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Implementing Socioscientific Issues in Biology Education: A Systematic Literature Review of Learning Contexts and Designs

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Abstract. Socio-Scientific Issues (SSI)-based learning can connect biological concepts with real-world problems involving social, ethical, and decision-making dimensions. This study aimed to identify the characteristics and contexts of SSI and map the learning designs and strategies used in biology teacher education. A Systematic Literature Review (SLR) was conducted following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines. The literature was retrieved from Scopus, Web of Science, and Google Scholar using keywords related to SSI, biology teacher education, and instructional design. Of the 600 articles identified, 22 articles published between 2013 and 2026 met the inclusion criteria and were analyzed. The findings showed that SSI was implemented across various issues, particularly climate change, deforestation, microplastics, biodiversity conservation, pollution, energy, public health, vaccination, biotechnology, and genetic engineering. Among the identified learning designs, SSI-based learning was the most frequently used strategy, appearing in 8 articles (36.36%), followed by project-based SSI and debate, each reported in 4 articles (18.18%). The findings indicate that SSI can be adapted through various learning designs to promote active engagement, the use of scientific evidence, argumentation, and decision-making. However, the use of strategies integrating media analysis, inquiry, and decision-making remains limited. This review highlights the need to develop more integrated SSI-based learning designs in biology teacher education.

Keywords: *Socio-Scientific Issues, preservice biology teachers, biology education, instructional design, systematic literature review*

INTRODUCTION

Socio-scientific issues (SSI) represent a contextual approach that integrates science-based controversial issues with social values, ethics, and public policy [1], [2]. In biology education, SSI holds strategic potential to enhance students' scientific literacy through learning experiences relevant to real-life situations. This approach enables students to understand the social dimensions of science and develop critical thinking skills for decision-making [3]. Consequently, the application of SSI in biology instruction can reinforce the role of science as a tool for addressing global challenges such as climate change, genetic engineering, and public health. Therefore, integrating SSI into biology education is increasingly vital amidst the complexities of multidimensional contemporary issues.

Biology education students are prospective biology teachers who play a role in developing students' scientific literacy skills. Scientific literacy encompasses not only an understanding of biological concepts but also the ability to evaluate scientific information and make responsible decisions [4]. Prospective teachers must possess pedagogical and epistemological competence when designing instruction [5]. Strengthening scientific literacy through Socio-Scientific Issues (SSI) relies heavily on the readiness of prospective teachers to integrate the cognitive, affective, and social aspects of the learning process. Consequently, fostering and strengthening the capacity of prospective biology teachers within the context of SSI has become a priority in contemporary teacher education.

Although the SSI approach offers numerous benefits, its implementation in instructional practice faces various challenges, including teachers' lack of understanding regarding the characteristics and structure of SSI, limited learning resources, and resistance to shifting away from conventional approaches [6]. Integrating social and ethical values into science topics often gives rise to sensitive pedagogical tensions [7]. The process of designing instruction presents a complex hurdle for teachers when facilitating classroom discussions; therefore, a systematic evaluation framework is needed to understand the quality and effectiveness of SSI-based instructional designs.

This study aims to systematically examine how SSI-based instructional designs are developed and evaluated in the education of prospective biology teachers. The primary research questions address: (1) the characteristics and context of SSI-based instruction, and (2) the designs and strategies employed in SSI-based instruction. By addressing these questions, the study is expected to make theoretical and practical contributions to the development of more effective and contextual SSI instructional designs.

METHODS

This study employs a Systematic Literature Review (SLR) approach to identify, evaluate, and synthesize research findings regarding the implementation of Socio-Scientific Issues (SSI)-based learning in the education of prospective biology teachers. The SLR approach was selected for its ability to provide a comprehensive mapping of research trends and SSI implementation practices within the higher education context in a systematic and structured manner. The research procedure adheres to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines, which assist researchers in organizing the processes of article identification, screening, and inclusion in a step-by-step and documented manner.

A literature search was conducted using the Harzing's Publish or Perish (PoP) application, drawing from three leading scholarly databases: Scopus, Google Scholar, and Web of Science (WoS). The search employed a combination of keywords: ("Socio-Scientific Issues" OR "SSI") AND ("biology teacher education" OR "preservice biology teachers") AND ("instructional design" OR "learning design"). The article selection process involved three stages: initial identification, screening, and eligibility assessment. The initial identification stage yielded 600 articles from Scopus (200), Web of Science (200), and Google Scholar (200). Subsequently, screening was performed to remove duplicates and assess relevance based on titles and abstracts. At this stage, 353 articles were excluded due to a lack of relevance, resulting in 247 relevant articles. From this pool, attempts were made to access the full text of 86 articles, though 158 could not be obtained. Ultimately, 22 articles were successfully accessed and evaluated for eligibility, while the remaining 64 were excluded for failing to meet inclusion criteria; these 22 articles were then included in the final synthesis and analysis for this review.

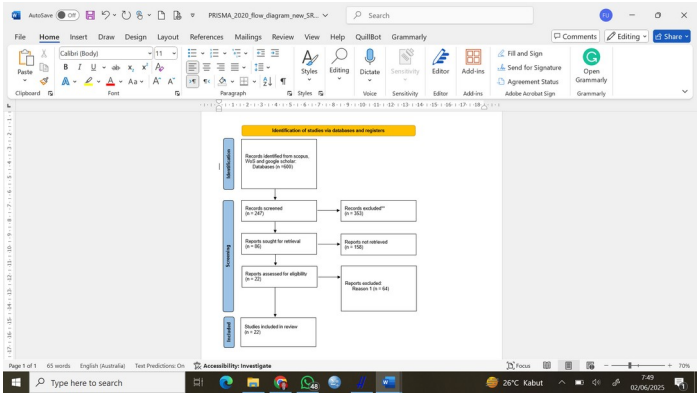

Figure 1. PRISMA protocol flow

Inclusion and exclusion criteria were employed to ensure that the analyzed articles aligned with the study's objective: the implementation of Socioscientific Issues (SSI) in biology and science education. The inclusion criteria were as follows: (1) published between 2013 and 2026; (2) primary research articles; (3) specifically addressing Socioscientific Issues as a context, approach, strategy, or component of instructional design; (4) situated within the context of biology or science education; and (5) providing information regarding the design, implementation process, learning activities, instructional materials, learner or teacher experiences, or learning outcomes associated with SSI application. Research participants could include pre-service teachers, in-service teachers, university students, or K-12 students, provided the research offered relevant information for understanding the design or implementation of SSI-based instruction.

Conversely, articles were excluded if they: (1) were published prior to 2013; (2) were conceptual articles, systematic reviews, scoping reviews, narrative reviews, or articles that did not present primary research findings; (3) discussed SSI solely from a theoretical perspective without providing empirical evidence regarding its application or learning experiences; (4) were unrelated to the context of biology or science education; (5) measured only specific competencies—such as argumentation, scientific literacy, or critical thinking—without providing sufficient information on the context or implementation of SSI; (6) were duplicate publications or versions of the same publication; or (7) did not provide sufficient methodological information and research findings to allow for data extraction and synthesis. These criteria were applied to distinguish articles serving as primary studies in the main synthesis from supporting literature used merely to reinforce the theoretical framework and the interpretation of results.

RESULTS AND DISCUSSION

Characteristics and Contexts of SSI Implementation

A total of 22 articles were collected and selected from a total of 600 articles. Based on the results of a comprehensive analysis of the articles' content, the following data were obtained:

Table 1. Mapping the Characteristics of SSI Research

No.	Author	Year	SSI Topic/Context	Educational Context	Learning Design
1	Sadler et al.	2022	Climate change	Science education	Inquiry-based SSI
2	Ardiyanti et al.	2026	Deforestation	Biology education	Project-based SSI
3	Nofiana et al	2025	Environmental sustainability	Biology/science education	SSI-based learning
4	Wibowo et al.	2023	Microplastics	Biology teacher education	SSI-based learning
5	Jho et al.	2014	Nuclear energy	Science education	SSI-based learning
6	Thomas & Hodson	2015	Fracking	Science education	Case-based learning
7	Tekin et al.	2020	Renewable energy	Teacher education	Case-based SSI
8	Kahn & Zeidler	2020	Public health	Science education	SSI discussion
9	Souza & Mixter	2016	Vaccination	Science education	Debate/role-play
10	Owen & Sadler	2023	Public health	Teacher education	SSI learning scenario
11	Kim & Lee	2020	GMO	Biology teacher education	SSI-based decision making
12	Park & Choi	2017	Biotechnology	Teacher education	Debate and reflection
13	Zeidler & Nichols	2019	Biotechnology	Science education	SSI-based learning
14	Oliveira & Barros	2018	Agriculture	Teacher education	Project-based SSI
15	Méndez-Herranz, M. & V. Cabello	2025	Biodiversity conservation	Teacher education	Project-based SSI
16	Nuraini & Widodo	2024	Tropical forest conservation	Biology education	SSI-based module
17	Maharani & Hatami	2025	Climate change	Teacher education	SSI-based learning
18	Dawson & Venville	2016	Health-related SSI	Science education	Discussion/ argumentation
19	Putri et al.	2025	Water scarcity	Teacher education	Project-based SSI
20	Evagorou et al.	2019	SSI and decision making	Teacher education	SSI-based learning
21	Lin et al.	2016	Air pollution	Science education	News/media-based SSI
22	Zhang & Liu	2022	Environmental issues	Biology/science education	SSI-based learning

Based on the 22 studies mapped, Socioscientific Issues (SSI) are utilized in various biology and science learning contexts that relate closely to everyday life issues. The issues identified include climate change, deforestation, microplastics, biodiversity conservation, air pollution, nuclear and renewable energy, public health, vaccination, as well as biotechnology and genetic engineering. This diversity demonstrates that SSI can be applied to a wide range of science topics, provided the selected issues link to scientific knowledge while simultaneously prompting social and ethical considerations or decision-making processes [8]–[9]. In the context of biology education, this characteristic is crucial because many biological issues facing society cannot be understood solely through scientific concepts; they also require consideration of values, interests, and the social consequences of decisions [2], [10], [11].

Environmental and sustainability issues appear to be among the most frequently utilized contexts in the reviewed studies. Topics such as climate change, deforestation, microplastics, water scarcity, air pollution, and biodiversity conservation serve as contexts for integrating real-world issues into the learning process [12]–[13]. Selecting these issues enables learners to connect scientific concepts with their surrounding environmental conditions while simultaneously considering various alternative solutions to problems. For instance, the issue of microplastics relates not only to the concept of pollution but also to human behavior, waste management, and ecosystem impacts [14]. Similarly, issues regarding conservation and environmental change can be used to encourage learners to understand the relationship between ecological processes and human decisions concerning resource management [12], [13].

In addition to environmental issues, some studies utilize topics related to energy, health, and biotechnology as contexts for SSI. Issues such as nuclear energy, renewable energy, vaccination, public health, GMOs, and genetic engineering provide opportunities for learners to weigh scientific evidence against the various consequences of available choices [15]–[16]. With such issues, learners encounter problems that do not necessarily have a single correct answer; consequently, the learning process must allow them to compare information, consider diverse perspectives, and justify the decisions they make. This distinguishes SSI from instruction that merely uses issues as illustrative examples for concepts, as the issues themselves become integral to the learners' thinking and decision-making processes [8].

Another interesting aspect of the reviewed studies is that SSI is not merely used to enhance conceptual understanding but is also directed toward developing broader competencies. Several studies link SSI-based learning to scientific literacy, argumentation, critical thinking, decision-making, ethical reasoning, and ecological awareness [10], [14], [15], [17]. These findings indicate that the strength of SSI lies in its ability to connect scientific knowledge with how learners understand and respond to real-world issues. Thus, the SSI context serves not just as a backdrop for learning but as a starting point for developing the ability to apply scientific knowledge when addressing complex problems. In biology education, this approach offers an opportunity to make learning more meaningful, as the concepts studied are directly linked to issues concerning the environment, health, technology, and society.

Learning Designs and Strategies for Implementing SSI

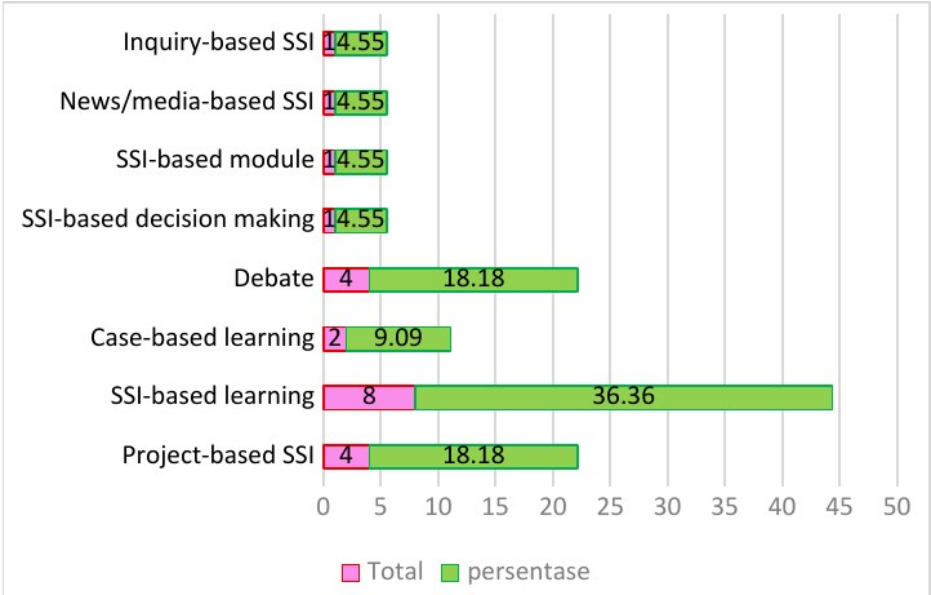

Figure 2. Instructional design in the implementation of SSI

A mapping of 22 articles reveals that the implementation of Socio-Scientific Issues (SSI) employs diverse learning designs and strategies, with "SSI-based learning" being the most prevalent approach. This strategy appears in eight articles—approximately 36.36% of the total—indicating that SSI is frequently positioned as the core foundation of the learning process rather than merely a supplementary element [1], [18]. Project-based SSI and debate-based approaches each appear in four articles (18.18%), demonstrating that SSI is also frequently developed through activities that actively engage learners in exploring issues and considering multiple perspectives [19]. Meanwhile, case-based learning is utilized in two articles (9.09%), whereas SSI-based decision-making, SSI-based modules, news/media-based SSI, and inquiry-based SSI each appear in only one article (4.55%). These patterns indicate that SSI implementation tends to emphasize active learner engagement in understanding real-world problems, applying scientific knowledge, and considering the social consequences of an issue.

The prevalence of SSI-based learning is understandable, given that this approach offers considerable flexibility for integrating SSI characteristics into various learning activities. In this approach, socioscientific issues serve not merely as context or examples but as integral components of the processes of conceptual understanding, problem analysis, information evaluation, and decision-making [9], [20]. The use of project-based SSI and debates further demonstrates a shift toward activities that require learners to articulate reasoning, weigh evidence, and engage with diverse perspectives [21] [22]. Strategies such as case-based learning, inquiry-based SSI, and news/media-based SSI broaden the scope of learning experiences by linking educational topics to real-world cases, investigations, and information circulating in society [23], [24]. Thus, this variety of instructional designs illustrates that SSI is not confined to a single learning model but can be adapted to suit specific learning objectives, learner characteristics, and the nature of the issues being addressed.

Another finding is the limited use of strategies specifically emphasizing decision-making, module development, and the utilization of news or media as learning resources. Each of these strategies appeared in only one article; consequently, their prevalence in the analyzed literature remains relatively low compared to SSI-based learning, project-based SSI, and debate. Nevertheless, decision-making is a crucial component of SSI learning, as the nature of socioscientific issues requires learners to weigh scientific evidence, values, consequences, and various interests before adopting a stance [22], [25]. This situation presents an opportunity to develop SSI learning designs that integrate multiple strategies—for instance,

combining news analysis with inquiry, debate, and evidence-based decision-making. Such integration has the potential to move SSI learning beyond mere issue comprehension, encouraging learners to evaluate evidence, construct arguments, consider social and scientific consequences, and make justifiable decisions [9], [23].

Prior SSI scholarship also emphasizes perspective-taking, project- and module-based implementation, and 5E-framed instruction as complementary routes for structuring issue-based learning [26], [27], [28], [29], [30].

CONCLUSION

The review of 22 articles shows that Socio-Scientific Issues (SSI)-based learning has been implemented across a range of issues closely related to everyday life and societal development. Environmental and sustainability issues, including climate change, deforestation, microplastics, pollution, water scarcity, and biodiversity conservation, were among the most frequently used contexts. In addition, issues related to health, energy, vaccination, biotechnology, and genetic engineering were used to connect biological knowledge with social concerns and decision-making. The diversity of these contexts indicates that SSI can be applied flexibly, provided that the selected issues are scientifically grounded and involve social, ethical, or decision-making considerations.

The learning designs and strategies identified across the 22 articles showed that SSI-based learning was the most frequently used strategy, appearing in 8 of the 22 articles (36.36%), while project-based SSI and debate were each reported in 4 articles (18.18%). Other strategies included case-based learning, SSI-based decision-making, SSI-based modules, news/media-based SSI, and inquiry-based SSI. These findings indicate that SSI implementation is not dependent on a single learning model but can be adapted to learning objectives, learner characteristics, and the complexity of the issues addressed. These diverse designs provide opportunities for learners to understand concepts, evaluate information, articulate reasons, consider different perspectives, and make evidence-based decisions.

This review also highlights opportunities to develop more integrated SSI-based learning designs. Strategies that specifically emphasize decision-making, the use of news or media, and module development remain limited in the reviewed literature. Future research could therefore develop SSI-based designs that integrate several strategies, such as news analysis, inquiry, debate, and evidence-based decision-making. In biology teacher education, such integration is important because preservice teachers need not only to understand biological concepts but also to gain experience in designing and facilitating learning that enables students to address complex scientific issues critically and responsibly.

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