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Socioscientific Issues Integration in Science Education for Developing Scientific Argumentation Skills and Supporting Sustainable Development Goals: A Systematic Review

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Abstract: Socioscientific Issues (SSI) integration in science education connects scientific concepts with complex real-world problems while fostering students' scientific argumentation skills. This systematic review examines SSI integration in science learning, its contribution to students' scientific argumentation, and the role of digital learning resources.The review followed PRISMA 2020 guidelines and analyzed empirical studies published between 2020 and 2025. Literature searches were conducted in October 2025 using Scopus, ScienceDirect, and Taylor & Francis Online with Boolean operators such as ("socioscientific issues" AND "scientific argumentation"). From an initial pool of 800 articles, 36 studies met the inclusion criteria and were analyzed through thematic synthesis. The findings reveal four dominant SSI integration patterns: scientific discuSSIon and debate, problem- and project-based learning, evidence-based decision-making, and digital instructional media. SSI integration consistently strengthens structural and dialogic argumentation, evidence evaluation, complexity-based reasoning, and consideration of ethical and social dimensions. However, studies integrating SSI into digital instructional resources remain limited. Teacher competence, argumentative scaffolding, and contextual issue relevance were identified as key supporting factors, while limited instructional materials and curriculum pressure became major barriers. These findings provide an empirical foundation for developing SSI-based science instruction and digital learning resources that support scientific argumentation in 21st-century education.

Keywords: **D**igital teaching materials; Science education; Scientific argumentation; Socioscientific Issues (SSI); Systematic literature review

Introduction

Twenty-first-century science education is no longer oriented solely toward mastering scientific concepts and laws; rather, it emphasizes the development of higher-order thinking skills, evidence-based decision-making, and scientific argumentation in addreSSIng complex, controversial, and multidimensional real-world problems. Global challenges such as climate change, energy crises, emerging technologies, and health and environmental issues position science not merely as a body of knowledge but as a social practice embedded with ethical, political, and value laden dimensions. Therefore, science learning is expected to facilitate students in evaluating scientific evidence, considering diverse perspectives, and formulating rational and responsible decisions as informed members of a knowledge based society (Högström et al., 2024; Viehmann et al., 2024).

Building on these empirical trends, the Socioscientific Issues (SSI) approach has emerged as a pedagogical framework that bridges scientific concepts with authentic social issues. SSI positions science based controversial issues as learning contexts to promote students' cognitive, epistemic, and moral engagement. A growing body of empirical research indicates that the

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integration of SSI into science instruction contributes positively to the enhancement of scientific literacy, conceptual understanding, and students' awareness of the relevance of science in everyday life (Agustin et al., 2025; Arthamena et al., 2025). Moreover, SSI provides a rich learning environment that enables students to engage in scientific argumentation practices through discussion, evidence evaluation, and decision making grounded in both values and scientific data (V. Dawson, 2024; Rapanta, 2021).

Scientific argumentation is one of the essential competencies in modern science education because it represents a core epistemic practice of science, namely the process of formulating claims, providing justification, and defending those claims through evidence and logical reasoning. However, within the context of Socioscientific Issues (SSI), argumentation extends beyond the structural relationship among claims, evidence, and reasoning. SSI-based argumentation, often conceptualized as socioscientific argumentation, also involves evaluating the credibility of information sources, managing scientific uncertainty, and considering ethical and social dimensions in decision-making processes (Jimenez et al., 2023; Sparks et al., 2022). Therefore, fostering socioscientific argumentation through SSI has the potential to equip students with the competencies needed to participate reflectively and responsibly in a science-based society (Sari et al., 2025; Smit et al., 2025).

Although research on SSI in science education continues to grow, existing findings remain fragmented and have not yet been systematically synthesized in three major areas. First, SSI has been integrated into science learning through various approaches, yet there is still no comprehensive synthesis that maps the dominant integration patterns and their implementation characteristics. Second, studies apply different socioscientific argumentation frameworks, such as Toulmin's Argument Pattern, socioscientific reasoning, and epistemic evaluation, making it difficult to compare findings across studies. Third, recent literature highlights the potential of digital technology in supporting SSI learning, but empirical evidence on SSI-based digital instructional materials remains limited and scattered. This issue has become increasingly important in the post pandemic and Education 4.0 era, where science education is expected to address rapidly evolving socioscientific issues such as artificial intelligence, biotechnology, and environmental sustainability through interactive and technology-supported learning. Without a systematic synthesis of digital SSI implementation, science instruction may continue to rely on conventional approaches that are less responsive to contemporary socioscientific challenges.

In addition, various studies have reported challenges in implementing SSI in formal education, particularly related to the limited availability of SSI-based instructional materials, teachers' competence in facilitating argumentative discuSSIons, and curriculum demands that remain predominantly content-oriented (Lee, 2022; Rahayu et al., 2025). On the other hand, the advancement of digital technology and the growing need for scientific and digital literacy create strategic opportunities to develop SSI-based argumentative learning that is more contextual, interactive, and sustainable (Annisa et al., 2023; Jiang et al., 2024). This condition underscores the need for studies that not only map empirical findings but also derive practical implications for the development of science instruction.

Based on these conditions, a systematic literature review is needed that not only summarizes empirical research findings related to SSI but also provides a critical synthesis of how SSI is integrated into science learning, its contribution to strengthening students' scientific argumentation skills, and the instructional design implications that may serve as a foundation for developing teaching materials, particularly SSI-based digital learning resources. The selection of the 2020–2025 period is considered relevant to represent the most recent developments in SSI research within the context of 21st-century science education.

In this review, SSI integration is defined as the use of controversial science-based issues that encompass social, ethical, and value dimensions as the primary context of instruction, rather than merely as supporting illustrations. Meanwhile, scientific argumentation skills are understood as students' ability to formulate claims, use relevant scientific evidence, provide coherent reasoning, evaluate the credibility of information sources, and consider social and ethical perspectives in decision-making.

In line with these objectives, this study aims to conduct a systematic literature review of empirical studies examining the integration of SSI in science education, with a particular focus on strengthening students' scientific argumentation skills. Specifically, this review is directed at answering the following research questions: (1) How is SSI integrated into science instruction, and what instructional media, including digital resources, are utilized based on empirical studies published during the 2020–2025 period?; (2) To what extent does SSI integration contribute to the strengthening of students' scientific argumentation skills?; (3) What factors are reported to support and hinder the implementation of the SSI approach, including the use of digital instructional resources, in developing scientific argumentation skills within formal educational settings?

By addressing these questions, this study is expected to provide a scholarly contribution in the form of a comprehensive mapping of SSI integration patterns in science education, while also serving as an empirical foundation for the development of instructional strategies and teaching materials, including digital resources, that support the enhancement of scientific argumentation in 21st-century science education.

The diversity of approaches to integrating Socioscientific Issues (SSI), as well as the variation in scientific argumentation frameworks employed in empirical studies, indicates that a literature synthesis cannot be conducted in a purely descriptive manner. Therefore, this systematic literature review is grounded in a theoretical framework that integrates the conceptualization of SSI, theories of scientific argumentation, and the modern science literacy paradigm as the basis for analyzing the research findings.

Method

This study employs a Systematic Literature Review (SLR) approach aimed at identifying, evaluating, and systematically synthesizing empirical findings related to the integration of Socioscientific Issues in science education and their contribution to strengthening students' scientific argumentation skills. The SLR approach was selected because it enables a transparent, systematic, and replicable synthesis of research evidence compared to traditional narrative literature reviews (Snyder, 2019). The SLR process was conducted in accordance with the PRISMA 2020 (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines to ensure transparency, traceability of procedures, reporting consistency, and research replicability (Page et al., 2021).

The literature search was conducted in October 2025 and included studies published between 2020 and 2025. To obtain broad yet relevant coverage of science education research while minimizing exceSSIve overlap among sources, this review used Scopus as the primary indexing database and ERIC as an additional education-focused database. These databases were selected because they provide extensive access to peer-reviewed international journals related to science education, SSI, and scientific argumentation.

The search strategy was developed based on three main concepts: SSI, science education, and scientific argumentation. The primary Boolean search string used in this review was: ("socioscientific issues" OR "socio-scientific issues" OR "SSI") AND ("science education" OR "science learning" OR "science teaching") AND ("scientific argumentation" OR "argumentation skills" OR "scientific reasoning"). Searches were conducted in the title, abstract, and keyword fields (TITLE-ABS-KEY). The applied filters included: (1) empirical research articles, (2) publication years between 2020 and 2025, (3) English-language publications, and (4) full-text availability. The initial search identified 800 potentially relevant articles.

Although this review prioritized studies with accessible full texts to support transparency and detailed thematic analysis, this criterion may also introduce selection bias because some high-quality SSI studies published in subscription-based journals may not have been included. Therefore, the restriction to accessible full-text articles is acknowledged as one of the methodological limitations of this review.

Selection and Deduplication Process

All retrieved articles were exported to Mendeley for the deduplication process. Duplicate records were identified based on similarities in titles, author names, publication years, and DOI numbers before the title and abstract screening stage. A total of 315 duplicate articles were removed, leaving 485 articles for the initial screening process.

The remaining articles were screened through title and abstract review using the predefined inclusion and exclusion criteria. At this stage, 370 articles were excluded because they were not directly related to SSI integration in science education, did not focus on scientific argumentation, were not empirical studies, or did not meet the language and accessibility criteria. As a result, 115 articles advanced to the full-text eligibility assessment stage.

During the eligibility assessment stage, the full texts of the remaining articles were examined in detail to ensure alignment with the objectives and research questions of this review. Articles were excluded if they did not provide sufficient empirical evidence regarding SSI integration and scientific argumentation, demonstrated methodological weaknesses, or lacked substantial relevance to the focus of the study. Following this process, 79 articles were excluded, resulting in 36 articles that met all eligibility criteria and were included in the final synthesis and thematic analysis. All stages of the selection process followed the PRISMA 2020 procedure and are presented in the PRISMA flow diagram.

Inclusion and Exclusion Criteria

The article selection process was conducted through a step-by-step screening procedure based on predefined inclusion and exclusion criteria to ensure alignment with the focus of this review, namely the enhancement of scientific argumentation skills through SSI integration in science education. The inclusion

criteria covered publication period, study type, relevance to the review focus, publication standards, language, and accessibility. Articles that did not meet these criteria were excluded from the review. The detailed criteria are presented in Table 1.

Table 1. Inclusion and Exclusion Criteria

Criteria type	Inclusion	Exclusion
Publication period	2020–2025	2019 and earlier
Document type	Empirical research articles	Conference proceedings, dissertations, theses, undergraduate theses, books, etc.
Nature of study	Focuses on the integration of SSI in science education with an emphasis on developing scientific argumentation	Does not focus on the integration of SSI in science education with an emphasis on developing scientific argumentation
Journal reputation	Published in reputable peer-reviewed scientific journals and indexed in credible academic databases	Non-indexed literature and non-peer-reviewed publications such as proceedings, theses, dissertations, research reports, and books (excluded to maintain academic validity and scientific authority)
Access	Available in full-text (open access)	Full-text not available
Language	Written in English	Not written in English

Result and Discussion

Result

The study selection process was conducted through the stages of identification, screening, eligibility assessment, and final inclusion in accordance with the PRISMA 2020 flow framework (Page et al., 2021).

Identification

The initial search was conducted in two databases, Scopus and ERIC, using predefined Boolean search strings and publication filters. This process identified 800 articles potentially relevant to the focus of the study published between 2020 and 2025.

Screening

All retrieved articles were exported to Mendeley for the deduplication process. Duplicate records were identified based on similarities in titles, author names, publication years, and DOI numbers. A total of 315 duplicate articles were removed, leaving 485 articles for the title and abstract screening stage. During the screening stage, the remaining articles were evaluated using the predefined inclusion and exclusion criteria presented in Table 1. Articles were excluded if they did not focus on SSI integration, scientific argumentation, science education contexts, empirical research designs, or English-language full-text publications. As a result, 370 articles were excluded during the screening process, and 115 articles advanced to the full-text eligibility assessment stage.

Eligibility

The eligibility stage involved a detailed full-text evaluation based on the quality assessment criteria presented in Table 2. Each article was carefully reviewed to examine the alignment of its research focus, methodological rigor, clarity of research objectives, relevance of the instructional context, and contribution to SSI-based science instruction. Articles were considered eligible if they fulfilled at least four out of the five quality assessment criteria. Based on the full-text eligibility assessment, 115 articles were reviewed at this stage. Of these, 79 articles were excluded because they did not sufficiently address scientific argumentation, used SSI only as a supplementary illustration rather than the main instructional context, lacked methodological clarity, or showed substantial overlap with other publications. Since some articles met more than one exclusion criterion, the exclusion categories were not mutually exclusive. Consequently, 36 articles met all eligibility criteria and were included in the final data synthesis of this systematic literature review.

Table 2. Article Quality Assessment Criteria

Criteria	Description	Score
Alignment with SSI Focus	The article clearly uses Socioscientific Issues or science–social issues as the instructional context.	0 = Does not meet 1 = Meets
Relevance to Scientific Argumentation	The article is directly related to argumentation, reasoning, decision-	0 = Does not meet 1 = Meets

Criteria	Description	Score
	making, epistemic evaluation, or critical thinking.	
Appropriateness of Science Education Context	The study is situated within a science education context (elementary to senior high school or pre-service science teacher education).	0 = Does not meet 1 = Meets
Methodological Rigor	The methodology is clearly described; data are adequate; SSI/argumentation instruments are measurable; and analysis is robust.	0 = Does not meet 1 = Meets
Contribution to SSI-Based Instructional Development	The article provides a tangible contribution, such as an instructional model, argumentation strategy, or enhancement of science literacy related to SSI.	0 = Does not meet 1 = Meets

Note: An article was considered eligible if it met at least four out of the five assessment criteria.

Final Inclusion

The final sample consisted of 36 empirical studies that were systematically analyzed to address the research questions of this review. All included studies were re-verified to ensure methodological consistency and substantial relevance to the integration of SSI in strengthening students' scientific argumentation skills. The complete article selection process is summarized in Figure 1 through the PRISMA flow diagram.

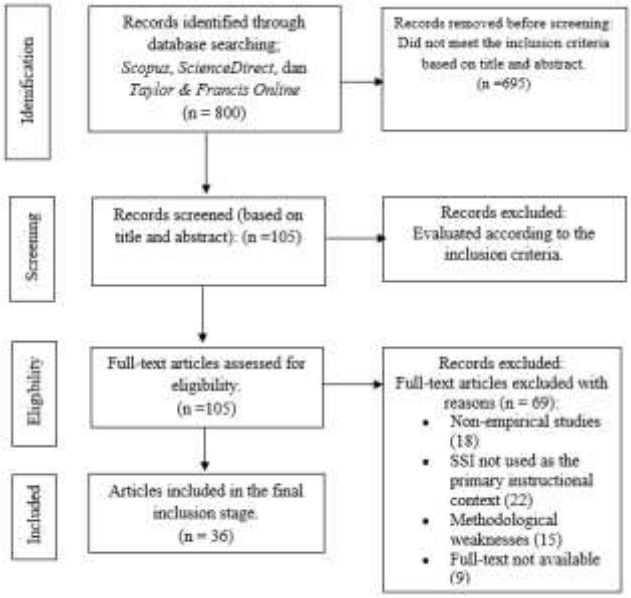

Figure 1. Steps of the Systematic Literature Review (SLR) Using the PRISMA Method

Data Extraction and Content Analysis

Data extraction was conducted systematically on the 36 articles that met the final inclusion criteria. This process aimed to consistently gather core information from each study, enabling cross-study comparison and synthesis. For this purpose, a structured data extraction sheet was developed based on the review objectives and the study's theoretical framework. The extracted information included: (1) Research context, including country and education level; (2) Science domain addressed in the study; (3) Type and characteristics of SSI used; (4) Research design and duration of instructional interventions; (5) Participant characteristics and sample size; (6) Scientific argumentation framework or indicators applied in the study (e.g., Toulmin's Argument Pattern, socioscientific reasoning, or epistemic evaluation indicators); and (7) Key findings relevant to the enhancement of students' scientific argumentation skills.

The extracted data served as the primary basis for analyzing and synthesizing research findings. After identifying the 36 relevant articles, the next stage involved extracting the main information from each study. This extraction was guided by the research questions, ensuring that each data element collected directly contributed to addressing the focus of the review: how SSI is integrated into science education and how this approach contributes to strengthening students' scientific argumentation skills.

Table 3. Characteristics of Studies Included in the Systematic Review

Authors	Country	Education level	Science domain	Type of SSI
(G. Kim et al., 2020)	Korea	High school	Environment	Air pollution
(Adams, 2020)	UK	Middle school	Biology	Health
(Ram, 2019)	New zealand	High school	Biology	Biosecurity
(Casas-Quiroga & Crujeiras-Pérez, 2020)	Spain	High school	Biology	Emergency nutrition

Authors	Country	Education level	Science domain	Type of SSI
(Rapanta, 2021)	Portugal	Middle school	General	General SSI
(Choi & Lee, 2021)	Korea	High school	Chemistry	Food additives
(Ottander & Simon, 2021)	Sweden	High school	Environment	Sustainable energy
(Christodoulou et al., 2021)	UK	High school	Biology	Science-economy
(Garrecht et al., 2021)	Germany	High school	Biology	Local issues
(Gottschling & Kammerer, 2021)	Germany	Middle school	General	Science conflicts
(Mun et al., 2022)	Korea	High school	Technology	Autonomous vehicles
(Lee, 2022)	Korea	Pre-service teachers	Science education	General SSI
(Kwon et al., 2022)	Korea	High school	Environment	Citizen science
(Na et al., 2022)	Korea	Pre-service teachers	Technology	General
(Leij et al., 2022)	Netherlands	High school	Energy	Sustainability
(J. E. Kim & Park, 2023)	Korea	Elementary school	Energy	Public energy
(W. Park et al., 2023)	Korea	Middle school	Environment	Disaster
(Christenson & Walan, 2021)	Sweden	Pre-service teachers	Biology	Gmo & nuclear
(Chadwick et al., 2021)	Ireland	Middle school	Environment	Inquiry SSI
(Schaik, 2023)	Netherlands	Middle school	Environment	Game & climate (global SSI)
(Engelen & Budke, 2023)	Germany	High school	Geography	Spatial conflicts
(Jiang et al., 2024)	China	High school	General	Technology
(J. Park et al., 2024)	Korea	Middle school	Technology	Risk perception
(Günther et al., 2024)	Germany	High school	Environment	Sustainability
(Alkaher & Carmi, 2024)	Israel	High school	Environment	Population
(V. Dawson, 2024)	UK	Middle school	Environment	Water
(Leij et al., 2024)	Netherlands	High school	Biology	Human-nature
(Jimenez et al., 2023)	Spain	High school	Environment	Energy
(Knain et al., 2025)	Norway	High school	Environment	Sustainability
(Marten et al., 2025)	Germany	High school	Energy	5g energy
(Baltikian et al., 2025)	Finland	High school	Environment	Climate
(Abrori et al., 2025)	Indonesia	Elementary school	Energy	Educational comics
(Smit et al., 2025)	Germany	High school	Environment	Energy
(Hite et al., 2025)	Netherlands	Middle school	Environment	Energy
(Assaraf et al., 2025)	Germany	High school	Environment	Energy
(Tolbert et al., 2025)	Netherlands	High school	Environmen	Human-nature

The reviewed studies were predominantly conducted in European and Asian countries, with high school students representing the most common educational level. Environmental and sustainability-related issues emerged as the dominant SSI contexts, indicating the growing relevance of global environmental challenges in contemporary science education.

Table 4. Key Features of Included Studies

Authors	Research design	Argumentation framework	Key findings related to argumentation
(G. Kim et al., 2020)	Quasi-experiment	Toulmin / issue concept map	Claims and evidence increased through issue mapping.
(Adams, 2020)	Case study	Socioscientific reasoning (SSR)	SSI fosters reflective and inclusive argumentation.
(Ram, 2019)	Case study	Toulmin	Risk evaluation & evidence-based arguments.
(Casas-Quiroga & Crujeiras-Pérez, 2020)	Case study	Epistemic	Role-play effective for decision-making.
(Rapanta, 2021)	Case study	Toulmin	SSI strengthens cross-curricular argumentation.
(Choi & Lee, 2021)	Experiment	Toulmin + SSR	Ethical and contextual arguments increased.

Authors	Research design	Argumentation framework	Key findings related to argumentation
(Ottander & Simon, 2021)	Case study	Toulmin	SSI supports vision ii literacy & democratic participation.
(Christodoulou et al., 2021)	Qualitative	SSR	Integration of scientific, moral, and social dimensions.
(Garrecht et al., 2021)	Case study	Vision ii literacy	Issue familiarity strengthens arguments.
(Gottschling & Kammerer, 2021)	Experiment	Source evaluation	Evaluating evidence credibility is crucial for argument quality.
(Mun et al., 2022)	Quasi-experiment	Toulmin	SSI discussions train complex argumentation.
(Na et al., 2022)	Qualitative	Inquiry-based argumentation	Teacher support is important in SSI inquiry.
(Lee, 2022)	Qualitative	Pedagogical argumentation	Teacher competence strongly determines students' argument quality.
(Kwon et al., 2022)	Case study	Evidence-based reasoning	Students act as producers of scientific knowledge/arguments.
(Leij et al., 2022)	Mixed-method	Moral reasoning	SSI supports students' moral development.
(J. E. Kim & Park, 2023)	Qualitative	Dialogic argumentation	Constructive conflict strengthens interaction.
(W. Park et al., 2023)	Case study	Toulmin	Evidence analysis & social aspects increased.
(Christenson & Walan, 2021)	Qualitative	Toulmin	Teacher and student argument quality assessment.
(Chadwick et al., 2021)	Experiment	Inquiry-based argumentation	Open and guided inquiry effective.
(Schaik, 2023)	Case study	Decision-making	SSI trains reflection on global issues.
(Engelen & Budke, 2023)	Case study	Multi-perspective argumentation	Data-based multiperspective arguments.
(Jiang et al., 2024)	Experiment	Toulmin + multimedia	Digital products strengthen arguments.
(J. Park et al., 2024)	Qualitative	Risk reasoning	Evidence evaluation & uncertainty increased.
(Günther et al., 2024)	Case study	Toulmin	System competence & collaboration improved.
(Alkaher & Carmi, 2024)	Case study	Toulmin	Critical argumentation & complex perspectives.
(V. Dawson, 2024)	Experiment	Toulmin + scaffolding	Teacher scaffolding improves argument quality.
(Leij et al., 2024)	Mixed-method	Toulmin	Value- and ethics-based arguments.
(Jimenez et al., 2023)	Case study	Trade-off reasoning	SSI trains reflective trade-off practices.
(Knain et al., 2025)	Qualitative	Toulmin	SSI strengthens citizen reflection & action.
(Marten et al., 2025)	Experiment	Toulmin	Evaluation of controversial claims.
(Baltikian et al., 2025)	Mixed-method	SSR	SSI literacy & engagement are influential.
(Abrori et al., 2025)	Case study	SSR	SSI makes science more relevant & critical.
(Smit et al., 2025)	Mixed-method	Toulmin	SSI trains trade-off reasoning.
(Hite et al., 2025)	Case study	Toulmin	SSI trains multiperspective argumentation.
(Assaraf et al., 2025)	Mixed-method	Toulmin	SSI trains claims & evidence reasoning.
(Tolbert et al., 2025)	Case study	Toulmin + SSR	Value- and ethics-based arguments.

Across the reviewed studies, Toulmin-based argumentation frameworks were the most frequently employed analytical approach. Most studies consistently reported improvements in students' abilities to formulate claims, evaluate evidence, and engage in reflective reasoning through SSI-based instruction.

All stages of article selection, quality assessment, and data extraction were conducted systematically in accordance with the PRISMA 2020 guidelines. Inclusion and exclusion decisions at each stage were based on the alignment of the articles with the research questions and the established methodological quality criteria. This procedure was intended to ensure that the synthesis of findings was grounded in studies that were relevant, methodologically credible, and capable of providing meaningful empirical insights into the integration of Socioscientific Issues (SSI) in strengthening students' scientific argumentation skills.

Figure 2. Trend of SSI Research in Science Education

Figure 2 presents the publication trend of empirical studies on SSI in science education during the 2020–2025 period. Four studies were identified in 2020, increasing to six studies in 2021. The number slightly decreased in 2022 (five studies) before gradually increasing again to six studies in 2023, seven studies in 2024, and eight studies in 2025. Overall, these findings indicate that research on SSI in science education has shown steady and consistent scholarly interest over the past five years, despite minor annual fluctuations. This trend suggests that SSI continues to remain a relevant area of discussion within contemporary science education research.

A thematic synthesis of the 36 selected articles identified four major patterns of SSI integration in science learning, as presented in Table 5.

Table 5. Synthesis of SSI Integration Patterns in Science Education (2020–2025)

SSI integration pattern	Number of articles	Argumentation indicators examined	Synthetic interpretation
SSI as a context for scientific discussion and debate	20 (56%)	Claim evidence reasoning structure (TAP), socioscientific reasoning	The dominant pattern that explicitly trains argument structure; strengthening of argumentation is most frequently reported, although with varied indicators
SSI integrated into problem- and project-based learning	8 (22%)	Argumentation integrated with higher-order thinking	Argumentation develops contextually as part of problem solving, but is often not measured using formal argumentation instruments
SSI as an evidence-based decision-making framework	6 (17%)	Epistemic reasoning, trade-offs, ethical dimensions	Strengthens the reflective and normative dimensions of scientific argumentation, but places less emphasis on formal argument structure
SSI through digital media and instructional materials	2 (5%)	Engagement and argumentative context	High potential to support argumentation, yet empirical evidence remains limited due to the small number of studies

Table 5 indicates that SSI is widely reported to contribute positively to the strengthening of students' scientific argumentation skills; however, the forms of integration and the argumentation frameworks employed vary considerably across studies. This variation suggests that the development of argumentation through SSI is highly contextual and strongly influenced by instructional design, learning objectives, and the evaluative frameworks adopted in each study.

Discussion

The findings of this review indicate that Socioscientific Issues (SSI) have been integrated into science education through a variety of instructional approaches, with discussion- and debate-based learning emerging as the most common pattern. This suggests that SSI is widely used to encourage students to engage in argumentative dialogue, evaluate evidence, and reflect on scientific and social issues in meaningful classroom contexts. Previous studies have also emphasized that SSI-based instruction can support scientific reasoning, ethical reflection, and informed decision-making in authentic real-world situations (Sadler, 2004; Zeidler & Nichols, 2009).

The synthesis further indicates that the contribution of SSI to students' scientific argumentation skills is closely shaped by the instructional design and argumentation framework adopted in each study. Studies employing formal frameworks, such as Toulmin's Argument Pattern (TAP), socioscientific reasoning, and epistemic reasoning indicators, generally reported improvements in students' abilities to construct claims, justify arguments with evidence, and develop coherent reasoning. These findings are in line with earlier studies suggesting that scientific argumentation involves not only expressing opinions, but also evaluating evidence and defending ideas through logical reasoning (Erduran et al., 2004; Kuhn, 2010).

At the same time, studies integrating SSI into problem-based learning, project-based learning, and evidence-based decision-making activities tended to position argumentation within broader higher-order

thinking processes. In these contexts, students were encouraged to consider multiple perspectives, reflect on ethical dimensions, and make reasoned judgments regarding complex socioscientific problems. This indicates that argumentation in SSI-based learning extends beyond the structural relationship between claims and evidence, encompassing epistemic evaluation, moral reflection, and contextual decision-making.

Another important finding concerns the still limited integration of SSI through digital media and technology-supported instruction. Although only a small number of studies explicitly explored digital SSI learning environments, the available evidence suggests that technology-supported instruction has promising potential to enhance student engagement, collaborative inquiry, and argumentative interaction. Given the increasing role of educational technology in contemporary learning environments, this area represents an important opportunity for future research and instructional development.

The review also identified several factors influencing the implementation of SSI in science education. As presented in Table 6, teacher competence in facilitating argumentative discussion and providing epistemic scaffolding emerged as the most frequently reported supporting factor. In addition, learning activities involving evidence evaluation and multiperspective analysis were consistently associated with stronger argumentation outcomes. These findings reinforce previous studies suggesting that successful SSI instruction depends greatly on teachers' ability to guide classroom discourse and support evidence-based reasoning (V. M. Dawson & Venville, 2010). At the same time, limited instructional materials, especially digital SSI resources, and low pedagogical readiness among teachers remain important challenges in implementing SSI effectively in formal educational settings. Table 6 presents the distribution of supporting and inhibiting factors identified across the reviewed studies.

Table 6. Supporting and Inhibiting Factors in the Implementation of Socioscientific Issues (SSI)

Category	Factor	Frequency	Percentage
Supporting	Teacher competence in discussion and argumentative scaffolding	21	31.34%
Supporting	Relevance of issues to students' real-life contexts	18	26.87%
Supporting	Activities involving evidence evaluation and multiperspective consideration	16	23.88%
Supporting	Teacher professional development	12	17.91%
	Total Supporting Factors	67	100%
Inhibiting	Limited SSI instructional materials, especially digital media	19	30.65%
Inhibiting	Low pedagogical readiness of teachers	17	27.42%
Inhibiting	Curriculum pressure focused on content mastery	15	24.19%

Despite the reported benefits of SSI-based instruction, several barriers continue to affect its implementation in formal educational settings. Limited instructional materials, particularly digital SSI resources, insufficient pedagogical readiness among teachers, and curriculum pressures focused on content mastery were among the most frequently reported challenges. These findings indicate that the successful implementation of SSI requires not only appropriate instructional design but also adequate teacher preparation, curriculum support, and accessible learning resources.

Overall, this review suggests that SSI-based instruction provides meaningful opportunities to strengthen students' scientific argumentation skills while simultaneously promoting reflective thinking, evidence evaluation, and informed decision-making in science education contexts. The findings also suggest that SSI-based instruction may contribute to broader educational goals related to the Sustainable Development Goals (SDGs), particularly SDG 4 (Quality Education) by promoting critical thinking, scientific literacy, and informed decision-making. In addition, the frequent use of environmental and sustainability-related SSI contexts reflects the relevance of science education in supporting students' awareness of global challenges associated with sustainability.

This review has several limitations. First, the study only included English-language empirical articles indexed in Scopus and ERIC, which may have excluded relevant studies published in other databases or languages. Second, the review focused primarily on accessible full-text articles, potentially limiting the inclusion of some high-quality subscription-based

publications. Third, the thematic synthesis involved variations in research designs, instructional contexts, and argumentation frameworks across studies, which may limit the comparability and broader interpretation of the findings.

Conclusion

This systematic literature review shows that the integration of Socioscientific Issues (SSI) in science education provides meaningful support for the development of students' scientific argumentation skills. Based on the synthesis of 36 empirical studies published between 2020 and 2025, SSI was most frequently implemented through discussion- and debate-based learning, while problem-based learning, decision-making activities, and digital learning environments were also identified as important approaches. These instructional contexts encourage students to evaluate evidence, consider multiple perspectives, and engage in reflective scientific reasoning. The reviewed studies consistently indicate that SSI-based instruction helps students develop stronger claims, evidence-based reasoning, and more reflective decision-making regarding complex scientific and social issues. However, the nature of argumentation developed through SSI depends strongly on the instructional design and argumentation framework applied in each study. This review also highlights that successful SSI implementation is influenced by teacher competence, relevant learning contexts, and opportunities for evidence evaluation and discussion. At the same time, limited instructional resources, insufficient pedagogical preparation, and curriculum pressures remain important challenges, particularly in the integration of digital SSI learning. Overall, SSI-based instruction offers valuable opportunities to promote scientific argumentation and reflective scientific literacy in contemporary science education. Future research should further explore technology-supported SSI learning environments and the development of digital instructional resources that can support collaborative inquiry and critical reasoning across diverse educational settings.

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