This research on scientific literacy examined the effectiveness of the implementation of learning models and tools. Nirmala et al. (2026) confirmed that PBL effectively improves scientific argumentation. STEM learning improves students' understanding of physics concepts and cognitive abilities (Hayat, 2024; Walidain, 2024). Studies on scientific argumentation are limited to the effectiveness of learning models.

Research that examines scientific arguments in physics learning and its influence on scientific literacy is still limited, especially those that use the SLR (Systematic Literature Review) method. Previous research emphasized the application of learning models and improving learning outcomes compared to a comprehensive analysis of scientific argumentation, physics learning, and scientific literacy. Based on this, a Systematic Literature Review study is needed to analyze the relationship between scientific argumentation, physics learning, and its influence on scientific literacy.

The novelty of this research lies in its combination of scientific argumentation, physics learning, and scientific literacy through a Systematic Literature Review method. This research specifically analyzes scientific argumentation in physics learning and its influence on scientific literacy.

This study focuses on several research questions, namely: research trends on scientific argumentation in physics learning, how scientific argumentation is implemented in physics learning, and

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how scientific argumentation influences students' scientific literacy. Therefore, this study aims to analyze scientific argumentation in physics learning and its influence on scientific literacy so that it can contribute to physics learning.

METHODS

This study employed a *Systematic Literature Review* (SLR) approach with the PRISMA *(Preferred Reporting Items for Systematic Reviews and Meta-Analysis)* method. The researchers conducted the following stages: identification, screening, eligibility, and inclusion. They utilized the Scopus and Google Scholar databases. Articles were thoroughly analyzed, yielding 22 articles that met the inclusion criteria relevant to the research question.

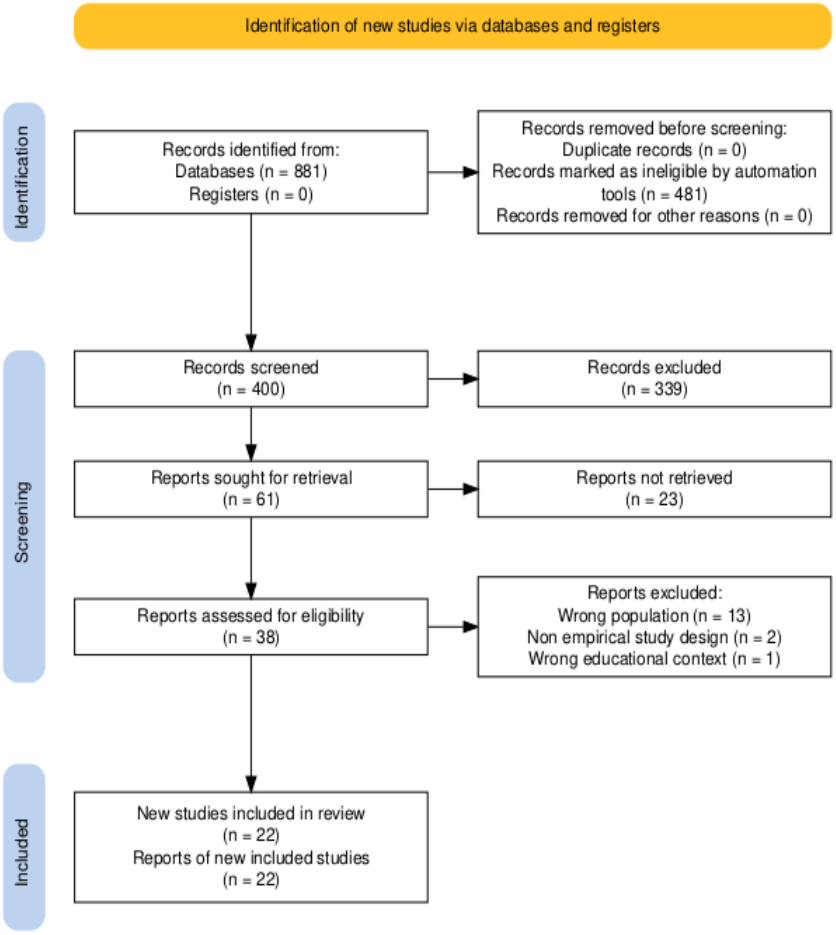


Figure 1. PRISMA flow diagram

The diagram above illustrates the PRISMA framework used by the researcher. In the identification stage, the initial selection yielded 365 articles from the Scopus database and 516 articles from the Google Scholar database. After selection based on the criteria of year, document type, type of publication source, language, and scientific field, 52 articles were obtained from the Scopus database and 348 articles from the Google Scholar database. The next stage was screening. At this stage, selection emphasized the title and abstract, and 38 articles were obtained. Furthermore, articles were selected based on research subjects, physics learning contexts, and empirical research, resulting in 22 articles. The research questions in this study are formulated as follows:

RQ1: What are the research trends on scientific argumentation in physics learning?
RQ2: How is scientific argumentation implemented in physics learning?
RQ3: How does scientific argumentation influence students' scientific literacy?

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This study used inclusion and exclusion criteria. The inclusion criteria included the context of physics learning, discussing scientific argumentation, discussing scientific literacy, using Indonesian or English, articles published within the last six years, research subjects being junior high and high school students, articles being fully accessible, and empirical research. The exclusion criteria included articles containing literature reviews and articles irrelevant to the research question.

RESULTS AND DISCUSSION

This study produced an in-depth literature review on scientific argumentation in physics learning and its impact on scientific literacy. Using the PRISMA *(Preferred Reporting Items for Systematic Reviews and Meta-Analysis)* method, 22 articles met the inclusion criteria and were analyzed.

RESULTS

Trends in scientific argumentation research in physics learning

The 22 articles included in this systematic literature review were analyzed based on their geographical distribution, publication year, research methods, and educational levels. Figure 2 presents the geographical distribution of the reviewed studies. The geographical distribution shows that Indonesia accounted for 68.2% of the reviewed studies. The Philippines, Italy, Colombia, Finland, Germany, and Turkey each accounted for 4.5% of the studies.

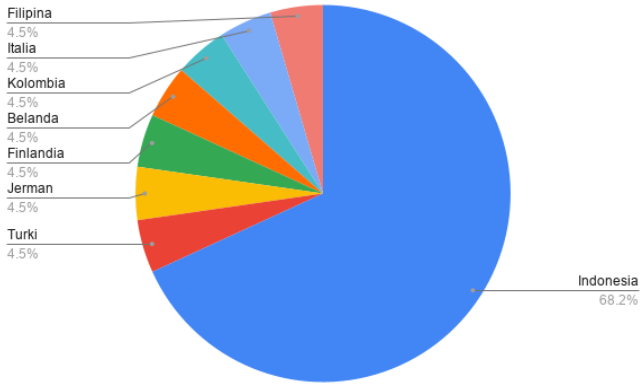


Figure 2. Geographical distribution of research

The annual distribution of publications on scientific argumentation in physics learning over the last six years is presented in Figure 3. The number of publications fluctuated over the six-year period, with the highest number recorded in 2025. Publications increased between 2022 and 2023 and between 2024 and 2025. Decreases occurred between 2021 and 2022, between 2023 and 2024, and between 2025 and 2026.

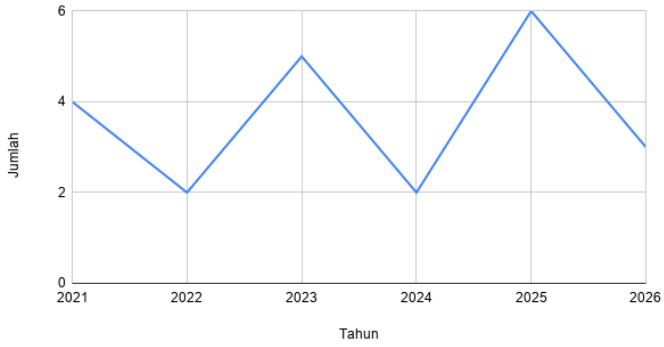


Figure 3. Number of articles published over the last six years

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The research methods used in the 22 reviewed articles are summarized in Table 1. As shown in Table 1, quantitative research was used in 10 articles, followed by mixed methods in six articles and qualitative research in five articles. One article employed classroom action research. The quantitative studies used experimental and non-experimental designs. Experimental designs included pre-experimental and quasi-experimental approaches, whereas non-experimental designs included ex post facto and quantitative descriptive studies. The qualitative studies employed case study, descriptive analysis, and hermeneutic approaches.

Table 1. Research methods used in the reviewed studies

Research method	Number of articles
Quantitative	10
Qualitative	5
Mixed methods	6
Classroom action research	1
Total	22

The educational levels represented in the reviewed articles are presented in Table 2. Table 2 shows that 15 articles investigated scientific argumentation at the senior high school level, six at the junior high school level, and one across both levels. The junior high school studies involved students in Grades 7, 8, and 9, while the senior high school studies involved students in Grades 10, 11, and 12. The study covering both educational levels included students in Grades 8, 9, and 10.

Table 2. Educational levels represented in the reviewed studies

Educational level	Number of articles
Junior high school	6
Senior high school	15
Combined junior and senior high school	1
Total	22

Implementation Of Scientific Argumentation In Physics Learning

The integration of science, technology, engineering, and mathematics (STEM) components in physics learning involving scientific argumentation is summarized in Table 3. As presented in Table 3, nine articles integrated science and technology, while seven focused on science alone. Two articles combined science and engineering. The combinations of science and mathematics, science with technology and engineering, all four STEM components, and science with technology and mathematics were each reported in one article. The technologies used in the reviewed studies included PhET virtual experiments, augmented reality, virtual reality, and AI chatbots.

Table 3. STEM components integrated into physics learning involving scientific argumentation

STEM components	Number of articles
Science + Technology	9
Science	7
Science + Engineering	2
Science + Mathematics	1
Science + Technology + Engineering	1
Science + Technology + Engineering + Mathematics	1
Science + Technology + Mathematics	1
Total	22

The scientific argumentation approaches used in the reviewed articles are presented in Table 4. Table 4 shows that the Toulmin Argumentation Pattern (TAP) was used in 10 articles, followed by Argument-Driven Inquiry (ADI) in four articles. Evidence- or justification-based argumentation and debate and argumentative writing were each reported in three articles. Dialogic argumentation was used in two articles. The approaches covered argument structures involving claims, evidence,

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reasoning, and rebuttals; inquiry activities using scientific evidence; dialogue; evidence evaluation; debate; and argumentative writing.

Table 4. Scientific argumentation approaches used in physics learning

Scientific argumentation approach	Number of articles
Toulmin Argumentation Pattern (TAP)	10
Argument-Driven Inquiry (ADI)	4
Dialogic argumentation	2
Evidence- or justification-based argumentation	3
Debate and argumentative writing	3
Total	22

The interventions incorporating scientific argumentation into physics learning are summarized in Table 5. As shown in Table 5, technology-supported argumentation was reported in six articles. Argumentation-based inquiry and collaborative and dialogic learning were each reported in four articles, while profiling or surveys of existing skills appeared in three articles. Project- or STEM-based learning, assessment-based argumentation, contextual learning, and laboratory-based argumentation were each reported in one article. The number of articles on writing-based argumentation was not specified in the available data.

Table 5. Interventions incorporating scientific argumentation in physics learning

Intervention	Number of articles
Argumentation-based inquiry	4
Technology-supported argumentation	6
Collaborative and dialogic learning	4
Project- or STEM-based learning	1
Writing-based argumentation	Not reported
Assessment-based argumentation	1
Contextual learning	1
Laboratory-based argumentation	1
Profiling or surveys of existing skills	3
Total	22

The interventions also included inquiry activities, technology-supported scaffolding and data presentation, scientific discussions, collaborative learning, project assignments, writing activities, assessment practices, and contextual learning. Some studies incorporated scientific argumentation into projects in which students constructed arguments based on project data. Other studies used writing activities to facilitate the expression of arguments, incorporated argumentation into assessment, or connected scientific argumentation with real-world problems and physical concepts, including ethnoscience contexts.

The Effect of Scientific Argumentation on Student Literacy

The distribution of articles according to the scientific literacy aspects addressed is presented in Table 6. As presented in Table 6, nine articles (40.9%) addressed interpreting data and scientific evidence, eight articles (36.4%) addressed explaining phenomena scientifically, and five articles (22.7%) addressed evaluating and designing scientific inquiry.

Table 6. Scientific literacy aspects addressed in the reviewed studies

Scientific literacy aspect	Number of articles	Percentage
Interpreting data and scientific evidence	9	40.9%
Explaining phenomena scientifically	8	36.4%
Evaluating and designing scientific inquiry	5	22.7%
Total	22	100%

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DISCUSSION

Research on scientific argumentation in physics learning during the 2021-2026 period was mostly found in Indonesia. Furthermore, research has also been conducted in several countries, including the Philippines, Italy, Colombia, Finland, Germany, and Turkiye. The distribution of research on scientific argumentation in physics learning in Indonesia was 68.2%, while in other countries it was 4.5%. This aligns with research by Mafaza et al. (2025), which found that the largest contributions to research on scientific argumentation in science learning came from Indonesia and the United States. Therefore, scientific argumentation in physics learning has become a research priority in various countries.

During the 2021-2026 period, the most research will be conducted in 2025. Research on scientific arguments in physics learning has a dynamic trend. The trend of research publications will increase from 2022-2023 to 2024-2025. In 2021-2022, 2023-2024, and 2025-2025, the trend of research publications on scientific arguments in physics learning will decrease. This shows that scientific argumentation in physics learning is a research topic that needs to be developed.

Most research on scientific arguments in physics learning uses a quantitative approach, namely 45.5%. The research design used is experimental and non-experimental. The research was conducted on junior high and senior high school students. Therefore, research on scientific arguments in physics learning needs to be followed up among junior high and senior high school students with a quantitative approach. The research trend of scientific argumentation in physics learning that integrates STEM only contains one or several STEM components. There is 1 out of 22 articles, or around 4.5%, that uses STEM components in full, including science, technology, engineering, and mathematics components.

The analysis results show that the implementation of the Toulmin argumentation pattern in physics learning is the most frequently used research. Muslim et al. (2024) revealed that the Toulmin argumentation pattern can significantly improve students' argumentation skills. According to Yuanata et al. (2022), students are only able to provide scientific arguments at the claim stage, without being accompanied by strong evidence and support. In line with the results of this study, Hasanah et al. (2022) stated that students' weaknesses in scientific argumentation lie at the reasoning stage. Thus, the Toulmin argumentation pattern in physics learning can improve students' argumentation skills but is limited to the claim stage. Therefore, special treatment is needed that focuses on improving students' scientific argumentation skills at the evidence and reasoning stages.

According to Limiansih et al. (2024), most teachers agree that scientific literacy is crucial to develop in schools. The influence of scientific argumentation on scientific literacy is most pronounced in the interpretation of data and scientific evidence. Sanjiartha (2024) revealed that scientific literacy can train data analysis, information evaluation, and decision-making skills. Scientific literacy skills can be improved through physics instruction in schools. Scientific argumentation in physics instruction has a positive impact on students' scientific literacy.

CONCLUSION

A systematic review of 22 research articles explains that, in research on scientific argumentation in physics learning during the period 2021-2026, Indonesia contributed the most; most of the research was conducted in 2025; the research method frequently used was quantitative; and the research subjects were junior high and senior high school students. The research integrated one or several STEM components, and the most widely used implementation of scientific argumentation in physics learning was the Toulmin argumentation pattern. These findings emphasize that scientific argumentation has a positive impact on students' scientific literacy. The most impacted aspect of scientific literacy is the interpretation of data and scientific evidence.

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Conflict of Interest

The authors declare that they have no conflict of interest related to this study.

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Author Contributions

D.N. contributed to the conceptualization, methodology, literature search, article screening, data extraction, data analysis, and preparation of the original manuscript. U.U. and W.I. contributed to supervision, validation, interpretation of the findings, and critical revision of the manuscript. All authors reviewed and approved the final version of the manuscript and agreed to be accountable for all aspects of the work.

Data Availability Statement

The data supporting the findings of this study are available from the corresponding author upon reasonable request.

Ethics Approval and Consent to Participate

Ethics approval and consent to participate were not required for this study because it involved a systematic literature review of previously published research and did not involve direct participation by human subjects or the collection of new data from human participants.

Generative AI Declaration

The authors declare that no generative artificial intelligence tools were used in the preparation, writing, or revision of this manuscript.

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