

# The Epistemic Structure of Ethnoscience and Scientific Argumentation Research in Elementary Science Education: A Hybrid Bibliometric and Systematic Review

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## ABSTRACT

Scientific argumentation plays a central role in science education by supporting reasoning, evidence evaluation, and knowledge construction. However, limited attention has been given to how ethnoscience and culturally grounded knowledge are positioned within scientific argumentation research. This study examines the intellectual development, thematic structure, and epistemic configuration of ethnoscience and scientific argumentation research in elementary science education. A hybrid approach integrating bibliometric analysis, systematic literature review, and epistemic synthesis was employed. The dataset consisted of 386 Scopus-indexed publications published between 1984 and April 2026. Bibliometric mapping was conducted using VOSviewer, while 20 selected studies were analyzed through thematic coding. The findings reveal substantial growth in scientific argumentation research, accompanied by thematic expansion across pedagogical, epistemic, socio-scientific, and technology-enhanced learning domains. Despite this growth, scientific knowledge remains the dominant epistemic authority, whereas local, indigenous, and heritage-based knowledge are primarily positioned as contextual resources rather than legitimate sources of evidence. Five epistemic gaps were identified: legitimacy, representation, authority, integration, and participation. Based on these findings, this study proposes the concept of an epistemic hierarchy of knowledge sources to explain the unequal positioning of scientific and culturally grounded knowledge within scientific argumentation research. The findings contribute to a deeper understanding of knowledge legitimacy in science education and provide directions for developing more pluralistic and culturally responsive approaches to scientific argumentation.

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## 1. INTRODUCTION

Over the last decade, scientific argumentation has emerged as one of the central topics in science education research, particularly within elementary education contexts. Numerous studies have demonstrated that inquiry-based argumentation, scaffolding strategies, and socio-scientific issue (SSI) approaches contribute significantly to the development of students' scientific reasoning, critical thinking, and scientific literacy (Broderick, 2022;

Sihombing & Putra, 2025; Tian & Osman, 2025; Xu et al., 2026). As a result, scientific argumentation is increasingly recognized as an essential practice through which learners construct, evaluate, and justify knowledge claims using evidence and reasoning (Driver et al., 2000; Jiménez-Aleixandre & Erduran, 2007). Despite this growing body of literature, research on scientific argumentation has largely focused on pedagogical effectiveness, cognitive development, classroom discourse, and instructional strategies (Caño & Sanz, 2025; Jin & Kim, 2021). Considerably less attention has been devoted to examining the epistemic foundations underlying argumentation practices. Questions concerning what counts as legitimate knowledge, whose knowledge is recognized as authoritative, and how different knowledge systems are positioned within scientific argumentation remain insufficiently explored. Consequently, the field has generated substantial knowledge about how students argue, while providing limited understanding of the epistemic structures that shape the production, validation, and circulation of knowledge in science education.

This limitation becomes particularly significant when scientific argumentation is examined alongside ethnoscience. Ethnoscience refers to culturally embedded systems of knowledge developed through long-term interactions between communities and their environments (Aikenhead & Ogawa, 2007; Cobern & Loving, 2001). Within elementary science education, ethnoscience has been widely acknowledged as a valuable resource for contextualizing scientific concepts and promoting meaningful learning experiences. Previous studies have shown that integrating local cultural practices into science instruction can enhance student engagement, motivation, and conceptual understanding (Seda Saracaloglu et al., 2011). However, ethnoscience is frequently positioned as a pedagogical context rather than as a legitimate epistemic resource within scientific argumentation. A growing body of scholarship suggests that students naturally draw upon personal experiences, community knowledge, and cultural understandings when constructing explanations and arguments about scientific phenomena (Driver et al., 2000; Evagorou et al., 2020; Ozden, 2020). Nevertheless, these forms of knowledge rarely receive the same epistemic status as formal scientific knowledge in classroom argumentation. Scientific evidence derived from established disciplinary frameworks is commonly treated as the primary source of legitimacy, while local and culturally grounded knowledge remains peripheral. This pattern indicates the existence of epistemic asymmetries that influence which forms of knowledge are accepted, valued, and legitimized within science education.

The issue extends beyond classroom practice and is also reflected in the broader landscape of knowledge production. Existing bibliometric evidence suggests that research on scientific argumentation is concentrated in a relatively small number of countries, particularly the United States, the United Kingdom, Australia, and several European nations (Martínez-Morales & Briceño-Martínez, 2025). Meanwhile, countries with rich traditions of indigenous and local knowledge, including Indonesia, India, Brazil, and many African nations, remain comparatively underrepresented in the international literature. Such patterns raise important questions concerning the global distribution of epistemic authority and the extent to which diverse knowledge traditions are represented within scientific argumentation research. From an epistemological perspective, ethnoscience possesses characteristics that potentially qualify it as a legitimate source of evidence and justification. Local knowledge systems are often grounded in empirical observations accumulated across generations, tested within specific ecological contexts, and maintained through coherent cultural practices (Aikenhead, 2006). Nevertheless, science education research continues to privilege formal scientific knowledge as the dominant epistemic authority. This tendency reflects the persistence of epistemological monism, where a single knowledge system functions as the primary criterion for evaluating truth claims (Fricker, 2007). Such conditions may contribute to forms of epistemic injustice by limiting recognition of alternative ways of knowing and restricting opportunities for epistemic participation among learners and communities whose knowledge originates outside formal scientific institutions (Rinehart et al., 2022).

Although previous studies have examined scientific argumentation and ethnoscience separately, limited research has systematically investigated the intellectual and epistemic structure connecting these two fields. Existing reviews primarily focus on instructional effectiveness, learning outcomes, or thematic developments. As a result, little is known about how knowledge domains are organized, how epistemic relationships are formed, which themes occupy central positions within the literature, and how local knowledge is positioned within the evolving research landscape. This gap reveals the need for a more comprehensive examination of the epistemic structure underlying ethnoscience and scientific argumentation research. To address this gap, the present study employs a hybrid approach integrating bibliometric analysis, systematic literature review, and epistemic synthesis. Rather than focusing solely on publication trends or instructional outcomes, this study seeks to map the epistemic structure of ethnoscience and scientific argumentation research in elementary science education. Specifically, it

investigates the intellectual organization of the field, the patterns of knowledge legitimacy that emerge within the literature, and the epistemic gaps that continue to shape relationships between scientific knowledge and local knowledge systems. By doing so, the study contributes to the development of a more nuanced understanding of knowledge production in science education and provides a foundation for advancing more pluralistic, dialogic, and epistemically just approaches to elementary science learning..

## 2. METHODS

This study employed a hybrid review design integrating bibliometric analysis, systematic literature review (SLR), and epistemic synthesis to examine the epistemic structure of ethnoscience and scientific argumentation research in elementary science education. The hybrid approach was selected because it enables the combination of large-scale quantitative mapping with in-depth qualitative interpretation of knowledge structures and epistemic relationships within a research field (Marzi et al., 2025). While bibliometric analysis identifies intellectual patterns, thematic clusters, and research evolution, systematic review and epistemic synthesis provide deeper insights into how different forms of knowledge are represented, legitimized, and positioned within scientific argumentation research. The systematic review process followed the PRISMA 2020 guidelines to ensure transparency, rigor, and reproducibility throughout the identification, screening, eligibility, and inclusion stages (Page et al., 2021). The review also adhered to systematic literature analysis principles emphasizing explicit inclusion and exclusion criteria, consistency in article selection, and transparency in analytical procedures (Hadi et al., 2023). Data were retrieved from the Scopus database on 14 April 2026 using the search term “*scientific argumentation*” in the title, abstract, and keyword fields. Scopus was selected because it is one of the largest and most comprehensive international databases for educational research and provides high-quality bibliographic metadata suitable for bibliometric analysis. The search was restricted to peer-reviewed journal articles published in English.

The inclusion criteria consisted of: (1) articles published up to 14 April 2026, (2) English-language publications, and (3) studies explicitly focusing on scientific argumentation as a primary research topic. Publications in which scientific argumentation appeared only as a secondary theme were excluded. The unit of analysis comprised scholarly journal articles meeting all inclusion criteria, with particular attention to bibliographic metadata and conceptual content related to scientific argumentation, ethnoscience, local knowledge, and elementary science education. Prior to bibliometric mapping, a data cleaning procedure was conducted to improve dataset reliability. Duplicate records were removed, author keywords and indexed keywords were standardized, and synonymous terms were normalized to reduce conceptual fragmentation. Keyword normalization included harmonizing singular and plural forms, abbreviations, and closely related concepts. This procedure enhanced the consistency of co-occurrence analysis and reduced noise within the bibliometric network. Bibliometric analysis was performed using VOSviewer. The analysis focused on keyword co-occurrence, country collaboration networks, publication trends, and subject-area distributions. A minimum occurrence threshold was applied to eliminate isolated terms and improve network interpretability. VOSviewer's association strength normalization method was employed to calculate relationships among terms and generate thematic clusters. This approach enabled the identification of intellectual structures, conceptual relationships, and thematic evolution within the field (van Raan, 2019; Jing et al., 2024; Chotisarn & Phuthong, 2025). To enhance methodological trustworthiness, multiple bibliometric indicators were analyzed and compared, including publication growth, subject-area distribution, country collaboration networks, and keyword co-occurrence structures. Consistency across these indicators was used as a validation strategy to strengthen the reliability of interpretations. Furthermore, all search procedures, screening decisions, inclusion criteria, and analytical steps were documented to support reproducibility.

The epistemic synthesis phase involved full-text analysis of selected articles using thematic coding. This stage aimed to move beyond descriptive mapping and examine how knowledge is constructed, legitimized, and represented within scientific argumentation research. Three analytical dimensions guided the coding process: (1) dominant knowledge sources, (2) epistemic positioning of local and indigenous knowledge, and (3) forms of knowledge legitimacy employed in argument construction. These dimensions were derived from epistemic justice and knowledge legitimacy literature and were used to identify recurring patterns across studies (Fricker, 2007; Rinehart et al., 2022).

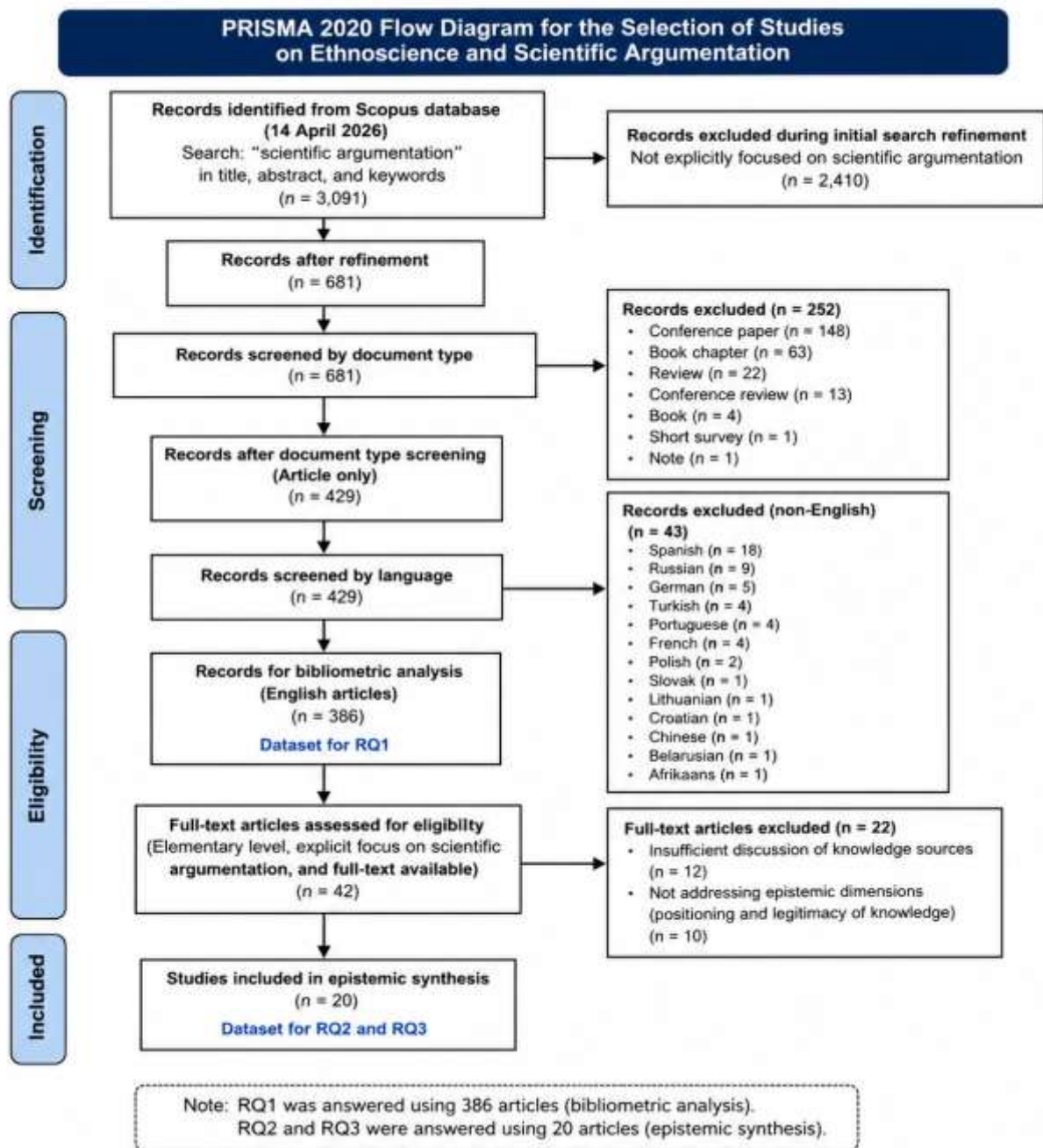


Figure 1 presents the PRISMA flow diagram describing the identification, screening, eligibility, and inclusion procedures.

The initial search yielded 3,091 documents. After refining the search to publications explicitly focused on scientific argumentation, 681 records remained. During the screening stage, document types other than journal articles were excluded, including conference papers (148), book chapters (63), reviews (22), conference reviews (13), books (4), short surveys (1), and notes (1). This process resulted in 429 journal articles.

The language screening stage excluded non-English publications, leaving 386 articles for bibliometric analysis. These articles constituted the dataset for Research Question 1, which examined publication trends, subject-area distributions, collaboration patterns, and thematic development. For Research Questions 2 and 3, additional eligibility criteria were applied. Articles were required to: (1) focus on elementary education (K-6) or

preservice elementary teachers, (2) explicitly investigate scientific argumentation, and (3) provide full-text access. This process identified 42 articles for full-text review. During detailed examination, 22 articles were excluded because they either lacked substantial discussion of knowledge sources (n = 12) or did not address epistemic dimensions related to knowledge positioning and legitimacy (n = 10). Consequently, 20 articles were retained for epistemic synthesis. Based on the final dataset, this study addressed the following research questions:

*RQ1. How have thematic trends, subject-area distributions, and research development patterns evolved within ethnoscience and scientific argumentation research?*

*RQ2. How are scientific knowledge, indigenous knowledge, local knowledge, and heritage-based knowledge positioned and legitimized within elementary scientific argumentation research?*

*RQ3. What epistemic gaps emerge in the integration of ethnoscience, heritage knowledge, and scientific argumentation in elementary science education?*

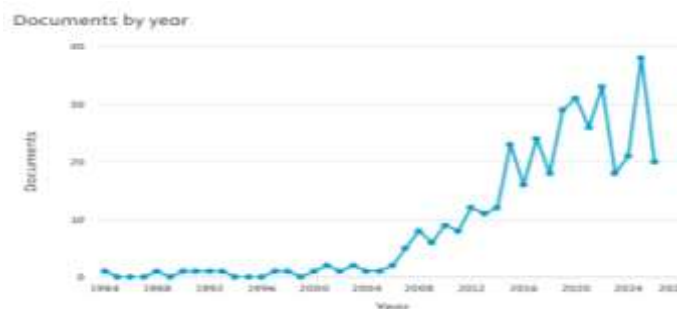
The integration of bibliometric mapping and epistemic synthesis enabled the study to move beyond descriptive trend analysis and generate a comprehensive understanding of the epistemic structure, knowledge legitimacy patterns, and intellectual development of ethnoscience and scientific argumentation research.

### 3. FINDINGS AND DISCUSSION

The results are presented according to the three research questions developed in this study. The first research question examines the thematic trends, disciplinary distributions, and development patterns of scientific argumentation research. The second research question explores how scientific, local, indigenous, and heritage-based knowledge are positioned and legitimized within elementary science education literature. The third research question identifies the epistemic gaps emerging from the relationship between scientific argumentation and ethnoscience. Together, these analyses provide a comprehensive understanding of the intellectual landscape, knowledge legitimacy patterns, and epistemic challenges that characterize the field.

*RQ1. How have thematic trends, subject-area distributions, and research development patterns evolved within ethnoscience and scientific argumentation research?*

The bibliometric analysis was conducted on 386 articles indexed in the Scopus database and published between 1984 and April 2026. The analysis aimed to identify publication trends, disciplinary distributions, and research development patterns within scientific argumentation research, particularly those relevant to the integration of ethnoscience and culturally grounded knowledge in science education.



Source: Scopus Database

Figure 2. Number of Scientific Argumentation Publications (1984–2026)

Figure 2 illustrates the annual publication trend of scientific argumentation research over a period of more than four decades. The results reveal a substantial increase in research output, particularly after 2015. During the early period between 1984 and 2000, publication activity remained relatively low and stable, with only a few articles published annually. This finding indicates that scientific argumentation had not yet become a prominent area of inquiry within science education research. A gradual increase emerged between 2001 and 2014, reflecting growing scholarly interest in argumentation as an instructional approach for developing scientific reasoning, inquiry skills, and critical thinking. During this phase, researchers increasingly explored the role of evidence,

reasoning, and classroom discourse in science learning. The expansion of research during this period contributed to the establishment of scientific argumentation as a recognized field within science education. The most significant growth occurred between 2015 and 2026. Annual publication output increased sharply, reaching its highest point in 2025 with 38 publications. This rapid growth demonstrates the increasing importance of scientific argumentation in contemporary science education research. The trend also reflects broader educational reforms emphasizing evidence-based reasoning, scientific literacy, and student-centered learning approaches. The publication trajectory suggests that scientific argumentation has evolved from a relatively specialized research topic into a major area of educational inquiry. The sustained increase in publication output indicates continued scholarly interest in understanding how learners construct, evaluate, and communicate scientific knowledge through argumentation processes. Furthermore, the growth pattern provides evidence of expanding research themes within the field. While early studies primarily focused on classroom discourse and inquiry-based learning, more recent research increasingly addresses socio-scientific issues, digital learning environments, artificial intelligence-supported argumentation, teacher professional development, and culturally responsive science education. These developments indicate a diversification of research interests and a broadening conceptualization of scientific argumentation in educational contexts. To further understand the disciplinary foundations of scientific argumentation research, an analysis of subject-area distribution was conducted using the Scopus classification system. This analysis provides insights into the academic disciplines that contribute to the development of the field and reveals the dominant perspectives shaping scientific argumentation research. Examining subject-area distribution is important for identifying the intellectual orientation of the field and understanding the extent to which scientific argumentation research has expanded across different domains of knowledge.

Figure 3 illustrates the disciplinary distribution of scientific argumentation research indexed in the Scopus database. The distribution provides an overview of the academic fields that have contributed to the development of scientific argumentation research and highlights the dominant disciplinary perspectives shaping the field. The findings reveal that scientific argumentation has evolved as an interdisciplinary area of inquiry, although its development remains concentrated within specific subject domains.

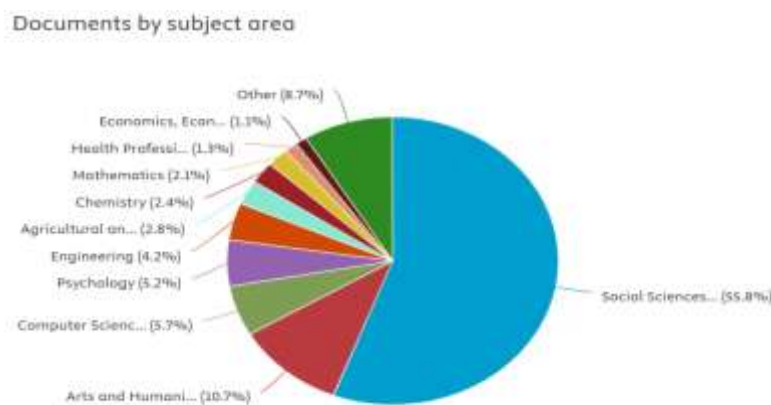


Figure 3. Distribution of Scientific Argumentation Research by Subject Area

The findings indicate that Social Sciences dominate the field, accounting for 55.8% of all publications. This is followed by Arts and Humanities (10.7%), Computer Science (5.7%), Psychology (5.2%), Engineering (4.2%), Agricultural and Biological Sciences (2.8%), Chemistry (2.4%), Mathematics (2.1%), Health Professions (1.3%), and Economics, Econometrics and Finance (1.1%). The remaining 8.7% are distributed across various other disciplines. The dominance of Social Sciences demonstrates that scientific argumentation research has primarily developed within educational and pedagogical contexts. Most studies focus on classroom instruction, inquiry-based learning, scientific literacy, reasoning skills, and strategies designed to improve students' argumentative competence. This finding suggests that scientific argumentation is widely viewed as a mechanism for supporting learning processes and facilitating the construction of scientific knowledge in educational settings. The contribution of Arts and Humanities reflects growing scholarly attention to language, discourse, communication, and sociocultural dimensions of argumentation. This trend indicates that researchers increasingly recognize argumentation as a social practice involving the negotiation of meaning, interpretation of evidence, and communication of knowledge. Such perspectives enrich the field by extending its focus beyond cognitive

outcomes toward broader cultural and communicative processes. The presence of Computer Science and Engineering highlights the increasing role of technology in supporting scientific argumentation. Recent studies have explored digital learning environments, online discussions, artificial intelligence-assisted learning systems, and collaborative platforms designed to facilitate evidence-based reasoning. These developments demonstrate the expanding influence of educational technology on the design and implementation of argumentation-based learning. Psychology contributes to understanding the cognitive mechanisms underlying argumentation, including reasoning, decision-making, conceptual change, and metacognitive processes. Together, these disciplinary contributions indicate that scientific argumentation research draws upon multiple perspectives to explain how learners construct, evaluate, and justify knowledge claims.

From an epistemic perspective, the subject-area distribution reveals that the field remains largely grounded in educational, cognitive, and communicative traditions. Disciplines specifically associated with indigenous knowledge systems, local wisdom, cultural epistemologies, or ethno-science are less visible within the overall publication landscape. This pattern suggests that the dominant intellectual structure of scientific argumentation research continues to be shaped by formal scientific and educational perspectives. Consequently, ethno-science and other culturally grounded knowledge systems occupy a relatively peripheral position within the broader research field. Overall, the subject-area distribution demonstrates that scientific argumentation has evolved into a multidisciplinary field with strong foundations in education and social sciences. At the same time, the limited representation of disciplines closely associated with local and indigenous knowledge highlights opportunities for future research to broaden the epistemic scope of scientific argumentation and strengthen the integration of diverse knowledge traditions in science education.

Overall, the subject-area distribution demonstrates that scientific argumentation research has evolved as a multidisciplinary field with strong foundations in education and social sciences. The growing contributions from fields such as Computer Science, Psychology, and Engineering indicate an expansion of research interests beyond traditional classroom-based studies toward technology-enhanced learning, cognitive processes, and interdisciplinary educational innovation. This disciplinary diversity reflects the increasing complexity of scientific argumentation research and highlights its growing relevance across multiple domains of science education.

To further understand the development patterns of scientific argumentation research, an analysis of geographical distribution was conducted. Examining publication productivity by country provides insights into the global expansion of the field and identifies regions that contribute most significantly to the development of scientific argumentation scholarship.

### Documents by country or territory

Compare the document counts for up to 15 countries/territories.

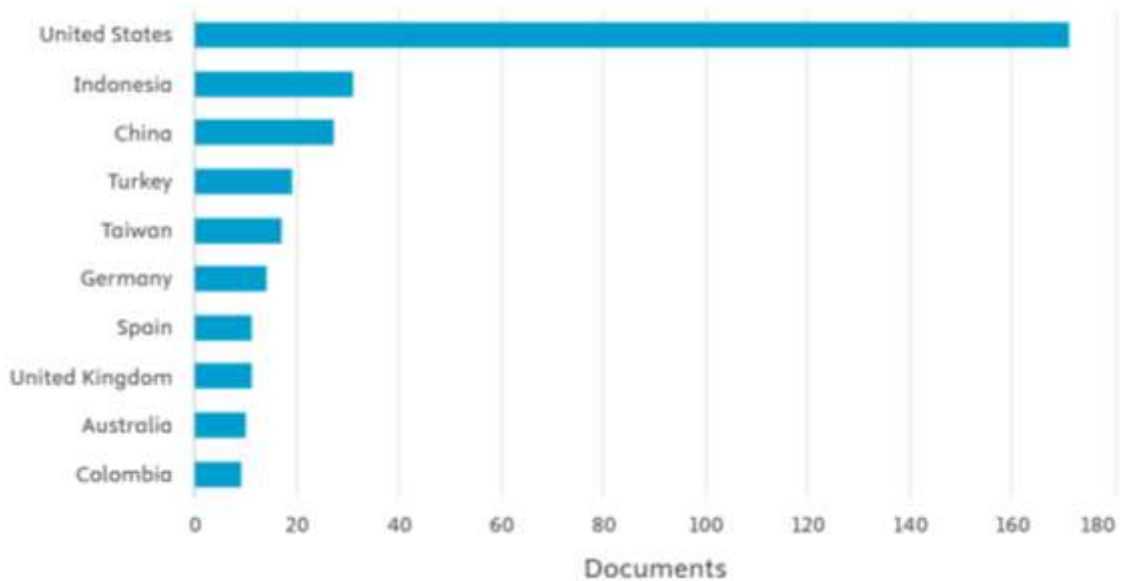


Figure 4. Distribution of Scientific Argumentation Research by Country/Territory

Figure 4 shows that scientific argumentation research has expanded across multiple regions of the world, although publication productivity remains unevenly distributed. The United States emerged as the most productive country with 171 publications, followed by Indonesia (31), China (27), Turkey (19), Taiwan (17), Germany (14), Spain (11), the United Kingdom (11), and Australia (10). Several emerging contributors, including Colombia, Malaysia, Thailand, and Brazil, also participated in the development of the field, albeit with lower publication outputs. The distribution indicates that scientific argumentation research is no longer concentrated exclusively within traditional research-intensive countries. The increasing contributions from Asian, Latin American, and other developing countries suggest a broader internationalization of the field. This trend reflects growing interest in argumentation-based science learning across diverse educational systems and cultural contexts. Nevertheless, the concentration of publications within a limited number of countries indicates that research productivity remains influenced by differences in research capacity, funding opportunities, and access to international publication channels. The findings suggest that while scientific argumentation has become a global research topic, its development continues to be driven primarily by countries with established research infrastructures. Beyond publication productivity, international collaboration plays an important role in shaping the development of a research field. Therefore, a country collaboration network analysis was conducted to identify patterns of cooperation and knowledge exchange among countries contributing to scientific argumentation research.

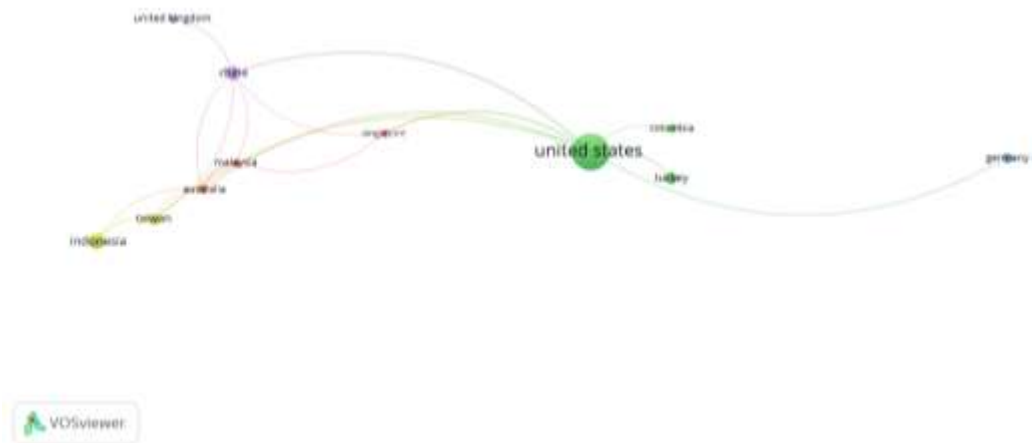


Figure 5. Network Country Visualization

Figure 5 presents the international collaboration network among countries involved in scientific argumentation research. The visualization reveals that the United States occupies the most central position within the network and maintains collaborative relationships with many major contributing countries, including Indonesia, China, Turkey, Germany, Australia, and the United Kingdom. This finding highlights the significant role of the United States in facilitating international research collaboration within the field. Several regional collaboration clusters are also visible. Countries such as Indonesia, Malaysia, Singapore, and Australia form a closely connected network, indicating active collaboration within the Asia-Pacific region. Similarly, European countries demonstrate strong collaborative relationships that contribute to the exchange of ideas and research practices across national boundaries. The network structure suggests that the development of scientific argumentation research is increasingly supported by international cooperation. The emergence of countries such as Indonesia, China, and Turkey as active participants in collaborative networks indicates that research leadership is becoming more geographically diverse. However, collaboration among developing countries remains relatively limited compared with connections involving major research-producing nations. Overall, the country collaboration network demonstrates that scientific argumentation research has developed through increasingly interconnected international partnerships. These collaborative relationships facilitate the dissemination of knowledge, promote methodological innovation, and contribute to the global growth of the field.

RQ2 : “How are scientific knowledge, indigenous knowledge, local knowledge, and heritage-based knowledge positioned and legitimized within elementary scientific argumentation research?”

Although Research Question 1 has revealed the publication trends, disciplinary distributions, and global development patterns of scientific argumentation research, these findings do not fully explain how different knowledge domains are represented within the intellectual structure of the field. Understanding publication growth and geographical expansion provides important contextual information; however, it offers limited insight into the conceptual relationships that shape research priorities and thematic development. Therefore, the next stage of analysis focuses on the thematic structure of the literature through keyword co-occurrence mapping. This analysis was conducted using VOSviewer to identify dominant research themes, conceptual connections among topics, and the broader intellectual landscape of scientific argumentation research. The resulting network provides a foundation for examining the relative visibility of scientific, local, indigenous, and heritage-based knowledge within the field.

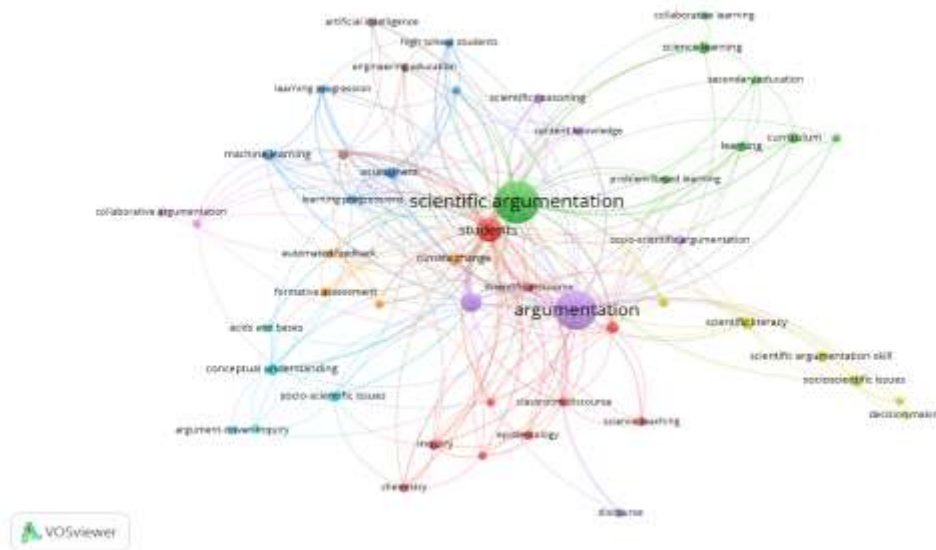


Figure 6. Co-occurrence Framework and Representation of Key Terms

Figure 6 presents the co-occurrence network of keywords generated using VOSviewer. The visualization reveals that the conceptual structure of scientific argumentation research is organized around three highly connected nodes, namely scientific argumentation, argumentation, and students. These keywords occupy the central positions within the network and demonstrate the highest levels of connectivity with other concepts. Their prominence indicates that scientific argumentation research has primarily developed within educational settings, where argumentation is examined as a learning process and students serve as the main subjects of investigation. The network visualization also reveals several interconnected thematic clusters that characterize the development of the field. The largest cluster, centered on scientific argumentation, is closely associated with learning, curriculum, science learning, collaborative learning, secondary education, and problem-based learning. This cluster suggests that scientific argumentation is predominantly studied as a pedagogical approach designed to enhance students' understanding of scientific concepts and support the development of reasoning skills. The strong connections among these keywords indicate that classroom implementation remains one of the most influential themes in the literature. A second cluster is associated with reasoning and epistemic processes, represented by keywords such as scientific reasoning, content knowledge, scientific discourse, epistemology, inquiry, and classroom discourse. The presence of these concepts demonstrates that researchers increasingly view argumentation as a mechanism through which scientific knowledge is constructed, justified, and evaluated. This cluster highlights the growing interest in understanding the relationship between evidence, reasoning, and knowledge construction within science education.

Another prominent cluster relates to socio-scientific and decision-making contexts. Keywords such as socio-scientific issues, scientific literacy, scientific argumentation skill, and decision making appear closely connected within the network. This pattern indicates that argumentation is frequently employed to support students in addressing complex real-world problems that require evidence-based judgments and informed decision-making. The integration of socio-scientific issues reflects the increasing emphasis on preparing learners to engage with contemporary scientific and societal challenges. The network also reveals an emerging technology-oriented cluster characterized by keywords such as artificial intelligence, machine learning, automated feedback, learning progression, assessment, and engineering education. The appearance of these concepts suggests that scientific argumentation research has expanded into digital learning environments and technology-enhanced educational contexts. Recent studies increasingly investigate how intelligent systems, online platforms, and automated feedback mechanisms can support students' argumentative practices and scientific reasoning.

In addition, a smaller cluster includes concepts related to collaborative argumentation, argument-driven inquiry, conceptual understanding, and climate change. These themes indicate continuing efforts to connect argumentation with inquiry-based learning and authentic scientific problems. The presence of climate change and socio-scientific issues demonstrates that argumentation is increasingly applied within contexts that require students to evaluate competing claims and evidence from multiple perspectives. Overall, the co-occurrence network demonstrates that scientific argumentation research has evolved into a multidisciplinary and interconnected field characterized by four major thematic orientations: pedagogical practices, epistemic and reasoning processes, socio-scientific applications, and technology-enhanced learning. The centrality of concepts such as scientific argumentation, argumentation, students, learning, and scientific reasoning indicates that research development continues to be strongly grounded in educational and cognitive perspectives. At the same time, the emergence of themes related to artificial intelligence, collaborative learning, and socio-scientific issues reflects the diversification of research interests and the expanding scope of scientific argumentation studies in contemporary science education.

While the bibliometric analysis presented in Research Question 1 revealed the thematic development and intellectual landscape of scientific argumentation research, it did not fully explain how different forms of knowledge are represented and legitimized within the literature. Understanding publication trends and thematic structures provides valuable insights into the evolution of the field, yet it offers limited evidence regarding the epistemic status of scientific, local, indigenous, and heritage-based knowledge in argumentative practices. Therefore, a deeper qualitative analysis was conducted to examine how knowledge sources are positioned within scientific argumentation research and the extent to which they are recognized as legitimate foundations for constructing claims, evidence, and reasoning.

To address this question, a full-text review was conducted on 20 articles selected through the eligibility process. The analysis employed thematic coding based on five analytical dimensions: dominant knowledge sources, the role of local and ethnoscientific knowledge, argumentative function, epistemic position, and epistemic legitimacy. These dimensions were used to identify recurring patterns in how knowledge is constructed, represented, and validated within elementary scientific argumentation research. The results of the coding process are summarized in Table 1.

Table 1. Epistemic Positioning of Knowledge Sources in Scientific Argumentation Research

Author (Year)	Dominant Knowledge Source	Role of Local/Ethnoscientific Knowledge	Function in Argumentation	Epistemic Position	Epistemic Legitimacy
Ozden (2020)	Scientific knowledge, intuition, emotion	Absent	Logical and intuitive reasoning	Experiential knowledge	Moderate
Mangiante (2013)	Scientific knowledge, teacher scaffolding	Absent	Evidence-based explanation	Pedagogical support	Moderate
Tobin et al. (2026)	Scientific modeling	Absent	Model-based claims	Scientific epistemic authority	High
Ozdem et al. (2013)	Scientific knowledge	Absent	Laboratory argument schema	Scientific epistemic authority	High
Saracaloglu et al. (2011)	Scientific training	Absent	Quality of written argument	Pedagogical support	Moderate

<b>Evagorou et al. (2020)</b>	Scientific modeling	Absent	Model-based rebuttal	Scientific epistemic authority	High
<b>Caño &amp; Sanz (2025)</b>	Scientific knowledge, prior knowledge	Indirect	Experimental data use	Experiential knowledge	Moderate
<b>Mikeska et al. (2022)</b>	Teacher scaffolding	Absent	Facilitation of argumentation	Pedagogical support	Moderate
<b>Manz (2016)</b>	Scientific classroom community	Absent	Transformation of observations into evidence	Scientific epistemic authority	High
<b>Chen (2020)</b>	Scientific knowledge, teacher scaffolding	Absent	Negotiation of authority	Shared epistemic authority	High
<b>Cullicott &amp; Chen (2018)</b>	Scientific dialogic teaching	Absent	Social negotiation of argument	Pedagogical support	Moderate
<b>Mikeska et al. (2023)</b>	Teacher scaffolding	Absent	Practice facilitation	Pedagogical support	Moderate
<b>Wilson et al. (2024)</b>	Scientific knowledge, machine learning	Absent	Automated modeling	Scientific epistemic authority	High
<b>Governor et al. (2025)</b>	Scientific evidence and models	Absent	Consensus negotiation	Scientific epistemic authority	High
<b>Lestari et al. (2024a)</b>	Scientific inquiry	Absent	Science literacy argumentation	Scientific epistemic authority	High
<b>Lestari et al. (2024b)</b>	Scientific inquiry	Absent	Scientific argument skills	Scientific epistemic authority	High
<b>Haudek &amp; Zhai (2024)</b>	Scientific knowledge, machine learning	Absent	Automated evaluation	Scientific epistemic authority	High
<b>Liu et al. (2024)</b>	Scientific knowledge (ADI framework)	Contextual adaptation	Cultural adaptation of model	Local knowledge as epistemic contributor	Moderate
<b>Viehmman et al. (2024)</b>	Scientific knowledge, SSI	Illustrative example	Contextualization	Peripheral knowledge	Moderate
<b>Muslu &amp; Isik (2024)</b>	Place-based knowledge	Contextual learning	Perspective-taking argumentation	Local knowledge as epistemic contributor	Moderate

The findings presented in Table 1 reveal a consistent pattern regarding the positioning and legitimacy of knowledge sources within scientific argumentation research. Across the reviewed studies, scientific knowledge emerged as the dominant epistemic foundation for argument construction. Scientific concepts, empirical evidence, scientific models, inquiry processes, and teacher-guided reasoning were consistently employed as the primary references for developing and evaluating arguments. This pattern indicates that scientific argumentation research remains strongly anchored in the epistemological traditions of modern science, where knowledge validity is primarily determined through empirical verification, logical coherence, and disciplinary standards. A notable finding concerns the limited representation of local, indigenous, and heritage-based knowledge within the reviewed literature. Most studies did not explicitly incorporate ethnoscience or culturally grounded knowledge into argumentative activities. When local knowledge was included, it generally functioned as contextual support, cultural illustration, or place-based learning content rather than as an independent source of evidence. This suggests that local knowledge is commonly positioned as a pedagogical resource that enhances relevance and engagement but rarely contributes to the epistemic validation of scientific claims.

The findings further demonstrate that students' experiential knowledge occupies an intermediate position within the epistemic structure of scientific argumentation. Several studies acknowledged the importance of prior experiences, observations, and intuitive understandings as starting points for argument construction. However, experiential knowledge typically required transformation into scientifically acceptable forms of evidence before it could be recognized as valid within classroom discourse. Consequently, learners' experiences functioned as preliminary resources that support reasoning processes rather than as autonomous epistemic authorities. Another important pattern emerging from Table 1 is the dominance of scientific epistemic authority across educational contexts. Whether the studies focused on elementary students, preservice teachers, or secondary education participants, the criteria used to evaluate argument quality remained largely consistent. Scientific evidence, conceptual accuracy, model based reasoning, and disciplinary explanations served as the primary standards for determining the strength and validity of arguments. Even in studies employing socio-scientific issues, contextual learning, or place-based approaches, scientific knowledge retained its central role in validating knowledge claims.

From an epistemic perspective, these findings reveal the existence of a hierarchical structure of knowledge legitimacy within scientific argumentation research. Scientific knowledge occupies the central

position of epistemic authority, experiential knowledge functions as a supporting layer, and local, indigenous, and heritage-based knowledge remain peripheral. This hierarchy influences not only which forms of knowledge are considered valid but also how students are encouraged to construct and justify their arguments. As a result, the literature tends to privilege scientific ways of knowing while providing limited opportunities for alternative knowledge traditions to participate in the construction of evidence and reasoning.

The asymmetrical positioning of knowledge sources identified in this review suggests that the integration of ethnoscience into scientific argumentation remains largely pedagogical rather than epistemological. Local knowledge is frequently used to contextualize learning experiences but rarely receives recognition as a legitimate contributor to knowledge production. Consequently, the current literature reflects an epistemic structure in which scientific knowledge functions as the dominant authority, while culturally grounded knowledge systems occupy supporting roles. This pattern provides important insights into the intellectual organization of the field and highlights the need for more inclusive approaches that recognize multiple forms of knowledge as potential contributors to scientific argumentation. Taken together, the findings suggest the emergence of an epistemic hierarchy of knowledge sources within scientific argumentation research. This hierarchy is characterized by the dominance of scientific knowledge, the conditional acceptance of experiential knowledge, and the marginal positioning of local and indigenous knowledge. Understanding this structure is essential for identifying the epistemic gaps that continue to shape the relationship between scientific argumentation and ethnoscience, which are examined further in the next section.

*RQ3. What Epistemic Gaps Emerge in the Integration of Ethnoscience, Heritage-Based Knowledge, and Scientific Argumentation Research?*

The findings presented in Table 1 reveal a persistent asymmetry in the positioning and legitimacy of knowledge sources within scientific argumentation research. To further understand the implications of this epistemic structure, the final stage of analysis examined the gaps emerging from the relationship between scientific knowledge, local knowledge, indigenous knowledge, and heritage-based knowledge. The analysis focused on identifying patterns of exclusion, unequal legitimacy, and structural limitations that influence the integration of ethnoscience within scientific argumentation research.

Table 2. Epistemic Gaps Identified in Scientific Argumentation Research

<b>Epistemic Gap</b>	<b>Description</b>	<b>Evidence from the Literature</b>
<b>Legitimacy Gap</b>	Scientific knowledge serves as the primary criterion for validating arguments.	Most studies relied on scientific concepts, empirical evidence, and disciplinary reasoning as the dominant standards of validity.
<b>Representation Gap</b>	Local and indigenous knowledge appear infrequently in argumentation research.	Ethnoscience and heritage-based knowledge were rarely included as central research themes.
<b>Authority Gap</b>	Scientific actors and institutions function as primary knowledge authorities.	Teachers, scientific models, and scientific evidence dominated the validation process.
<b>Integration Gap</b>	Local knowledge is commonly used as context rather than evidence.	Ethnoscience was primarily employed for contextualization and engagement.
<b>Participation Gap</b>	Local communities and cultural knowledge holders play limited roles in knowledge construction.	Most studies focused on students and teachers within formal educational settings.

The first gap identified in the reviewed literature is a legitimacy gap. Scientific knowledge consistently functions as the dominant criterion for determining the quality and validity of arguments. Across the reviewed studies, evidence derived from scientific concepts, empirical observations, and disciplinary reasoning receives the highest level of acceptance. Consequently, alternative forms of knowledge rarely obtain equivalent recognition within argumentative practices. The second gap concerns representation. Although the reviewed literature demonstrates substantial growth in scientific argumentation research, local, indigenous, and heritage-based knowledge remain largely absent from the dominant research agenda. The limited visibility of these knowledge traditions suggests that the expansion of scientific argumentation research has not been accompanied by a comparable diversification of epistemic perspectives. A third gap emerges in relation to epistemic authority. The findings indicate that teachers, scientific models, disciplinary concepts, and scientific evidence function as the principal authorities responsible for validating knowledge claims. In contrast, local communities, cultural practitioners, and indigenous knowledge holders rarely participate in determining what constitutes acceptable evidence within scientific argumentation.

The fourth gap involves the integration of ethnoscience within argumentation research. When local knowledge is incorporated into learning activities, it generally serves a contextual or motivational function. Its contribution to claim construction, evidence generation, and argument evaluation remains limited. This pattern indicates that ethnoscience has been integrated pedagogically but has not yet been fully integrated epistemologically. The final gap concerns participation in knowledge production. Most studies conceptualize students as learners who engage with scientific knowledge rather than as participants who negotiate among multiple knowledge traditions. As a result, opportunities for epistemic dialogue between scientific knowledge and culturally grounded knowledge remain restricted. The identified epistemic gaps are consistent with recent developments in science education research that emphasize the central role of epistemic criteria in knowledge construction and evaluation. Shtechman et al. (2025) found that elementary school students increasingly rely on mechanistic explanations when constructing biological arguments and employ epistemic criteria such as coherence, causal adequacy, and explanatory power to evaluate competing claims. Their findings demonstrate that scientific argumentation is fundamentally linked to the establishment of epistemic standards that determine what counts as acceptable knowledge. The present study extends this perspective by showing that while scientific criteria are strongly represented in the literature, alternative knowledge systems such as ethnoscience and heritage-based knowledge rarely participate in shaping these standards. Consequently, epistemic evaluation within scientific argumentation research remains largely confined to formal scientific frameworks.

The dominance of scientific epistemic authority identified in this review also aligns with the findings of Küçükaydın and Ayaz (2025), who demonstrated significant relationships between scientific reasoning competencies, epistemological beliefs, and analytical thinking. Their study suggests that successful argumentation is frequently associated with scientifically oriented epistemological beliefs that privilege evidence-based reasoning and analytical evaluation. Although such competencies are essential for science learning, the current review indicates that they are commonly operationalized through formal scientific knowledge alone. This tendency may inadvertently restrict opportunities for students to engage with alternative epistemic traditions that possess their own criteria of credibility and justification. A similar pattern emerges when viewed through the lens of epistemic network analysis. Reid et al. (2025) reported that science education research increasingly conceptualizes learning as a network of interconnected epistemic practices involving evidence, reasoning, explanation, and disciplinary discourse. Their review highlighted the complexity of relationships among cognitive, social, and epistemic dimensions of learning. However, the present findings suggest that these networks are predominantly organized around scientific epistemologies. Local knowledge, indigenous perspectives, and heritage-based knowledge remain weakly connected to the dominant conceptual structures of scientific argumentation research, resulting in limited epistemic integration despite growing recognition of cultural diversity in science education.

The authority gap identified in this study can also be interpreted through broader epistemological perspectives. Flores (2025) argues that knowledge evaluation is influenced not only by evidence and reasoning but also by social and political mechanisms that shape whose knowledge is considered credible and worthy of acceptance. From this perspective, the marginal position of ethnoscience within scientific argumentation research cannot be understood solely as a methodological issue. Rather, it reflects broader patterns of epistemic recognition in which particular forms of knowledge are systematically privileged while others remain peripheral. The findings of the present study provide empirical support for this argument by demonstrating that scientific knowledge consistently occupies the highest position of legitimacy, whereas local and heritage-based knowledge are primarily assigned contextual functions. Taken together, these comparisons indicate that contemporary scientific argumentation research has achieved considerable sophistication in understanding reasoning, evidence evaluation, and epistemic cognition. Nevertheless, the literature continues to exhibit a relatively narrow conception of epistemic legitimacy. The five epistemic gaps identified in this review suggest that future research should move beyond improving students' argumentation skills within existing scientific frameworks and begin exploring how multiple knowledge systems can participate in the construction, justification, and evaluation of scientific arguments. Such a shift would contribute to a more pluralistic model of science education in which scientific knowledge and culturally grounded knowledge are positioned as complementary rather than hierarchical sources of understanding.

#### 4. CONCLUSION

This study examined the intellectual development, thematic structure, and epistemic configuration of ethnoscience and scientific argumentation research through a hybrid bibliometric and systematic review approach. The findings revealed a substantial increase in scientific argumentation research over the past four decades, accompanied by thematic diversification across pedagogical, epistemic, socio-scientific, and technology-enhanced learning domains. The field has evolved into a multidisciplinary area of inquiry strongly influenced by educational, cognitive, and communicative perspectives. Beyond mapping research trends, this study identified a persistent asymmetry in the positioning and legitimacy of knowledge sources within scientific argumentation research. Scientific knowledge consistently occupies the central position of epistemic authority, serving as the primary basis for validating claims, evidence, and reasoning. In contrast, local, indigenous, and heritage-based knowledge are predominantly positioned as contextual resources that support engagement and relevance but rarely function as legitimate sources of evidence within argumentative practices. These findings indicate that the integration of ethnoscience in scientific argumentation remains largely pedagogical rather than epistemological. The study further identified five interrelated epistemic gaps, namely legitimacy gaps, representation gaps, authority gaps, integration gaps, and participation gaps. Collectively, these gaps reveal the existence of an epistemic hierarchy in which scientific knowledge occupies a dominant position while culturally grounded knowledge systems remain peripheral. Based on these findings, this study contributes a conceptual understanding of the epistemic structure underlying scientific argumentation research and highlights the need for more inclusive approaches to knowledge construction in science education. Theoretically, this study extends the literature on scientific argumentation by demonstrating how knowledge legitimacy is distributed across different knowledge systems and by introducing the concept of an epistemic hierarchy of knowledge sources. Practically, the findings provide implications for curriculum development, science instruction, and teacher education by encouraging the incorporation of culturally grounded knowledge into argumentative practices as epistemically meaningful resources rather than merely contextual learning tools. Future research should develop and empirically test argumentation models that integrate scientific knowledge, ethnoscience, indigenous knowledge, and heritage-based knowledge within a shared epistemic framework. Further studies may also explore how students negotiate multiple knowledge traditions during argument construction and how epistemic pluralism can be fostered within science classrooms to support more inclusive and culturally responsive science education..

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