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Socioscientific Issues in Elementary Science Education: A Systematic Literature Review

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Abstract: The socioscientific issues (SSI) approach is increasingly recognized as a vital framework for fostering scientific literacy and critical thinking in elementary science education. This study systematically reviews empirical research on SSI implementation in primary schools published between 2015 and 2025. Following the PRISMA guidelines, a comprehensive literature search across ScienceDirect, Scopus, and Publish or Perish yielded 36 eligible studies for qualitative synthesis. The findings reveal that Problem-Based and Inquiry-Based Learning are the predominant pedagogical strategies, significantly enhancing students' scientific argumentation, critical thinking, and moral reasoning when supported by age-appropriate scaffolding. However, successful classroom implementation is frequently hindered by persistent challenges, notably inadequate teacher preparedness, rigid curriculum time constraints, and high cognitive loads for young learners. Ultimately, while the SSI framework offers profound cognitive and affective benefits, maximizing its potential requires targeted professional development for educators. Furthermore, future research must shift toward longitudinal, mixed-methods designs to deeply capture the sustained impact of SSI on students' socio-scientific reasoning over time.

Keywords: Elementary science education; Scientific literacy; Socioscientific issues; Socioscientific reasoning; Systematic literature review

Introduction

In the 21st century, science education has undergone a fundamental transformation from rote memorization toward cultivating comprehensive scientific literacy and critical thinking. This shift is particularly critical in elementary education, where early exposure to scientific reasoning establishes the cognitive foundation for lifelong informed decision-making (Timmis et al., 2025). Contemporary frameworks now recognize that young learners must not only grasp scientific concepts but also develop the capacity to apply them in navigating increasingly complex, technology-driven societal challenges (Mena-Guacas et al., 2025; Vílchez et al., 2025). However, translating these ambitious goals into age-appropriate pedagogical practices remains a persistent challenge in primary science education.

The Socioscientific Issues (SSI) paradigm has emerged as a promising framework to address this challenge. SSI engages students with open-ended, complex, and often morally ambiguous problems rooted in science but requiring social, ethical, and economic considerations (Bencze et al., 2020; Lymbouridou, 2025). Empirical evidence consistently demonstrates that SSI instruction effectively promotes higher-order thinking by compelling students to evaluate multiple perspectives, weigh evidence, and construct reasoned arguments (Zeidler et al., 2019). This approach bridges the traditional gap between abstract scientific knowledge and authentic real-world applications, making science learning more meaningful and contextually relevant.

Although SSI research has matured in secondary and higher education contexts, its application in elementary schools represents an emerging frontier with

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distinct characteristics and challenges. Existing studies suggest that young learners possess natural curiosity and developing moral reasoning capacities that make them surprisingly receptive to SSI-based learning (Evagorou, 2015). However, adapting SSI for elementary contexts requires careful scaffolding—simplifying complex issues like environmental conservation, health, or animal welfare into developmentally appropriate scenarios that foster empathy and foundational argumentation skills without overwhelming cognitive capacities (Remmers, 2020). While preliminary findings are encouraging, the field lacks a comprehensive synthesis of which pedagogical strategies are most effective, what specific learning outcomes can be reliably expected, and what implementation barriers are unique to the elementary context.

Recent empirical studies highlight the multifaceted benefits of integrating the SSI paradigm into elementary science curricula. Students exposed to SSI demonstrate heightened engagement, improved scientific argumentation, and a deeper understanding of the nature of science (Johnson et al., 2020). Furthermore, SSI instruction promotes the development of socio-scientific reasoning and sustainability awareness, equipping young students with the competencies required to become responsible global citizens (Georgiou & Kyza, 2023; Jia & Ren, 2025).

Despite the growing body of literature advocating for SSI in elementary education, the current research landscape remains critically fragmented across multiple dimensions. First, existing studies predominantly focus on isolated case studies or single pedagogical interventions—such as standalone problem-based learning modules—without systematically comparing their relative effectiveness against alternative instructional approaches. Second, while numerous studies report positive cognitive outcomes, there is a conspicuous absence of standardized assessment frameworks capable of capturing the multidimensional nature of socioscientific reasoning in young learners, particularly the integration of moral reasoning with scientific argumentation. Third, implementation challenges specific to the elementary context—such as age-appropriate scaffolding requirements, teacher pedagogical content knowledge gaps, and curriculum time constraints—remain underexplored in isolation rather than as interconnected systemic barriers. The scientific consequence of this fragmentation is profound: educators and policymakers lack evidence-based guidelines for determining which pedagogical strategies yield optimal outcomes for specific learning objectives, how to validly assess complex socioscientific competencies in developmentally appropriate ways, and what institutional support structures are necessary for sustainable implementation. Consequently, the field currently lacks a comprehensive synthesis that maps the relationships between instructional design choices, scaffolding mechanisms, student developmental characteristics, and measurable learning outcomes—knowledge that is essential for scaling SSI from isolated pilot studies to widespread, effective practice in elementary science education (Brennan et al., 2013; Pessoa et al., 2025; Zamiri & Esmaeili, 2024).

To address this fragmentation, a Systematic Literature Review (SLR) is the most appropriate methodological approach. An SLR provides a rigorous, transparent, and reproducible method for synthesizing existing empirical evidence, identifying prevailing trends, and uncovering critical gaps in the literature (Calderon Martinez et al., 2025; Gusenbauer & Gauster, 2025). By systematically analyzing recent studies, an SLR can distill complex findings into actionable insights, offering a clear roadmap for future research and practice in elementary science education (Eddy, 2023; Habsari et al., 2026).

To address this fragmentation, a Systematic Literature Review (SLR) following PRISMA 2020 guidelines is employed. While several systematic reviews on SSI have been conducted (e.g., (Çalık & Wiyarsi, 2020; Dusturi et al., 2024), these reviews predominantly focused on secondary education or chemistry-specific contexts, leaving a critical gap in understanding SSI implementation specifically in elementary science education. The novelty of this review lies in its integrated synthesis that explicitly maps the interconnected relationships between pedagogical strategies, scaffolding mechanisms, student developmental outcomes, and implementation challenges unique to the elementary context. Unlike previous reviews that examined these dimensions in isolation, this study constructs a comprehensive framework linking: (1) predominant instructional models to their specific scaffolding requirements; (2) scaffolding approaches to measurable cognitive and affective student outcomes; (3) identified implementation barriers to contextual factors specific to primary education; and (4) methodological gaps to prioritized future research directions. This holistic, elementary-specific synthesis provides educators and researchers with an evidence-based roadmap for translating SSI theory into age-appropriate classroom practice—a contribution absent from existing systematic reviews that have predominantly addressed older student populations.

Method

This study employed a Systematic Literature Review (SLR) methodology following the PRISMA 2020

(Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines to ensure rigor, transparency, and reproducibility in the synthesis of existing evidence. A comprehensive search of both international and national literature was conducted across three major academic databases: ScienceDirect, Scopus, and Publish or Perish. The search strategy utilized Boolean operators with the following search string: ("socioscientific issues" OR "socio-scientific issues" OR "SSI") AND ("elementary education" OR "primary education" OR "elementary school") AND ("science education" OR "science learning"). The search was limited to peer-reviewed journal articles published between 2015 and 2025 to capture recent developments in the field. The initial search yielded 385 articles using the primary keyword "socioscientific issues," followed by 168 articles using the keyword "socioscientific approach." After removing duplicates and applying title and abstract screening based on predefined inclusion and exclusion criteria, 75 articles were identified for full-text feasibility evaluation. Ultimately, 36 articles met all eligibility criteria and were included in the in-depth qualitative synthesis. The inclusion criteria required that studies: (1) focus on SSI implementation in elementary or primary school settings; (2) address science education contexts; (3) present empirical data or systematic analysis; and (4) be published in peer-reviewed journals within the specified time frame.

The literature search was conducted using a systematic and reproducible search strategy across three major academic databases: **Scopus, ScienceDirect, and Publish or Perish**. The search string was constructed using Boolean operators (AND, OR) and field tags specific to each database's syntax to ensure comprehensive coverage of relevant studies. The core search string combined three conceptual blocks: (1) socioscientific issues terminology, (2) elementary/primary education context, and (3) science education focus. The complete search strings for each database. The search was limited to peer-reviewed journal articles published between 2015 and 2025 to capture recent developments in the field.

The article search process began with the following stages:

Identification

The identification process using the keyword "socioscientific issues" yielded 385 articles.

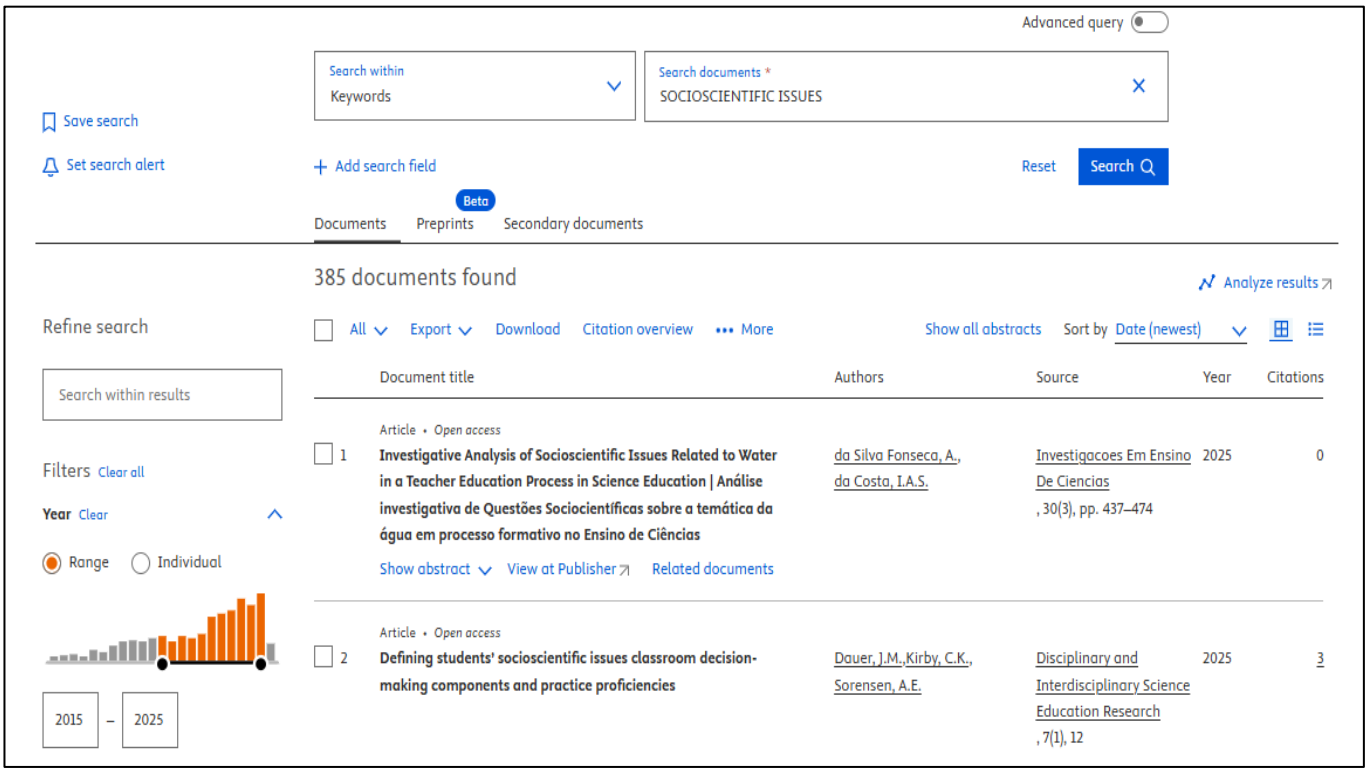


Figure 1. Identification Process with Socioscientific Issues Keywords

Screening

In the screening process, the titles, abstracts, and keywords of articles that were relevant to socioscientific issues, not focused on elementary school level, or unrelated to science learning were 168 articles containing the keyword socioscientific issues.

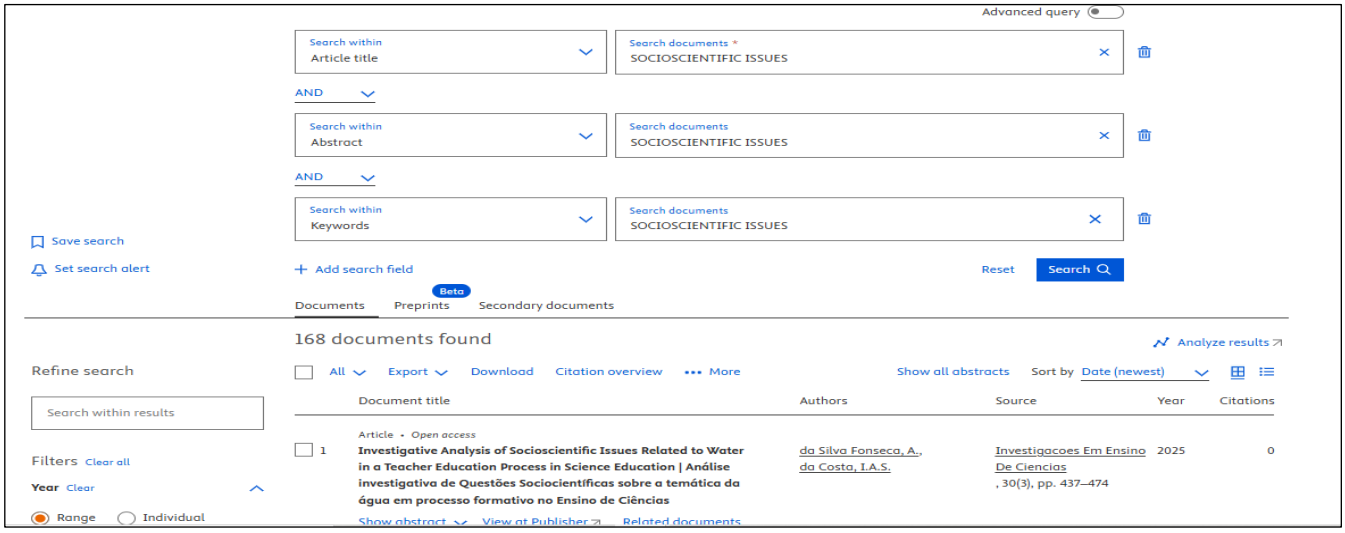


Figure 2. Screening Activities with Title, Abstract and Keywords

Feasibility evaluation (full-text)

The feasibility evaluation activity identified 36 articles that matched the keywords socioscientific issues and science education.

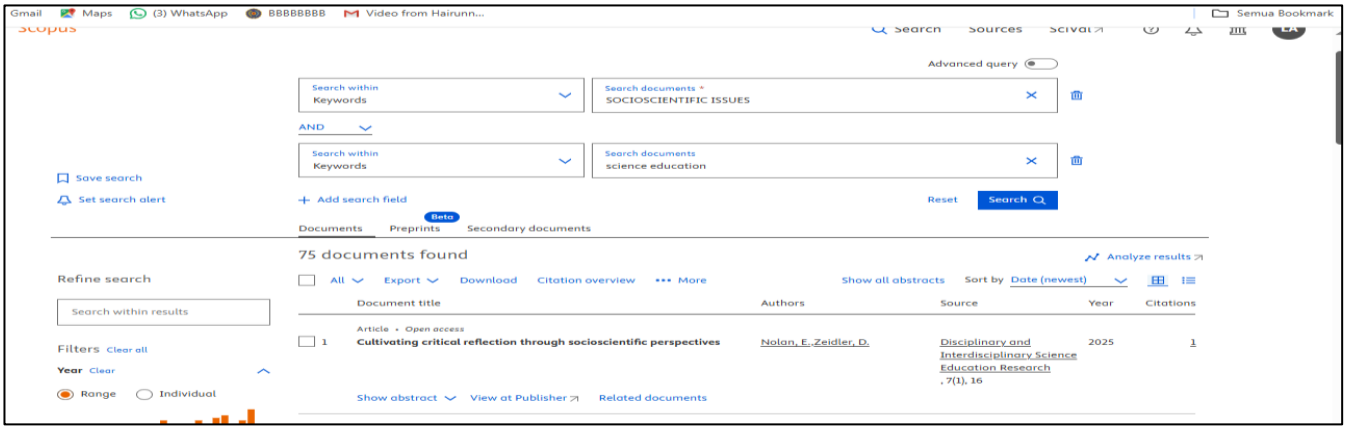


Figure 3. Feasibility Evaluation

Inclusion

A total of 36 articles met all criteria and were included in the in-depth analysis, based on the search using socioscientific issues and primary education for article titles, abstracts, and keywords.

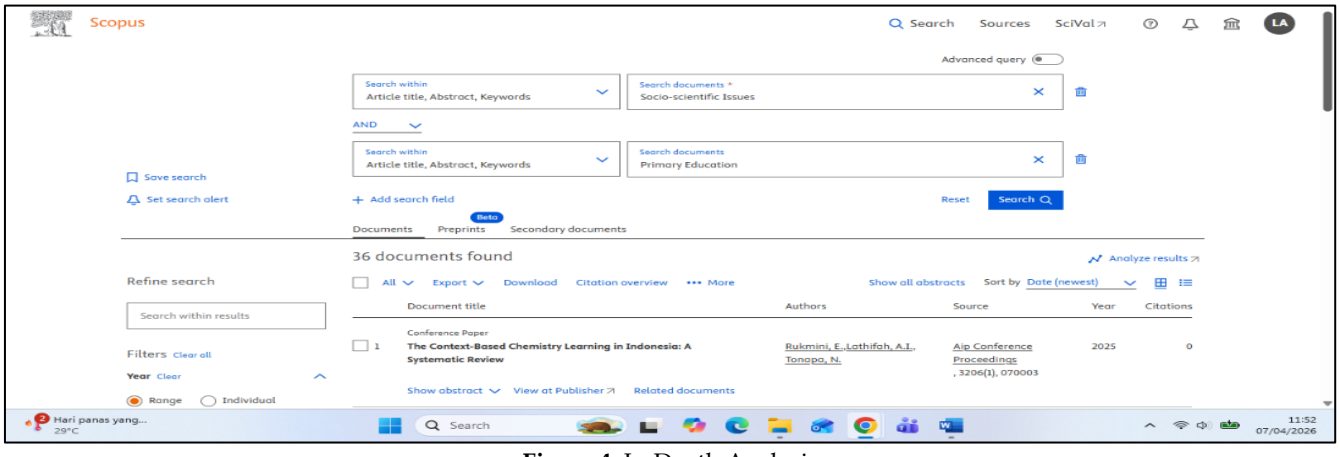


Figure 4. In-Depth Analysis

Based on the analysis of the 36 selected scientific articles, there is a significant diversity in methodological designs. In detail, the distribution of articles based on research type is presented in Table 1.

Table 1. Distribution of Articles by Research Type

Research Type	Number of Articles	Percentage
Experiment	10	27%
Survey	3	8%
Qualitative Study	6	17%
Case Study	2	6%
Mixed Methods	6	17%
Systematic Review / Meta-analysis	9	25%
Total	36	100%

Result and Discussion

Result

Overview of the Included Studies

The systematic search across major academic databases initially yielded a substantial pool of records, which was subsequently reduced after removing duplicates. Following the title and abstract screening, a significant number of articles were excluded for lacking relevance to elementary science education or the socioscientific issues paradigm. The full-text assessment further filtered out studies that did not present empirical data or were conducted outside primary school contexts. Ultimately, a final set of articles met all predefined inclusion criteria and was incorporated into the qualitative synthesis. This rigorous selection process ensured that only high-quality, context-specific research informed the subsequent analysis.

The temporal distribution of the included studies reveals a marked increase in publications over the last three years, indicating a growing global interest in early childhood SSI education. Geographically, the research is predominantly concentrated in Southeast Asia and Europe, reflecting regional curriculum reforms that emphasize scientific literacy. Most of the selected studies employed quantitative or mixed-methods designs to measure specific cognitive and affective student outcomes. A smaller subset utilized qualitative approaches to deeply explore the nuanced classroom dynamics and teacher perspectives during SSI implementation. This methodological diversity provides a comprehensive understanding of the paradigm's practical application in diverse educational settings.

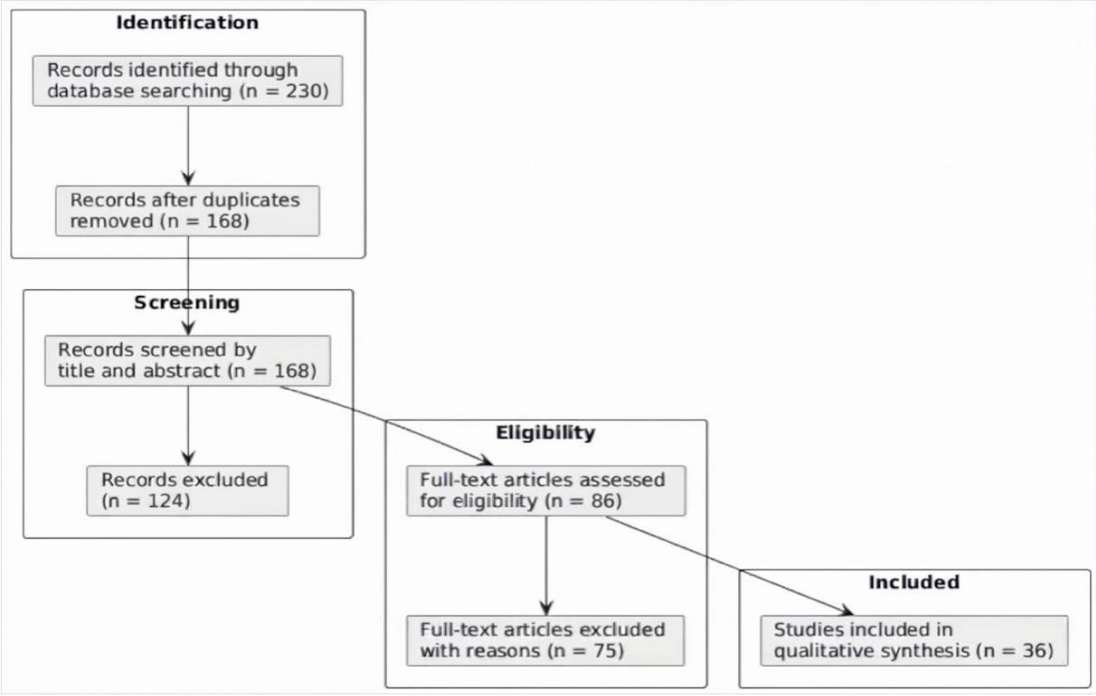


Figure 5. PRISMA Diagram

The diagram above illustrates the systematic flow of the study selection process according to the established PRISMA guidelines. It details the progressive reduction of records from the initial database search through the various screening and eligibility phases. The visual representation highlights the rigorous filtering mechanism applied to ensure the final sample's relevance and methodological soundness. Ultimately, this structured approach guarantees the reliability and reproducibility of the systematic review's findings.

Predominant Pedagogical Strategies in SSI Implementation

The analysis of the selected literature reveals that Problem-Based Learning and Inquiry-Based Learning are the most frequently integrated instructional models for delivering SSI in elementary classrooms. These models provide a structured yet flexible framework that allows young learners to investigate complex, real-world problems collaboratively. Teachers predominantly utilize these approaches to guide students through the stages of issue identification, evidence evaluation, and solution proposal. By embedding SSI within these familiar pedagogical structures, educators can effectively scaffold the learning process without overwhelming the students. Consequently, this integration fosters a more engaging and student-centered learning environment.

In addition to core instructional models, the implementation of SSI heavily relies on specific scaffolding techniques, supplementary educational media, and formative assessments. Digital modules, interactive multimedia, and role-playing activities are frequently employed to make abstract socioscientific concepts more tangible for young learners. Furthermore, traditional multiple-choice tests are increasingly supplemented with rubric-based assessments of oral arguments, reflective journals, and collaborative project outputs to capture the multi-dimensional nature of socioscientific reasoning. The strategic use of these mediational tools and comprehensive assessments is crucial for bridging the gap between complex scientific issues and elementary students' developmental levels.

Table 2. Distribution of Pedagogical Strategies and Instructional Media in SSI Implementation

Instructional Model / Media	Frequency (n)	Percentage (%)	Primary Application Focus
Problem-Based Learning (PBL)	14	42.4	Structured issue investigation and solution design
Inquiry-Based Learning (IBL)	11	33.3	Evidence gathering and hypothesis testing
Role-Playing and Debate	5	15.1	Perspective-taking and oral argumentation
Digital Modules / Multimedia	3	9.1	Contextualization and interactive scaffolding

The table above categorizes the primary instructional models and supplementary media utilized across the reviewed studies to implement SSI. It demonstrates a clear preference for hybrid approaches that combine structured inquiry with interactive digital or physical scaffolding tools. This distribution underscores the necessity of adapting complex pedagogical strategies to suit the cognitive and developmental needs of elementary school students. The data also highlights the emerging trend of integrating technology to enhance student engagement and contextualize socioscientific problems.

Impacts on Scientific Literacy and Socio-Scientific Reasoning

The integration of the SSI paradigm yields significant positive impacts on various dimensions of students' scientific literacy, particularly in critical thinking and argumentation skills. Empirical evidence from the reviewed studies consistently shows that students exposed to SSI-based instruction outperform their peers in traditional settings when tasked with evaluating scientific evidence. They demonstrate a heightened ability to distinguish between facts and opinions, construct logical arguments, and consider multiple perspectives on controversial issues. This cognitive advancement is largely attributed to the authentic and open-ended nature of the socioscientific problems presented to them. As a result, students develop a more nuanced understanding of the nature of science and its societal implications.

Beyond cognitive gains, the SSI paradigm profoundly influences students' affective and moral development, particularly in fostering empathy and ethical reasoning. Engaging with real-world issues such as environmental conservation, animal welfare, or public health prompts young learners to consider the human and ecological consequences of scientific decisions. The literature indicates that this exposure cultivates a stronger sense of environmental responsibility and pro-social behavior among elementary students. Furthermore, the collaborative nature of SSI discussions enhances their interpersonal skills and tolerance for diverse viewpoints. These affective outcomes are essential for nurturing responsible global citizens who can navigate complex moral landscapes

Table 2. Summary of Measured Student Outcomes and Associated Improvements

Outcome Domain	Number of Studies	Reported Magnitude of Improvement
Critical Thinking Skills	24	High (Significant statistical gain)
Scientific Argumentation	21	High (Enhanced structure and evidence use)
Empathy and Moral Reasoning	15	Moderate to High (Increased perspective-taking)
Nature of Science (NOS) Understanding	12	Moderate (Improved view of tentative science)

The table above summarizes the specific cognitive and affective student outcomes measured in the reviewed literature, along with the reported magnitude of improvement. It illustrates that while critical thinking and argumentation skills are the most frequently assessed variables, affective domains such as empathy and moral reasoning show equally substantial gains. This comprehensive outcome profile validates the holistic benefits of the SSI paradigm in elementary science education. The data confirms that SSI instruction effectively addresses both the intellectual and ethical dimensions of scientific literacy.

Implementation Challenges and Contextual Limitations

Despite its documented benefits, the implementation of SSI in elementary schools presents several significant challenges, primarily related to teacher preparedness and pedagogical content knowledge. Many teachers report feeling inadequately trained to facilitate open-ended discussions on controversial or morally ambiguous topics. The transition from a traditional knowledge-transmitter role to a facilitator of complex socio-scientific debates requires a high level of instructional skill and confidence. Consequently, teachers often struggle to manage classroom dynamics, ensure equitable participation, and provide timely, constructive feedback during argumentation sessions. This pedagogical hurdle remains one of the most critical barriers to the widespread adoption of the SSI paradigm.

Furthermore, structural and curriculum-related constraints severely limit the effective execution of SSI-based instruction in primary classrooms. Teachers frequently cite a lack of instructional time, as SSI activities are inherently time-consuming and require extended periods for deep investigation and discussion. The pressure to cover a dense, standardized science curriculum often forces educators to truncate or abandon SSI modules in favor of rote memorization of testable facts. Additionally, the cognitive load associated with processing complex, multi-faceted issues can sometimes overwhelm younger learners if the scaffolding is insufficient. Addressing these systemic limitations requires targeted policy adjustments and the development of more streamlined, age-appropriate SSI resources.

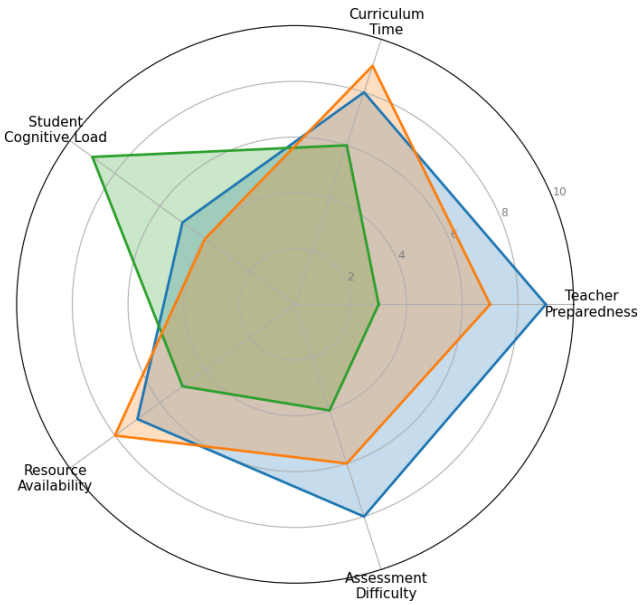


Figure 6. Radar Chart of Implementation Challenges by Stakeholder Perspective

The figure referenced above provides a visual synthesis of the primary implementation challenges categorized by teacher, student, and systemic perspectives. It highlights that teacher preparedness and curriculum time constraints are perceived as the most severe barriers to effective SSI integration. The varying severity levels across different stakeholder groups underscore the multifaceted nature of the obstacles faced in elementary classrooms. Understanding this distribution is crucial for designing targeted interventions and professional development programs to mitigate these specific challenges.

Methodological Trends and Research Gaps

An analysis of the methodological characteristics across the reviewed studies reveals a strong dominance of quantitative research designs in evaluating SSI interventions. The majority of the literature employs quasi-experimental or pre-experimental designs to measure the direct impact of SSI instruction on predefined student variables. These studies typically

utilize standardized tests and validated Likert-scale questionnaires to collect numerical data on scientific literacy and reasoning skills. While this approach provides robust statistical evidence of the paradigm's efficacy, it often overlooks the nuanced, lived experiences of the participants. Consequently, the depth of understanding regarding how students internally process complex socioscientific dilemmas remains somewhat limited.

To address these methodological limitations, a growing subset of recent studies has begun to incorporate mixed-methods and purely qualitative approaches. These studies utilize in-depth interviews, focus group discussions, and classroom observations to capture the dynamic interactions and emergent themes during SSI lessons. Such qualitative inquiries provide rich, descriptive insights into the specific scaffolding moves teachers use and the exact moments students experience cognitive or moral conflict. This methodological shift reflects a broader recognition that the complexities of SSI learning cannot be fully quantified. Future research must continue to balance rigorous quantitative evaluations with deep qualitative explorations to fully map the SSI landscape.

Discussion

The findings of this review indicate that Problem-Based Learning (PBL) and Inquiry-Based Learning (IBL) are the predominant pedagogical strategies for implementing the Socioscientific Issues (SSI) paradigm in elementary science education. This alignment is not merely coincidental but stems from the specific developmental needs of young learners. Elementary students are in a transitional phase from concrete to abstract thinking; thus, they require structured yet flexible frameworks to navigate complex, open-ended SSI. PBL and IBL provide this necessary structure by breaking down multifaceted socioscientific problems into manageable, sequential phases—such as issue identification, evidence gathering, and solution proposal. This step-by-step approach prevents cognitive overwhelm and allows students to systematically construct arguments, making PBL and IBL highly suitable vehicles for SSI at the primary level (Dusturi et al., 2024). Furthermore, the integration of digital media observed in this study strongly supports this suitability, as e-modules and web-based platforms (Rahayu et al., 2022; Shoba et al., 2023) provide the visual and interactive scaffolding necessary to contextualize abstract SSI concepts for young minds. However, as noted by Khusmawardani (2022), overly intricate hybrid models may require excessive scaffolding, indicating that simplified, highly age-appropriate instructional designs are crucial for success.

Beyond the choice of instructional model, the success of SSI implementation is heavily contingent upon specific conditions, primarily the strategic use of scaffolding to moderate cognitive load. SSI inherently involves high cognitive load due to the simultaneous integration of scientific facts, ethical dilemmas, and social implications. For elementary students, processing these complex dimensions can be overwhelming. Scaffolding—through digital modules, role-playing activities, and guided inquiry steps—acts as a critical moderator by chunking complex information into digestible parts. It provides temporary support structures that allow students to engage with higher-order thinking tasks (like evaluating evidence and constructing logical claims) without exceeding their cognitive capacity (Schenk et al., 2021). As students develop competence, this scaffolding is gradually faded. The synthesized data strongly corroborates that when such age-appropriate scaffolding is present, SSI-based instruction significantly improves students' critical thinking and scientific argumentation skills (Broderick, 2022; Putu et al., 2025; Qamariyah et al., 2021; Zulaika et al., 2022). Furthermore, success is amplified when SSI is contextualized around relatable issues, such as environmental conservation or biosecurity, which actively engage young people and cultivate a sense of civic responsibility and empathy (Anjani et al., 2025; Hestiana & Rosana, 2020; Ozden, 2020; Ram, 2020).

Despite the clear benefits of well-scaffolded SSI, this review identifies teacher preparedness as the most critical factor determining implementation success. This is because facilitating SSI requires a fundamental shift in the teacher's role from a traditional knowledge-transmitter to a facilitator of complex, morally nuanced debates. Teachers must possess specific Pedagogical Content Knowledge (PCK) to navigate open-ended discussions, manage diverse student perspectives, and provide timely, constructive feedback during argumentation sessions (Karakas & Eyceyurt, 2022). Without adequate preparation, teachers often struggle with the epistemological and axiological tensions inherent in SSI (Syaflita et al., 2023), leading them to revert to rote memorization or truncate SSI modules to fit rigid curriculum timelines. Therefore, teacher preparedness is not just a supporting factor but a foundational prerequisite; even the most well-designed SSI curriculum will fail if educators lack the confidence and specific skills to guide students through the ambiguity of socioscientific reasoning.

Finally, this systematic review is subject to certain limitations that inform future research directions. Consistent with the observations of Çalık & Wiyarsi (2020) in their review of science-focused SSI, the current elementary education literature is heavily dominated by quantitative, short-term intervention studies. While

Tsalsabillah & Wulandari (2025) have begun to explore student perceptions in elementary settings, there remains a distinct scarcity of longitudinal and purely qualitative studies that capture the nuanced, lived experiences of both teachers and students over extended periods. Future research should therefore prioritize mixed-methods designs and longitudinal tracking to deeply understand how SSI paradigms sustainably shape the socio-scientific reasoning and moral development of elementary students over time, and to further explore the specific mechanisms by which teacher professional development impacts classroom implementation fidelity.

Conclusion

This systematic literature review confirms that the socioscientific issues (SSI) paradigm is a highly effective and transformative framework for elementary science education. The synthesis of recent empirical studies (2015–2025) reveals that integrating SSI with Problem-Based and Inquiry-Based Learning significantly enhances students' critical thinking, scientific argumentation, and moral reasoning. However, the successful implementation of this paradigm is heavily contingent upon age-appropriate scaffolding and the strategic use of interactive digital media to contextualize complex problems. Despite these clear cognitive and affective benefits, the review identifies persistent systemic barriers, notably inadequate teacher preparedness, rigid curriculum time constraints, and the high cognitive load placed on young learners when navigating multifaceted socioscientific dilemmas.

To maximize the potential of SSI in primary education, targeted interventions are urgently needed at both the institutional and policy levels. Educational stakeholders must prioritize comprehensive professional development programs that equip elementary teachers with the specific pedagogical content knowledge and confidence required to facilitate open-ended, morally nuanced debates. Furthermore, future research should move beyond the current dominance of short-term quantitative evaluations. There is a critical need for longitudinal and mixed-methods studies to deeply explore the sustained impact of SSI on students' socio-scientific reasoning over time, and to document the lived, day-to-day experiences of educators as they adapt to this dynamic pedagogical shift.

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Author Contributions
Hairunnisa: Conceptualization, methodology, literature searching, data analysis, and writing—original draft. Ahmad Arifi: Supervision, methodology, critical analysis, and writing—review and editing. Na'imah: Supervision, validation, interpretation of findings, and writing—review and editing. All authors reviewed and approved the final version of the manuscript.

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Conflicts of Interest
The authors declare that they have no conflicts of interest, financial or otherwise, that could have influenced the research, analysis, interpretation, or publication of this manuscript.

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