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SCIENTIFIC DECISION-MAKING IN SCIENCE EDUCATION: A SYSTEMATIC LITERATURE REVIEW OF TRENDS, RESEARCH GAPS, AND LEARNING IMPLICATIONS

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ABSTRACT

Scientific decision-making is an essential competence in science education, particularly for addressing complex real-world problems requiring evidence-based reasoning. However, although related constructs such as socioscientific issues, scientific reasoning, and argumentation are widely examined, scientific decision-making is often embedded within these constructs rather than examined as a distinct competency. This fragmentation makes it difficult to understand how scientific decision-making is conceptualized, developed, and assessed. This study aims to analyze research trends, dominant themes, research gaps, and learning implications of scientific decision-making in science education. A systematic literature review was conducted using articles published between 2021 and 2025, retrieved from Scopus on March 8, 2026, using the search query TITLE-ABS-KEY ("scientific decision making" AND "science education"). The inclusion criteria focused on peer-reviewed Scopus-indexed articles addressing scientific decision-making in science education and available in full text. Fourteen articles were selected through a focused search targeting scientific decision-making in science education and analyzed using qualitative synthesis supported by bibliometric visualization. Given the limited dataset, the findings are interpreted as indicative of emerging research patterns rather than comprehensive evidence. Findings show that research on scientific decision-making remains limited and fragmented, with studies embedding it within socioscientific issues, scientific reasoning, and argumentation rather than examining it as a distinct construct. Quantitative approaches dominate, and research is concentrated at primary and secondary education levels. These findings indicate a need for integrated conceptual frameworks, process-oriented research approaches, and explicit integration of scientific decision-making in learning design and assessment.

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1. INTRODUCTION

Science education plays an important role in equipping students not only to understand scientific concepts, but also to use such knowledge to make rational and evidence-based decisions.

The ability of scientific decision-making has become increasingly crucial in the context of the 21st century, where individuals are confronted with various complex issues such as climate change, health, and environmental sustainability, which require evidence-based argumentation and scientific reasoning within the context of socioscientific issues (Forsythe & Chan, 2025). Therefore, science education needs to develop students' abilities to evaluate information, consider alternatives, and make decisions based on scientific evidence. However, students still experience difficulties in applying scientific knowledge to analyze real-world problems and make evidence-based decisions. This is largely due to learning practices that remain oriented toward conceptual mastery and memorization, thereby failing to sufficiently promote higher-order thinking skills such as scientific reasoning and evidence evaluation (OECD, 2023). This condition indicates a gap between the goals of scientific literacy and classroom practices.

In the science education literature, scientific decision-making is closely related to socioscientific issues (SSI), scientific reasoning, and argumentation but these concepts represent different roles in the decision-making process. SSI primarily provides an authentic context in which students encounter complex scientific problems involving social and ethical considerations (Viehmann et al., 2024), and connect scientific concepts with real-life problems (Qalfin et al., 2024). Meanwhile, scientific reasoning and argumentation support the evaluation of evidence and the logical justification of decisions (Vázquez-Bernal & Jiménez-Pérez, 2023). Scientific reasoning involves evaluating evidence, interpreting information, and drawing logical conclusions (Bailey et al., 2022), whereas argumentation involves constructing and justifying claims based on evidence (Kahraman & Kaya, 2021). Scientific decision-making, in contrast, involves integrating scientific knowledge, evaluating evidence, considering alternative options and their potential consequences, and selecting and justifying an appropriate course of action (Dauer et al., 2025). Thus, scientific reasoning and argumentation function as important processes that support scientific decision-making, while SSI serves as a context in which these processes can be applied.

Although previous studies have contributed to the understanding of decision-making and its related constructs, their focuses remain distinct. Dauer et al. (2025), for example, developed a framework for understanding students' decision-making practices in the context of socioscientific issues by identifying key components of structured decision-making and examining variations in students' proficiency. However, their study primarily focused on developing and empirically examining a conceptual framework rather than systematically mapping the broader development of scientific decision-making research. Similarly, Arifin et al. (2025), conducted a systematic and bibliometric analysis of socioscientific issues in sustainable science education, identifying publication trends, research themes, collaboration patterns, and research frontiers across the field. However, their analysis addressed SSI as a broad research domain rather than scientific decision-making as a distinct construct. Consequently, a comprehensive synthesis that specifically maps the trends, dominant themes, research gaps, and instructional implications of scientific decision-making in science education remains lacking.

Based on these considerations, there is a need for a systematic study that integrates the analysis of research trends, thematic mapping, identification of research gaps, and instructional implications within a unified framework. To address this gap, this study integrates a systematic literature review with bibliometric analysis to reveal the development, conceptual structure, and research directions of scientific decision-making more comprehensively. The novelty of this study lies in demonstrating that scientific decision-making has not yet been established as an

independent construct in science education. Although decision-making is addressed across studies involving socioscientific issues, scientific reasoning, and argumentation, it is often embedded within these related constructs rather than explicitly conceptualized, operationalized, and examined as an integrated competency. By synthesizing the existing literature, this study identifies this conceptual fragmentation and highlights the need to position scientific decision-making more explicitly within science education research and instructional design. This study aims to analyze research trends, dominant themes, research gaps, and instructional implications related to scientific decision-making in science education. Specifically, this study addresses the following research questions: (1) what are the research trends, (2) what are the dominant themes, (3) what are the research gaps, and (4) what are the implications for the development of research and science education practices. The answers to these research questions are expected to provide a more comprehensive understanding of the development of research in scientific decision-making and serve as a basis for future research and the advancement of science education practices.

2. METHOD

This study employed a Systematic Literature Review (SLR) approach to analyze the development of research on scientific decision-making in science education. This approach was selected because it enables the processes of identification, evaluation, and synthesis of literature to be conducted in a systematic, transparent, and replicable manner (Xiao & Watson, 2019). To support the analysis, this study also utilized a bibliometric approach to map the relationships among concepts and research trends. However, this study was not intended as a comprehensive bibliometric study, but rather as an SLR strengthened by data visualization.

The data were obtained from the Scopus database due to its broad coverage of reputable international journals and the availability of metadata that supports systematic analysis (Donthu et al., 2021). The literature search was conducted on March 8, 2026, using the keywords TITLE-ABS-KEY ("scientific decision making" AND "science education") with a publication range of 2021–2025, ensuring that the retrieved articles were directly relevant to the research topic.

To ensure the relevance of the analyzed articles, this study established inclusion and exclusion criteria based on the PRISMA guidelines (Page et al., 2021), as follows:

Table 1. Inclusion and exclusion criteria

Inclusion Criteria	Exclusion Criteria
Addressing scientific decision-making in the context of science education	Articles not relevant to the research topic
Indexed in Scopus	Articles not indexed in Scopus
Available in full text	Articles not available in full text

These criteria were applied to ensure that the analyzed articles were directly related to the research focus and met scientific quality standards.

In addition, a quality assessment was conducted to ensure the quality of the analyzed articles. The assessment was based on topic relevance, clarity of research objectives, methodological appropriateness, and contributions to the study of scientific decision-making (Page et al., 2021). Articles that did not meet these criteria were eliminated at the eligibility stage.

The use of Scopus also functioned as an initial quality filter due to its rigorous selection standards (Baas et al., 2020).

The article selection process followed the PRISMA stages, namely identification, screening, eligibility, and inclusion. The initial search yielded 81 articles without duplication. After title and abstract screening, 41 articles were excluded because they did not address scientific decision-making in science education or did not meet the predefined scope of the review. Subsequently, 40 articles were assessed through full-text review. Of these, 26 articles were excluded because they did not explicitly address scientific decision-making as a relevant construct, focused primarily on related but distinct constructs without a clear decision-making component, or did not meet the predetermined inclusion criteria. Finally, 14 articles met all eligibility criteria and were included as the research dataset. The selection process was conducted by the primary researcher and consulted with the academic supervisor to ensure consistency and minimize bias. The selection flow diagram is presented in Figure 1, which was prepared using the latest PRISMA 2020 template available on the official PRISMA website.

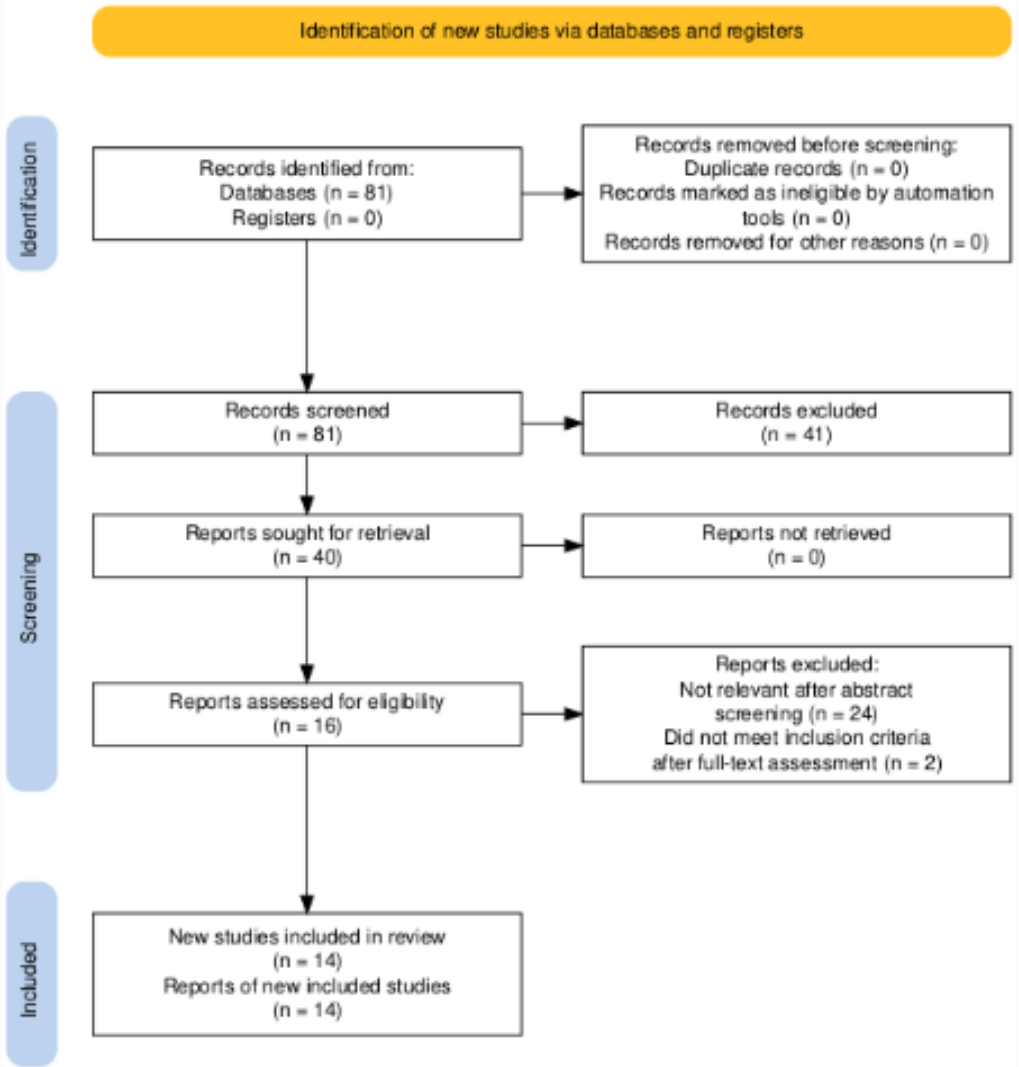


Figure 1. PRISMA flow diagram

The number of analyzed articles was relatively limited (n = 14), which is a consequence of the specific search strategy and strict selection criteria to ensure the relevance and quality of the

studies. This approach is consistent with the principles of SLR that emphasize quality over quantity, where studies are selected selectively based on specific criteria to ensure the relevance and credibility of the analyzed findings (Brignardello-Petersen et al., 2025). Therefore, this study is positioned as an exploratory review aimed at identifying trends, themes, and research gaps, rather than as a comprehensive bibliometric mapping. Data extraction was conducted systematically, including author and year of publication, research objectives, methods, main findings, and contributions to scientific decision-making. The data were then organized into a summary table to facilitate synthesis and comparison across studies. Data analysis was carried out using two approaches. First, qualitative analysis was used to identify research themes, instructional approaches, and the relationships among scientific decision-making, socioscientific issues, scientific reasoning, and argumentation, as well as to identify research gaps. Second, bibliometric analysis was used as a supporting approach with the assistance of VOSviewer and Biblioshiny software to map keyword co-occurrence and research trends. Given the limited dataset, bibliometric analysis was used as a supporting visualization, while the main interpretation was based on qualitative analysis.

3. RESULTS AND DISCUSSION

Fourteen articles that met the inclusion criteria were systematically analyzed to identify the characteristics of research on scientific decision-making in science learning. A summary of the extracted results is presented in Table 2, which provides an overview of the research focus, methodological design, and instructional approaches, while also presenting a synthesis of the analyzed studies, including authors and year of publication, research titles, and main findings, and serving as a basis for identifying patterns of novelty and trends in the contributions of each study within this field.

Table 2. Summary of Reviewed Articles

Author (Year)	Focus/Key Finding	Novelty & Contribution
(Kahraman & Kaya, 2021)	Dominance of rhetorical argumentation in science education studies	Thematic analysis of argumentation; recommends strengthening dialectical argumentation
(Marthaliakirana et al., 2022)	PBL with metacognitive prompts improves argumentation	Integration of metacognition in PBL to enhance thinking skills
(Alcaraz-Dominguez & Barajas, 2021)	SSI supports scientific literacy and inquiry-based learning	Conceptual framework of SSI in STEM education
(Klaver et al., 2024)	SSI improves students' attitudes, influenced by knowledge sources	Highlights the role of students' resources as a moderating factor
(Ottander & Simon, 2021)	SSI discussions shape students' social understanding	Discursive psychology approach in SSI
(Dauer et al., 2021)	Structured decision-making enhances civic engagement	Integration of decision-making frameworks in SSI

Author (Year)	Focus/Key Finding	Novelty & Contribution
(Takegami et al., 2025)	Virtual games improve scientific reasoning	Integration of immersive games for reasoning analysis
(Şenel Zor et al., 2023)	SSI scenarios elicit informal reasoning	Systematic development model of SSI scenarios
(Abate et al., 2024)	Reasoning develops through knowledge integration	MMSR model for assessing students' reasoning
(Bailey et al., 2022)	Scaffolding improves evidence evaluation	Comparative model of scientific argumentation scaffolding
(Henderson et al., 2025)	SSI topics influence emotions and learning	Narrative BioStories approach in SSI
(da Silva Fonseca & da Costa, 2025)	SSI integrates conceptual and attitudinal aspects	Analysis of SSI-based teaching sequences
(Chionas & Emvalotis, 2025)	ESRQ instrument is valid for measuring reasoning	Development of a multidimensional reasoning instrument
(Evagorou et al., 2023)	Written argumentation is challenging in counterargument construction	Framework for evaluating argumentation sub-skills

Table 2 shows that research on scientific decision-making in science education varies in terms of focus, approaches, and contributions; however, it is generally dominated by its integration with socioscientific issues, scientific reasoning, and argumentation. This variation in findings indicates that scientific decision-making has not yet developed as a unified construct, but rather remains fragmented across different research perspectives.

3.1. Research Trends of Scientific Decision-Making in Science Learning

As part of efforts to understand the development of scientific decision-making research in science education, analyzing research trends is essential to identify directions of development, research focus, and methodological tendencies used in previous studies. These trends not only provide a quantitative overview of research distribution, but also reflect how scientific decision-making is positioned within the framework of modern science education, particularly in relation to scientific literacy, issue-based learning, and 21st-century competencies (van Laar et al., 2019). Therefore, the discussion in this section focuses not only on data distribution but also on a critical interpretation of the implications of the identified patterns.

Table 3. Distribution of Publication Years

Year	Number of Articles
2021	4
2022	2
2023	2
2024	2
2025	4
Total	**14**

Based on the analysis of the reviewed articles, research on scientific decision-making in science learning shows an increasing trend in recent years. This increase indicates that scientific decision-making is gaining broader attention as an essential competency in science education, particularly in strengthening scientific literacy and higher-order thinking skills among students. However, despite the growing number of studies, this does not necessarily indicate that scientific decision-making has developed optimally from a conceptual and methodological perspective. On the contrary, this increase in quantity highlights the need for further analysis of how the construct of scientific decision-making is defined, integrated, and measured across studies, so that its development is not merely trend-driven but also grounded in strong theoretical and empirical foundations. This pattern suggests that the increasing attention to scientific decision-making has not yet been accompanied by a comparable consolidation of the construct across research contexts.

Table 4. Distribution by region

Region (Continent)	Country	Number of Studies
Asia	Turkey, Indonesia, Cyprus	4
Europe	Spain, the Netherlands, Sweden, Greece	4
America	United States, Colombia, Brazil	4
Africa	Ethiopia	1
Australia	Australia	1
Total		**14**

The dominance of research in certain regions indicates an imbalance in the distribution of scientific studies across regions, which may affect the generalizability of findings in a global context and reflects a gap in regional representation within science education research. This imbalance suggests that most findings may primarily represent the characteristics of educational systems, learning cultures, and educational policies in dominant regions, thereby limiting their applicability to more diverse global contexts. In this regard, social and cultural factors cannot be overlooked in scientific decision-making. Social and cultural contexts play a crucial role in the process of scientific decision-making in education, as students consider not only cognitive aspects but also values, norms, and social backgrounds when evaluating scientific issues (Ladachart & Ladachart, 2021). Therefore, the dominance of certain regions in research may constrain the understanding of how contextual variations influence students' evaluation of evidence and science-based decision-making. This suggests that scientific decision-making cannot be understood solely as a context-independent cognitive competency, as the evaluation of evidence and selection of decisions may also be shaped by the social, cultural, and educational contexts in which students learn.

Table 5. Distribution by educational level

Educational Level	Number of Studies
Primary School (Elementary)	6
Secondary School (Middle/High School)	6
Higher Education	1
Others/ Not specified	4
Total	**17***

Note: Multiple educational-level classifications were allowed because one article could address more than one educational level; therefore, the total number of classifications may exceed the 14 included articles.

The total number in Table 5 exceeding the number of analyzed articles (n = 14) indicates that some studies encompass multiple educational levels rather than focusing exclusively on a single level. The comparable representation of primary and secondary education, with six studies each, suggests that scientific decision-making is being investigated across different stages of schooling rather than being restricted to a particular educational level. This distribution indicates that the development of scientific decision-making is relevant across stages of science learning, although the limited representation of higher education suggests that its development and application beyond school contexts remain relatively underexplored.

At the school level, both primary and secondary education receive substantial attention, reflecting the relevance of scientific decision-making to students' development of evidence-based reasoning and evaluation of alternatives. As students encounter increasingly complex scientific and socioscientific problems, decision-making requires the integration of scientific knowledge, evidence evaluation, reasoning, and consideration of consequences (Dawson et al., 2024). Therefore, the relatively limited representation of higher education constitutes a contextual gap, as the development of scientific decision-making among university students and its application in more advanced science learning contexts remain insufficiently examined.

Table 6. Distribution of research design

Research Design	Number of Studies
Qualitative	3
Quantitative	6
Mixed Methods	1
Conceptual / Review / Model Development	4
Total	**14**

When linked to the distribution of research designs, the dominance of quantitative approaches in the analyzed studies indicates a tendency to emphasize outcomes rather than processes. This methodological tendency has theoretical implications because scientific decision-making involves not only the final choice but also the processes through which learners evaluate evidence, weigh alternatives, consider consequences, and justify their decisions. Although quantitative approaches provide a general overview of students' ability levels, they may not adequately capture these underlying cognitive and value-based processes.

Overall, the identified research trends indicate that scientific decision-making is gaining attention in science education, but its development remains uneven across geographical contexts, educational levels, and research approaches. The increasing number of publications suggests growing recognition of scientific decision-making as an important competency; however, the limited representation of some regions and higher education contexts indicates that current knowledge remains contextually concentrated. In addition, the dominance of quantitative research suggests that the field has primarily emphasized measurable outcomes, while the processes through which students evaluate evidence, consider alternatives, and justify decisions remain less

extensively explored. Taken together, these patterns indicate that research on scientific decision-making is still developing and requires greater conceptual, contextual, and methodological diversification to establish a more comprehensive understanding of the construct.

From a theoretical and educational perspective, these findings suggest that scientific decision-making should be positioned as an explicit learning outcome in science education rather than merely an implicit result of science instruction. Its assessment should also extend beyond final decision outcomes to examine the underlying processes of evidence evaluation, reasoning, consideration of alternatives, and justification. This requires more authentic and contextualized learning and assessment approaches that can capture the complexity of scientific decision-making within science education (Muliastrini, 2025).

3.2. Dominant Themes in Scientific Decision-Making Studies

To understand how scientific decision-making is examined in science education, it is important to identify the dominant themes emerging from the analyzed studies. Theme analysis not only categorizes research focuses but also reveals how scientific decision-making is conceptually positioned within the literature, whether as an independent competency or in relation to constructs such as socioscientific issues, scientific reasoning, and argumentation (Naeem et al., 2023). Therefore, this section focuses on the interconnections among themes and their implications for the conceptual development of scientific decision-making.

Table 7. Distribution of Research Themes

Research Theme	Number of Studies	Percentage (%)
Socioscientific issues (SSI)	8	57%
Scientific reasoning	4	29%
Argumentation	4	29%
Decision-Making	2	14%
Integration (more than one theme)	6	43%

Note: Multiple thematic classifications were allowed because one article could address more than one research theme; therefore, the total number of classifications may exceed the 14 included articles and percentages do not sum to 100%.

Table 7 shows that the research themes are distributed across multiple dimensions of scientific decision-making. The dominance of socioscientific issues (SSI), scientific reasoning, and argumentation, together with studies integrating more than one theme, indicates that scientific decision-making is closely interconnected with contextual, cognitive, and social dimensions of science learning. However, the distribution also indicates that these dimensions have not yet been consistently integrated into scientific decision-making as a clearly defined construct.

The dominance of socioscientific issues (SSI), identified in 8 studies (57%), indicates that scientific decision-making is predominantly examined within contextualized problems involving social and ethical dimensions. While this provides an authentic setting for decision-making, it may also blur the distinction between SSI as a learning context and scientific decision-making as a competency. Meanwhile, scientific reasoning and argumentation, each identified in 4 studies (29%), represent important processes for evaluating evidence and justifying decisions (Eriksen, 2022). The coexistence of these themes suggests that the literature recognizes several essential

components of scientific decision-making, but their relationships have not yet been consistently articulated within an integrated conceptual framework.

The 6 studies (43%) integrating more than one theme further support this interpretation. The combination of SSI, scientific reasoning, and argumentation suggests that scientific decision-making involves the interaction of context, cognitive processes, and justification rather than a single skill. However, when these components are examined without explicitly defining their respective roles within the decision-making process, conceptual boundaries may remain unclear. Thus, the findings point to a need to position scientific decision-making as an explicit construct that integrates these dimensions while maintaining clear distinctions among them.

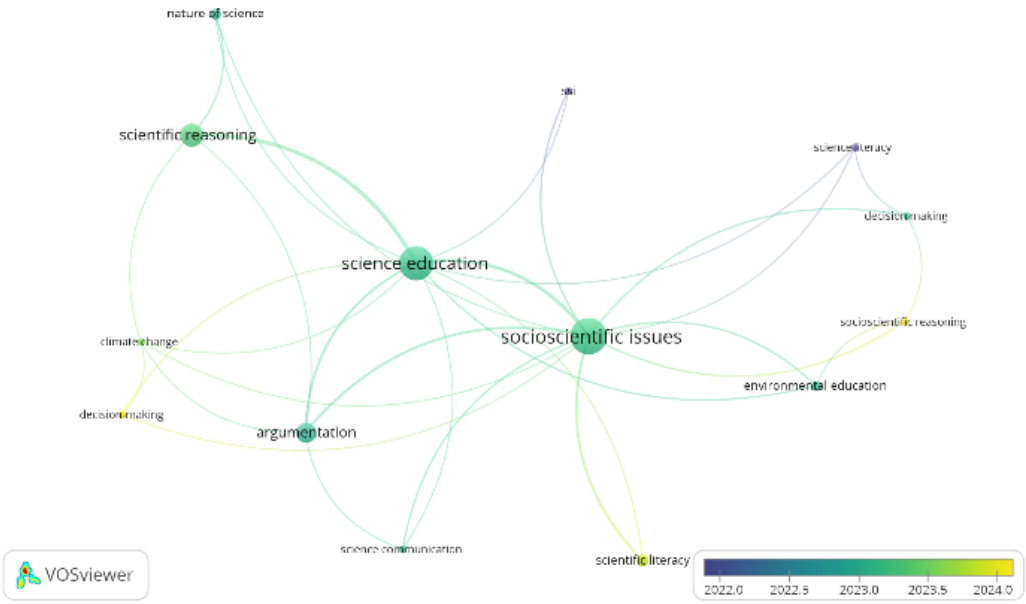


Figure 2. VOSviewer Analysis Results

The bibliometric visualization in Figure 2 reinforces this pattern by showing the close co-occurrence of scientific decision-making, socioscientific issues (SSI), scientific reasoning, and argumentation. Rather than indicating that these concepts are equivalent, their co-occurrence suggests that they are frequently studied in relation to one another. This pattern strengthens the conceptual interpretation that SSI provides a contextual dimension, while scientific reasoning and argumentation support the processes involved in scientific decision-making. The findings therefore support the need for a more explicit conceptual framework that defines how these dimensions contribute to scientific decision-making.

Overall, the thematic analysis indicates that scientific decision-making is more often examined through its related contexts and supporting processes than as an explicitly defined competency. This conceptual pattern highlights the need to distinguish the roles of SSI, scientific reasoning, and argumentation while integrating them within a coherent framework of scientific decision-making. Such conceptual clarity is important for developing learning objectives and assessment approaches that capture not only decision outcomes but also the processes underlying evidence-based decisions. In the context of science education, this is essential because evidence-based decision-making is a key indicator of scientific literacy and students' readiness to address complex global issues (Sari et al., 2025).

3.3. Identified Research Gaps

Based on the synthesis of findings presented in Tables 3–7 and Figure 2, this study identifies several major gaps indicating that research on scientific decision-making in science education has not yet developed comprehensively. These gaps reflect not only the limited number of studies but also fundamental issues in how this concept is understood, investigated, and implemented. Identifying these gaps provides a basis for strengthening future research and educational practices.

3.3.1. Conceptual Gap: Fragmentation of the Scientific Decision-Making Construct

The primary gap lies in the lack of an identified integrated conceptual framework for scientific decision-making. Most studies position this concept as an implication of socioscientific issues, scientific reasoning, or argumentation, rather than as a primary construct with clearly defined dimensions and indicators. This indicates conceptual fragmentation that limits the development of scientific decision-making as a distinct field of study. Theoretically, this fragmentation may lead to inconsistencies in instructional design and assessment. Without a clear conceptual framework, scientific decision-making is difficult to define and measure consistently. Within the framework of scientific literacy, this ability integrates knowledge, reasoning, evidence evaluation, and value-based considerations in real-world contexts (Dawson et al., 2024). Therefore, future research needs to establish a more structured and operational conceptual model.

3.3.2. Methodological Gap: Dominance of Quantitative Approaches and Limited Exploration of Processes

The methodological gap is reflected in the dominance of quantitative approaches that primarily focus on outcomes. Most studies emphasize scores or relationships between variables, while the cognitive processes underlying scientific decision-making remain less explored. This tendency may reduce scientific decision-making to a final outcome rather than a complex process. Theoretically, scientific decision-making involves interactions among cognitive, social, and affective aspects (Morese & Palermo, 2025), while decisions in socioscientific issues are also influenced by values, emotions, and social considerations (Lacorte, 2024). Therefore, greater use of exploratory, qualitative, and mixed-method approaches is needed to capture the processes underlying scientific decision-making.

3.3.3. Contextual Gap: Regional and Educational Level Disparities

Another gap lies in the imbalance of research contexts, both geographically and across educational levels. Existing studies are concentrated in Asia, Europe, and America, while contributions from other regions remain limited. Research is also predominantly conducted at primary and secondary education levels, with relatively few studies at the higher education level. This contextual limitation may constrain understanding of how scientific decision-making develops across diverse social, cultural, and educational settings, as decision-making processes are influenced by contextual factors (Ladachart & Ladachart, 2021). Furthermore, the limited representation of higher education indicates that the development of this competency in more advanced learning contexts remains underexplored.

3.3.4. Assessment Gap: Limited Instruments for Measuring Scientific Decision-Making

The assessment gap concerns the limited availability of comprehensive instruments specifically designed to measure scientific decision-making. Although some studies have developed instruments for scientific reasoning or argumentation, fewer have addressed the decision-making process as a whole. Consequently, existing assessment approaches may capture only particular components rather than the full competency. In the context of 21st-century assessment, scientific decision-making should be evaluated through authentic approaches that capture not only final outcomes but also evidence evaluation and the thinking processes underlying decisions (Saidah & Muhid, 2025). Developing valid and reliable instruments is therefore essential for systematically assessing the development of this competency.

3.3.5. Gap in Integration with Curriculum and Instructional Practices

The final gap concerns the integration of scientific decision-making within curricula and instructional practices. Although many studies indicate that socioscientific issues-based learning can support this competency, relatively few explicitly examine scientific decision-making as a learning outcome within the curriculum. This suggests that the competency is still more often positioned as an indirect outcome rather than as an explicitly designed learning objective. Within modern curriculum frameworks emphasizing scientific literacy and 21st-century competencies, scientific decision-making should be explicitly incorporated into science learning objectives (Yunita & Mandasari, 2025). Therefore, future research should examine how curriculum, instructional strategies, and assessment can be systematically aligned to develop this competency.

Overall, the identified research gaps indicate that the development of scientific decision-making remains limited across conceptual, methodological, contextual, assessment, and instructional dimensions. These gaps collectively point to the need for clearer conceptualization, greater methodological diversity, broader research contexts, comprehensive assessment, and explicit integration into science education. Addressing these areas can strengthen the theoretical and practical development of scientific decision-making as a distinct competency in science education.

3.4. Implications for the Development of Research and Science Learning

Based on the findings regarding research trends, dominant themes, and the identified gaps, this section outlines implications that can serve as a foundation for the development of future research and science learning practices. These implications focus not only on strengthening theoretical studies but also on how scientific decision-making can be more systematically integrated into curriculum, instruction, and assessment. Thus, this section aims to bridge research findings with practical needs in 21st-century science education.

3.4.1. Implications for Research Development

The findings highlight the need to develop an integrated conceptual framework because scientific decision-making remains fragmented across related constructs. Future research should therefore formulate models that explicitly integrate scientific reasoning, argumentation, and socioscientific issues while maintaining clear distinctions among their respective roles. In addition, the dominance of quantitative research (Table 6) indicates the need for greater methodological diversity. Qualitative and mixed-methods approaches, supported where appropriate by longitudinal designs, could provide deeper insight into the cognitive, social, and affective

processes underlying scientific decision-making. The findings also indicate a need to expand research contexts. The limited variation across regions and educational levels (Tables 4 and 5) suggests that future studies should examine scientific decision-making across diverse cultural contexts and higher education levels. Such expansion would provide a broader understanding of how the competency develops under different social, cultural, and educational conditions.

3.4.2. Implications for the Development of Science Learning

In instructional contexts, the dominance of socioscientific issues (SSI) indicates its potential as an authentic context for developing scientific decision-making. However, SSI should not function merely as a context for discussing issues; instructional activities need to explicitly target the decision-making process. Learning activities can therefore facilitate processes such as problem identification, evidence evaluation, consideration of alternatives, and justification of decisions. Inquiry-based, argumentation-based, and problem-based learning approaches may support this development when their activities are intentionally aligned with these decision-making processes.

From a curriculum perspective, scientific decision-making should be positioned as an explicit learning outcome. Curriculum indicators should therefore reflect students' ability to evaluate evidence, consider alternatives, and make and justify evidence-based decisions in real-world contexts. Such explicit integration can help ensure that the competency is intentionally developed and subsequently assessed rather than emerging only as an indirect outcome of science learning.

3.4.3. Implications for Assessment Development

The findings also highlight the need for assessment approaches that measure scientific decision-making comprehensively rather than focusing only on individual components such as scientific reasoning or argumentation. Evaluation should capture not only final decisions but also the processes of evidence evaluation, consideration of alternatives, and decision justification. Therefore, authentic assessment tasks involving real-world issues can provide opportunities to examine these processes. Assessment should also consider the cognitive and affective dimensions of decision-making, including values, attitudes, and social considerations. A multidimensional assessment approach would therefore better reflect the complexity of scientific decision-making and support more meaningful evaluation of its development. Overall, the implications of this study indicate that the development of scientific decision-making requires alignment among conceptualization, research methodology, learning design, curriculum, and assessment. Rather than treating decision-making as an implicit outcome of related science learning activities, future research and practice should position it as an explicit competency supported by appropriate contexts, processes, and assessment approaches. As a conceptual contribution, this study provides a comprehensive synthesis showing how scientific decision-making is currently positioned in relation to socioscientific issues, scientific reasoning, and argumentation. The findings further indicate that these dimensions need to be conceptually distinguished while being integrated within a coherent framework of scientific decision-making. By mapping the major research gaps and their implications, this study also provides directions for future research, particularly in conceptual framework development, methodological diversification, comprehensive assessment, broader research contexts, and explicit integration into science learning.

4. CONCLUSION

This study shows that research on scientific decision-making in science education remains limited and unevenly developed, with research generally examining it through its integration with socioscientific issues, scientific reasoning, and argumentation, rather than consistently positioning it as an independent construct. Several major gaps remain, including the absence of an integrated conceptual framework, limited methodological diversity, uneven research contexts, and a lack of comprehensive assessment instruments specifically designed to measure scientific decision-making. These findings imply the need to explicitly integrate scientific decision-making into science curricula and issue-based learning, supported by authentic assessment approaches that capture evidence-based decision-making processes. Future research should focus on developing integrated conceptual models, exploring decision-making processes through qualitative and mixed-methods approaches, and expanding research across educational levels and geographical contexts. Nevertheless, this study has limitations, particularly its reliance on a single database (Scopus) and a relatively limited number of articles. Therefore, the findings may not fully represent the broader development of research on scientific decision-making in science education.

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