A Systematic Literature Review of Socioscientific Issues in Science Education: Integration and Instructional Effect in Science Learning

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Abstract

Socioscientific issues (SSI) have become a familiar topic in science education. Research on SSI is widely found in various literature, highlighting its growing importance. This review aims to analyze and categorize the development of SSI over the past seven years, including its integration and contribution to science learning and its impact on learners. Employing the 4-step PRISMA-P process, this review identified 74 relevant journal articles from the Scopus Open Access database. The findings reveal that these 74 articles, drawn from 43 Scopus journals, predominantly cover ecosystems and environmental change, biotechnology, energy sources, and biodiversity. Standard learning components used to support SSI in science education include various methods, approaches, models, and teaching media. This review also notes the dominant involvement of learners in SSI education, with instructional and follow-up impacts reflected in their knowledge, skills, and attitudes. Therefore, integrating SSI topics into science education is crucial for learners to understand scientific issues impacting social life.

Introduction

Education in the 21st century has undergone rapid changes in line with advancements in science and technology. This condition reflects a new paradigm in 21st-century education: a transformation in the education system heavily reliant on technology and skill demands [1]. Herein, education becomes the spearhead of a nation's progress, emphasizing the importance of all communities' access to quality education, enabling them to compete internationally. A significant focus is also placed on science education, which contributes substantially to 21st-century education. Broadly, science education positions learners as members of a democracy involved in functional science literacy [2]. To enhance the quality of science education, learners need to be equipped with adequate knowledge, experience, and skills for global competition. Learners must improve the skills required in the 21st century [3]. Moreover, integrating learner abilities such as independence, collaboration, critical and creative thinking, problem solving, self-efficacy, and meaningfulness in science learning is essential [4]. Learners as students should not only master textual knowledge but also contextual knowledge that can be widely applied in the social realities of community life.

In science education, it is hoped that learners will actively participate in addressing environmental and social issues from a scientific perspective. Therefore, to realize this aspiration, teachers must innovate, and learners should be given opportunities for direct learning experiences [5]. Critical elements of science education include developing knowledge, skills, and attitudes. These abilities are crucial for students to address real-world science issues and engage in the urgency of resolving Socioscientific Issues (SSI) [6]. Aligning with 21st-century competency mastery, students must understand scientific content and current global trends, enabling them to apply scientific contexts in daily social life. For instance, in recent years, projects initiated by the European Union have focused on introducing scientific literacy by involving SSI [7]. Integrating scientific issues into society or the context of Socioscientific Issues offers potential as a discussion topic in science education. Socio-scientific problems involve complex issues in real-life situations grounded in relevant science and have scientific, ethical, and social implications [8], [9]. Usually, the problems raised in SSI are controversial issues requiring the involvement of various related fields. Problems in socio-scientific (SSI) involve the deliberate use of scientific topics, requiring students to engage in dialogue, discussion, and debate [8]. Socioscientific Issues (SSI) present science issues closely related to social dimensions.

The importance of SSI teaching, as demonstrated in several studies in Turkey and at the international level, where SSI is used in contexts to achieve other goals and is related to science education [10]. Debates and controversies are viewed from various socio-scientific perspectives in the resolution process. Educators use SSI topics in science teaching for specific reasons. SSI topics place science in the everyday context of students, revealing the effects of science felt by society, both positive and negative. To build students' competencies in responding to SSI, education should emphasize the urgency of social issues connected to science, from personal to global scopes, involving ethical considerations and conflicts of interest [11]. Discussing SSI topics allows students to offer informal reasoning based on unique conceptual understanding [12]. Students' knowledge of relevant scientific content is crucial to comprehend and negotiate SSI. However, some studies show that students rarely apply scientific content in their reasoning activities [13]. With a good understanding of scientific content, students might find it easier to engage in SSI contexts [14]. Therefore, students involved in SSI learning should have a good understanding of scientific concepts to provide the best arguments and solutions.

The importance of socio-scientific argumentation in SSI decision-making and its relation to the nature of science. Hence, understanding the nature of scientific knowledge and how it is
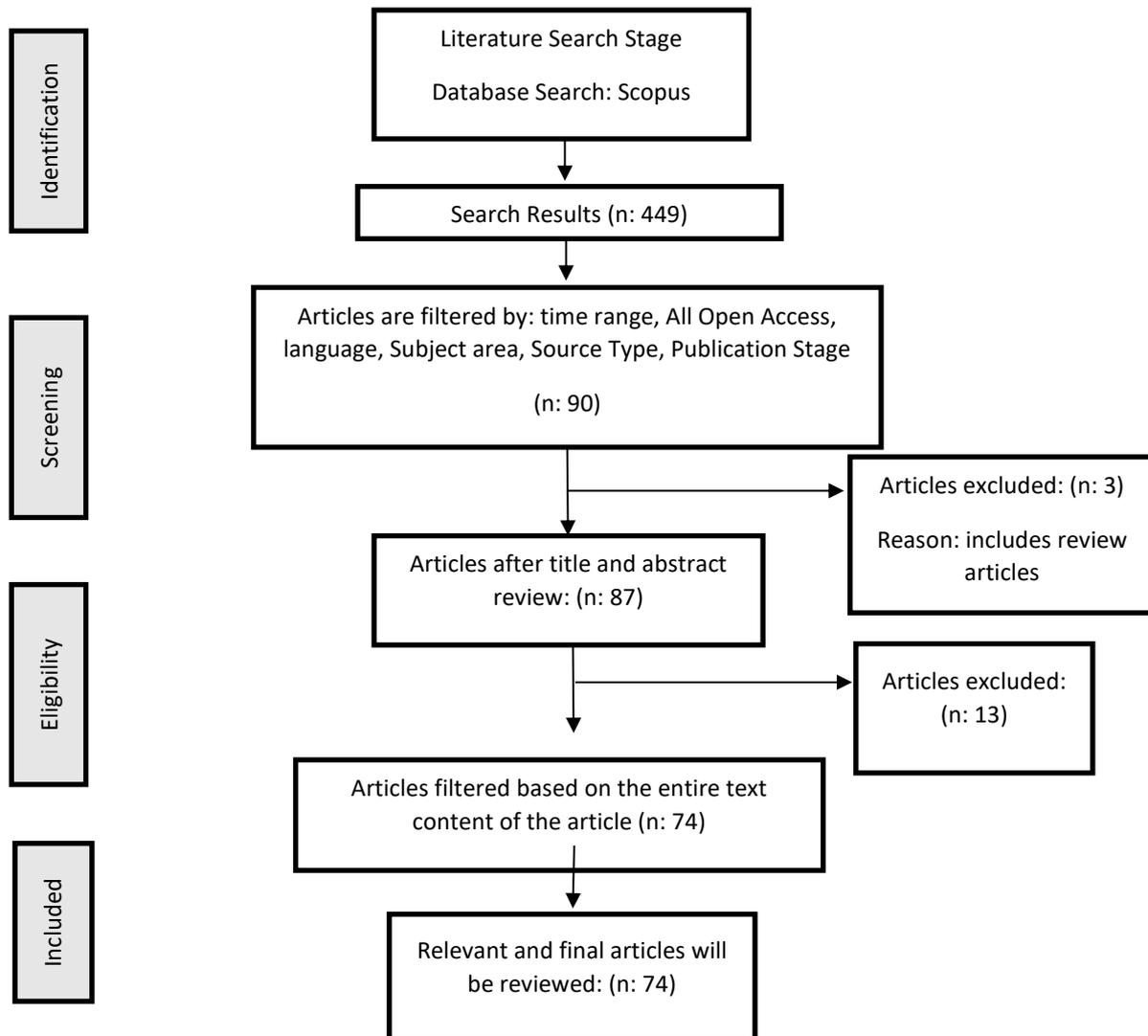
produced is vital in negotiating and making decisions on SSI [15]. This is supported by another study finding that when students are presented with internet news, they respond with an SSI scientific perspective and uncritically use scientific arguments contextualized within interest groups [16]. Additionally, moral sentiment significantly influences students' ethical decision-making beyond rational arguments [17]. It is crucial to emphasize the ethical aspect in handling socio-scientific contexts, particularly conceptualizing morality and its development. However, other review studies indicate that not all research uses the four-component model of character in concrete character conceptualization, often overlooking moral situational awareness [18]. Furthermore, scientific content knowledge can enhance students' understanding of debates and the consequences of different actions [19]. SSI contexts can sharpen high-level thinking skills and generate student interest [20].

Integrating SSI into science education is an effective way to familiarize students with being responsive and caring towards their environment. In ongoing efforts, this education becomes a way to respond to the unbalanced environmental challenges due to human actions [21], [22]. An essential SSI topic in science discussions is Biodiversity. According to Reliantoro [23], Biodiversity is a primary topic in G-20 meetings because 1 million plant species worldwide are threatened with extinction. Indonesia, for instance, has committed to ratifying the biodiversity convention and initiated conservation efforts on 22 million hectares of land by 2020. From a scientific perspective, conservation is crucial for the survival of various species. Conservation efforts continue to ensure the existence of biodiversity and a safe living environment. Additionally, focusing on the social aspect can significantly impact conservation efforts. A review of SSI trends in science education publications from 2004 – 2022 in the Web of Science database shows increased SSI publications, hot SSI topics, SSI teaching focus, and the values presented in SSI teaching, generally and quantitatively [24]. Another study reveals that science literacy among the Spanish population has not considered differences in the community members' backgrounds in interpreting socio-scientific issues [25].

Despite the popularity of discussions surrounding Socioscientific Issues (SSI) contexts, more detailed information still needs to be provided concerning the integration of SSI and its impact on learning within science education. Consequently, this review focuses on three pivotal questions: Firstly, it seeks to identify and explore the Socioscientific Issues that have been the research subject over the past seven years. Secondly, it aims to determine the components that facilitate successful learning integration of SSI contexts in science education. Finally, the review examines the instructional approaches and their consequent effects on students from incorporating SSI contexts into science education.

Methods

This systematic review focuses on research articles published in the last seven years, specifically from 2017 to 2023, with a concentration in science education. The review employs the PRISMA model, encompassing four steps [26], [27]. The stages in the PRISMA model include 1) Identification, involving the literature search relevant to the research; 2) Screening and filtering literature according to criteria set by the author. 3) Eligibility, selecting articles filtered in alignment with the theme determined by the author, and 4) Inclusion, incorporating articles and determining those utilized for the review. The specific stages of the PRISMA model are illustrated in Figure 1 below

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┌─────────────────┐        ┌──────────────────────────────┐
│                 │        │      Literature Search Stage   │
│  Identification │        │                                │
│                 │        │   Database Search: Scopus      │
└─────────────────┘        └──────────────────────────────┘
                                         │
                                         ▼
                           ┌──────────────────────────────┐
                           │   Search Results (n: 449)      │
                           └──────────────────────────────┘
                                         │
                                         ▼
                    ┌──────────────────────────────────────────┐
                    │  Articles are filtered by: time range,     │
                    │  All Open Access, language, Subject area,  │
                    │  Source Type, Publication Stage            │
                    │              (n: 90)                       │
                    └──────────────────────────────────────────┘
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Identification

Screening

Eligibility

Included

Literature Search Stage

Database Search: Scopus

Search Results (n: 449)

Articles are filtered by: time range, All Open Access, language, Subject area, Source Type, Publication Stage (n: 90)

Articles after title and abstract review: (n: 87)

Articles excluded: (n: 3)

Reason: includes review articles

Articles excluded: (n: 13)

Articles filtered based on the entire text content of the article (n: 74)

Relevant and final articles will be reviewed: (n: 74)

Identification. In the identification stage, literature is sourced from the Scopus database due to its holistic journal scope, ease of access through keyword usage, and coverage of various disciplines. The search for journal articles in the Scopus database using keywords such as "socioscientific issues science" yielded 449 articles.

Screening during the screening stage, not all literature identified in the Scopus database is utilized, leading to the exclusion of specific articles. Articles deemed irrelevant and excluded are those on socioscientific issues that do not comply with the author's stipulations. Relevant articles are selected by checking titles, abstracts, and the overall content of the articles.

Initially, a search limited to 2016 – 2023 (last seven years) identified 273 document articles. Further constraints included All Open Access, Publication Stage: Final, Source Type: Journal, Language: English, and Subject areas: Social Science, Environmental Science; Biochemistry, Genetics, and Molecular Biology. After these limitations, 90 document articles on socioscientific issues in science education were obtained. A further filter excluded 3 review articles for research articles, leaving 87 document articles for review.

Eligibility. Articles identified and filtered needed to be thoroughly checked for text content. The papers definitively used were then grouped according to the author's stipulations. The classification is based on socioscientific issues integrated into science education. After grouping, 13 articles were excluded for not relating to the research topic, resulting in 74 pieces ready for review.

Included. The inclusion stage follows the previous three identification, screening, and classification stages. The final inclusion of articles chosen and relevant for review amounts to 74. The four-step process applied in selecting pieces for this review is depicted in Figure 1

Result And Discussion

Based on a systematic review of research conducted regarding socio-scientific issues in science education from 2016 to 2023, the findings are as follows: In the last seven years, numerous research articles on socio-scientific topics in science education have been published in Scopus-indexed international journals. Journals that frequently feature articles on socio-scientific issues in science education are illustrated in Figure 2.
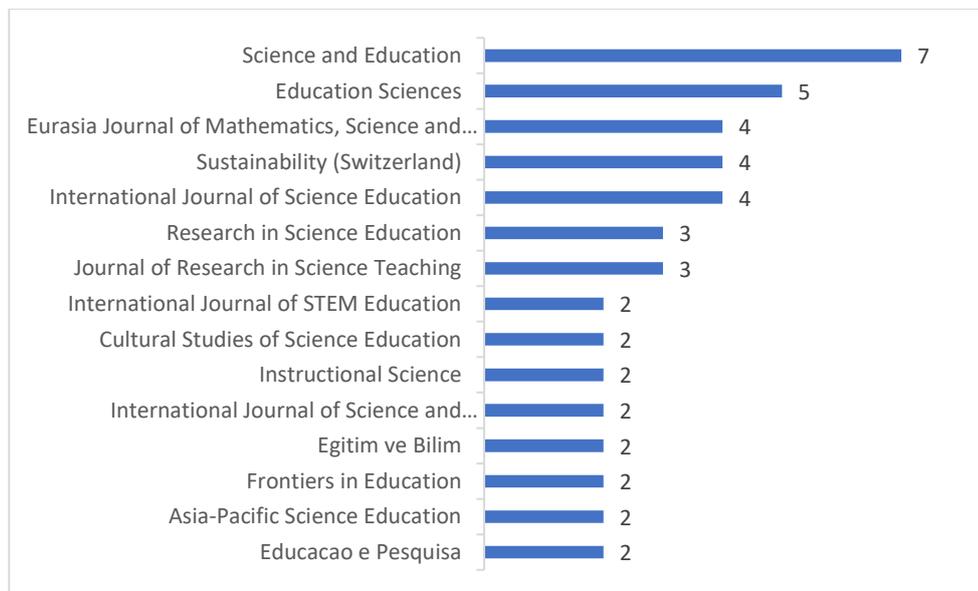

Figure 2. Journals Publishing Articles on SSI in Science Education

Seventy-four articles from all open-access journals from 43 Scopus database journals were reviewed. However, 28 journals each published only one writing on SSI. Thus, their names are not included in this diagram. Figure 2 shows 15 journals that have published more than one article on SSI in science education. Among them, the journal Science and Education has published the most articles on SSI in science education, totaling seven. Following this, 'Education Sciences' has published five articles on SSI in science education. It is also observed that eight journals have published the fewest articles on SSI in science education, with only two pieces each. All published articles in these journals characteristically focus on themes related to socio- scientific issues in science education, which are intriguing, including the most researched and globally significant cases in recent years. The detailed socio-scientific issues in science education are depicted in Figure 3 and Table 1
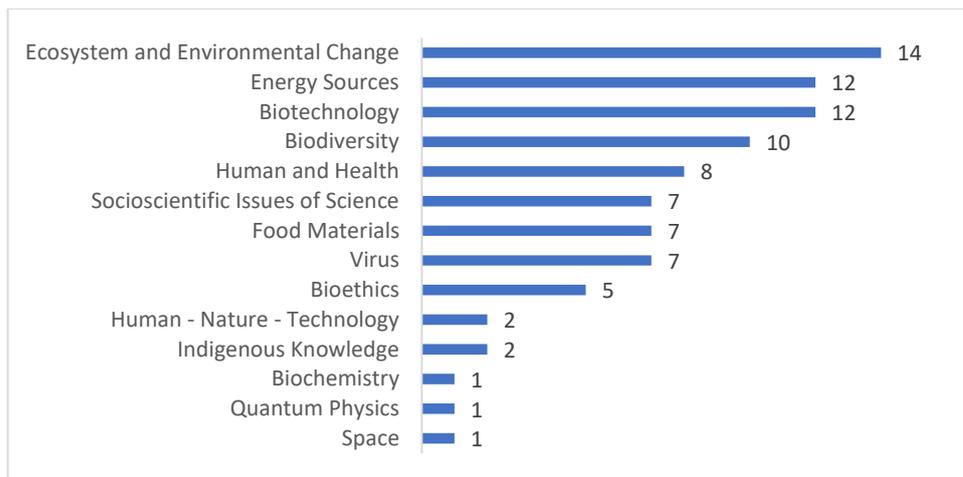
Figure 3. Major Topics of Socio-Scientific Issues in Science Education

Figure 3 identifies 13 significant themes of socio-scientific issues from the 74 articles. The articles' most dominant issues are ecosystems and environmental change, covering 14 specific socio-scientific topics. Following this are biotechnology and energy sources, each comprising 12 particular cases, and biodiversity encompasses 10 topics. Additionally, there are three socio-scientific issues with the least number of specific subjects, namely biochemistry, quantum physics, and space science. The particular issues selected within each SSI theme are detailed in Table 1.

Table 1. Selected Topics Related to SSI in Science Education

No	Topics Socioscientific Issues in Science Education	Topics Selected Related to Socioscientific Issues in Science Education
1	Virus	COVID-19 Virus (Pathogenic Virus); COVID-19 pandemic; Zika virus; Genetic Testing; The global COVID-19 pandemic caused by the SARS-CoV-2 virus was published on social media; How to deal with viruses during the Covid-19 pandemic; the relationship between 5G technology and Covid 19
2	Biotechnology	Bacterial resistance to antibiotics; Gene Therapy Cases; SSI in the context of abortion (genetics and biotechnology); genetic diagnostic tests; Genetically engineered organisms, hereditary disorders, and complex human traits; Genetically Engineered Organisms (GMO); Reproductive Technology assisted by Invitro Fertilization (IVF); Stem Cells; HPV Vaccine Issues; Cloning; vaccination; GMF
3	Biodiversity	Wolves in Sweden and Biodiversity; Biodiversity and citizenship; prairie dog conservation; Biosecurity (biosecurity) for the economy, environment, and society; conservation and zone management coastal, and environmental policy in Puerto Rico; Conservation and Management of mountain lions; Biology Exhibition at the Science Museum; Forest Depletion; Beach Care; Water conservation; dolphinarium
4	Ecosystems and Environmental Change	Climate change; Limnology ecology and ecosystems; Pollution, ecology, environment; Climate and anthropogenic changes in marine ecosystems; Wolf reintroduction to the Yellowstone ecosystem and scientific and sociocultural themes; plastic pollution; global warming; space pollution; Climate Change --> ecological, social and economic demands; Human role in global climate change; local coastal environmental situation, marine ecosystem; The problem of environmental toxins in fatty fish from the Baltic Sea; The issue of ecological impacts due to nitrates in rivers Raccoons; Kyoto Protocol
5	Foodstuffs	Artificial food additives; Artificial meat products; world food supply; food insecurity; Bottled water; Food Preservation; Organic agriculture
6	Energy sources	Illegal use of electricity; world energy supply; Hydroelectric power plant; Nuclear power plant; energy resources and the environment; biofuels; wind energy; electrical energy; mining; Nuclear Power: closure of nuclear power plants in Spanish; power plants
7	Humans and Health	diseases and endocrine disruptors, the obesity epidemic; cholesterol; Neuroscience, Alternative medicine; Preventing Brazilian teen pregnancies and our world's sustainability, BMO Sustainability Gallery in Canada; Health and lifestyle, sex education (human sexuality); Physiology of Obesity - exercise; musculoskeletal, circulatory, and digestive systems;
8	Bioethics	Animal testing issues; Experimental Animals; use of animals for scientific research; ethics of experimentation on animals; environmental ethics
9	Indigenous Knowledge	indigenous science in Baduy society (Indonesia); agriculture, medicine, natural dyes, household chemicals, renewable energy,

No	Topics Socioscientific Issues in Science Education	Topics Selected Related to Socioscientific Issues in Science Education
		and astronomy; Traditional vegetable pesticides (Ethnochemical context in the Baduy indigenous community)
10	Human-Nature-Technology	Relationship between man-natural environment and Man - technology; Human and environmental interaction
11	Space	space—technology, environment, economics, and public policy
12	Quantum Physics	Quantum Physics and quantum computers
13	Biochemistry	Biochemical aspects and context of SSI
14	Socioscientific Issues of Science	Complex SSI Problems in a Transdisciplinary Context; science; use of knowledge sources about SSI and attitudes towards SSI; 4 aspects of SSI, namely: (a) introduction of SSI, (b) argumentation in the context of SSI, (c) operationalization of SSI, and (d) science communication; Conceptualization of SSI; Nature of Science; Mapping controversies on science education issue-based in Class --> actor-network theory (ANT) in Science Class

Table 1 shows that the SSI themes of ecosystems and climate change are most frequently discussed. These themes relate to the current global realities of climate instability, global warming, and environmental pollution impacting ecosystem balance. Other prominent SSI themes include biotechnology, closely related to genetic engineering in organisms, and energy sources, focusing on power generation and renewable energy. The topic of biodiversity extensively covers world biodiversity conservation. These topics form the subject matter in SSI science education. The review article involves several subjects critical to implementing science education for research purposes. More details on the issues involved in SSI science education learning can be found in Figure 4.
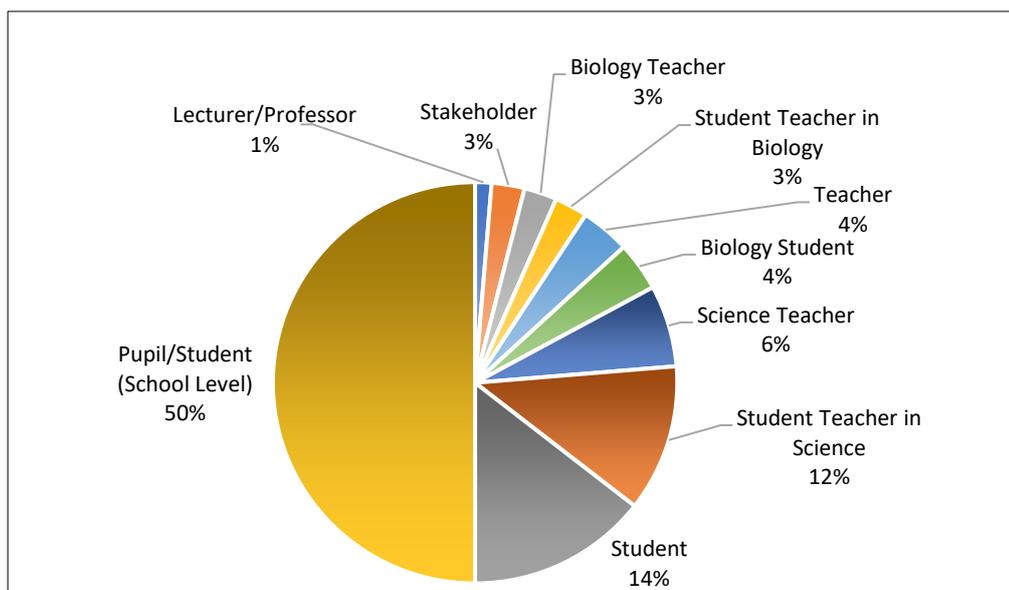

Figure 4. Research Subjects in SSI Science Education Learning

Figure 4 illustrates that students are the most involved subjects in SSI learning, accounting for 50%. Students are the central focus of teachers and are true learners. On the other hand, the smallest percentages, 3% and 4%, are attributed to biology student teachers, biology teachers, stakeholders, and biology students and teachers. Teachers and students are focused on SSI in science education in competence development workshops. For the success of SSI science education learning, several learning components must interact positively to ensure an effective and efficient learning process [28]. For instance, integrating local content into the details of models, media, teaching materials, and learning resources can enhance students' competencies, character, and skills [29]. The

journal article review identified several important learning components used in SSI science education, as shown in Figure 4
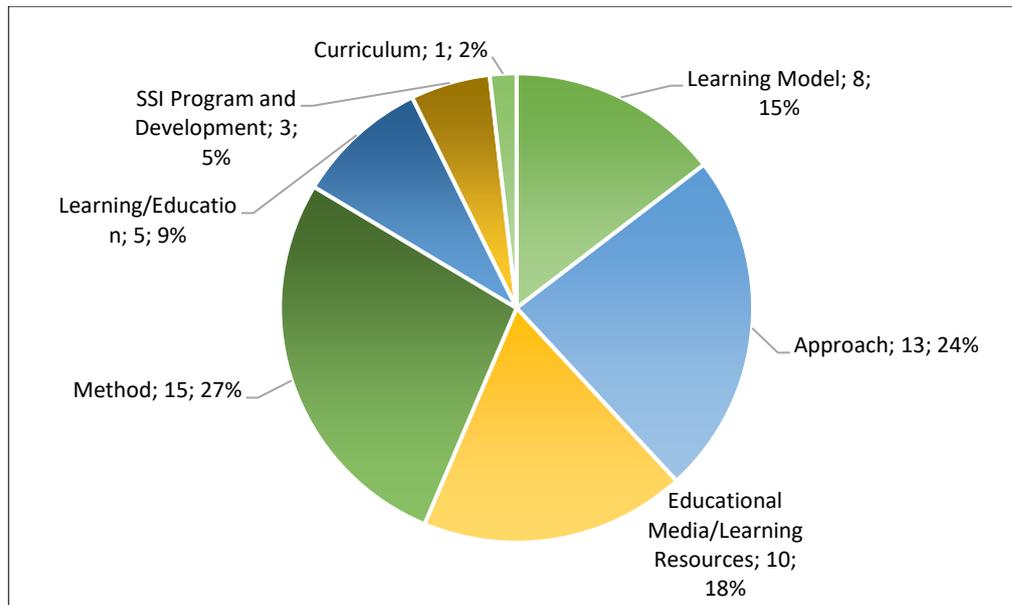

Figure 5. Learning Components Used in SSI Science Education

Figure 5 presents various learning components in the reviewed articles related to SSI science education. The learning method and approach components contribute significantly, accounting for 27% and 24%, respectively. Educators should carefully align the chosen learning methods with the fundamental goals of science education: learning science, learning about science, conducting science, and addressing socio- scientific problems. For instance, educators should use inquiry-oriented approaches to facilitate effective science learning [30].

Furthermore, the components of the curriculum and SSI programs and development are among the lowest percentages, at 1% and 5%, respectively. Future science education requires the development of creative and enjoyable curricula that emphasize thought, content, and integrated material organization within a project [31]. The context of SSI should be integrated into the science curriculum to enhance scientific literacy, knowledge exploration, and values in social issues through student-centered activities [32]. Integrating SSI presents challenges in teaching, particularly regarding the teacher's role as a knowledge transmitter [33], [34]. Consequently, educators must redesign their teaching approach. Educators should identify appropriate learning components when teaching SSI to students according to the SSI's characteristics. The reviewed articles suggest that SSI needs to be more integrated into curricula and SSI programs and their development. For more details, the specifications of the learning components selected for SSI science education are listed in Table 2.

Table 2. Specifications of Components Involved in SSI Science Education Learning

No	Components Learning	Specifications Learning components used in SSI learning
1	Learning model	DM Fractal Model (Decision making); The SEE-SEP model (science, environment, ethics/morality, sociology/culture, economics, and policy) was adopted to explore the reasons behind prospective teachers' decisions; comprehensive SSI PD model; Case Based Learning Model; Socioscientific Argumentation Model; Role Playing Games (RPG); Metacognitive Problem-based learning (MPBL); ENACT Model (Engage, Navigate, Anticipate, Conduct, and Take action)

No	Components Learning	Specifications Learning components used in SSI learning
2	Approach	STSE Approach; Dialogic Inquiry for Socioscientific and Conceptual Understanding in School Science (DISCUSS) approach based on SSI; teaching approach based on socioscientific issues; authoritative communicative (dialogue) approach; STS approach; Contextual approach and context-based learning; SSIBL-STEAM program approach, SSIBL (sociality, morality, emotions); interdisciplinary approach; contextual approach; systemic teaching approach; Open and guided inquiry pedagogical approach; Reflective practice; Critical Reflection Approach through Epistemic Process; STEM approach
3	Method	Group discussion; Fiction story narrative scenario method; Exploration of the use of knowledge sources; Direct experimental methods and interactive computer simulations; Individual performance and group performance; small group discussions; Debate method; Role Play Method; Critical Integrative Argumentation; Task; Exercise; Online Search; semi-structured interviews; presentation
4	Instructional Media	Biosecurity Poster Media; cartoon media; dilemma card; Argument Concept Cartoon; Demonstration video; Meet; SPADA; SSI digital mapping tools; digital tools and media such as Gephi visualization software; SSI exhibition at the Catavento Museum
5	Learning	Lectures; Teaching Practices in the Classroom; Dialogic classroom practice; SSI Based learning; Place-based SSI teaching
6	SSI program and development	Research-based SSI instruction program; The Science Education Program for Public Understanding System (SEPUP), Next Generation Science Standards (NGSS) Guidelines; professional development programs focused on STEM and SSI literacy practices
7	Curriculum	STEM Curriculum

Table 2 details the variety of learning component specifications chosen for SSI science education, including learning models (like the Fractal DM Decision-Making Model and the SEE-SEP Model for exploring teacher candidate decisions), approaches (such as the STSE Approach and Dialogic Inquiry), and methods (group discussions, narrative scenario methods, and individual and group performances). Finally, Figure 6 depicts the competency domains achieved by students in SSI learning.
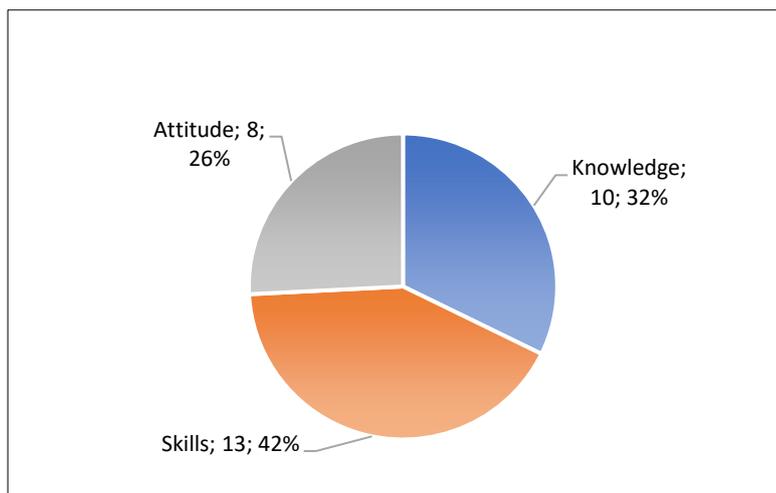

Figure 6. Competency Domains Achieved by Students in SSI Learning

Figure 6 shows the instructional impact on students after participating in SSI science education. The highest competency mastery is in the skills domain, with a 42% percentage. For student teachers, mastering these skills is crucial to becoming efficient 21st-century educators [35]. The other competencies include knowledge and attitudes, with 32% and 26%, respectively. The knowledge domain encompasses learning skills related to mental thinking processes [36]. The right instructional design is essential to develop students' knowledge, attitude, and skill abilities. For example, students' conceptual understanding can be improved through discovery learning integrated with learning media [37]. Moreover, instructional strategies integrating religion and science positively impact students' character-building and attitude formation [38]. Thus, developing student competencies requires a balance of knowledge, skills, and attitudes.

Detailed achievements of student competencies in each domain related to SSI in science education are listed in Table 3.

Table 3. Domains and Aspects of Student Competency Mastery

No	Competency Domain	Aspects of Students' Competency Mastery
1	Knowledge	Conceptual understanding; High-level thinking; Conceptual perception; Complexity of reasoning; Students' conceptions and thinking; Scientific and informal reasoning in science education; Environmental literacy skills; Science literacy skills; Students' ability to evaluate information based on three main criteria: the presence of new information, presentation style, and relevance to issues; Application of scientific knowledge in real-world contexts
2	Skills	Argumentation skills; Decision-making competencies; Science literacy; Problem-solving; Creative and structured thinking; Mitigation actions towards socioscientific issues; Developing critical thinking skills through cognitive empathy; Communication; Students' reflective abilities; Enhancing prospective science teachers' skills in assessing SSA (Socioscientific Argumentation); Project execution skills through exploration; Digital literacy; Encouraging students to engage in productive collaborative negotiations on understanding a controversy
3	Attitudes	Ethics/morality in decision making; Situational interest; Positive attitude; Curiosity; Developing students' positive emotions; Independence; Convergence; Increased social responsibility leading to a more significant commitment to resolving SSI

Table 3 presents a detailed breakdown of student competency domains in the context of Socioscientific Issues (SSI) education, emphasizing the multifaceted nature of learning outcomes in science education. The Knowledge domain includes critical aspects like conceptual understanding and high-level thinking, highlighting the shift towards nurturing complex reasoning and environmental literacy skills among students [39]. As a separate domain, skills cover a broad range of competencies, including argumentation skills, decision-making, and problem-solving abilities, underscoring the importance of equipping students with practical skills for addressing real-world socioscientific issues. The Attitudes domain encapsulates ethics in decision-making and situational interest, focusing on shaping students' perspectives and values about SSI. This table illustrates the comprehensive approach to SSI education, where the goal is to impart scientific knowledge and develop critical thinking, practical skills, and responsible attitudes among students, preparing them for the complexities of contemporary social challenges.

Conclusion

The findings from the 74 reviewed articles on SSI in science education are highly informative for global development. SSI topics in science education are crucial for students to understand, as they closely relate to scientific issues impacting social life. SSI topics in science learning often provoke debates among students regarding argumentation, decision-making, and morality. Students' formal and informal reasoning skills also lead to new understandings in resolving SSI problems, considering scientific and social perspectives. Sometimes, scientific views cannot be reconciled with social attitudes, and vice versa. Therefore, effectively teaching SSI to students requires attention to several important aspects: the SSI topics discussed, the involved subjects, the used learning components, and the expected competency achievements. All these aspects must be harmonized for effective and contextual learning with SSI in science education.

References

Afandi, T. Junanto, and R. Afriani, "Prosiding Seminar Nasional Pendidikan Sains (SNPS) 2016," 2016, p. 113. [Online]. Available: http://worldbank.org/m/publication/wdr2016/

D. L. Zeidler, S. M. Applebaum, and T. D. Sadler, "Enacting a socioscientific issues classroom: Transformative transformations," in *Socio-scientific issues in the classroom*, T. D. Sadler, Ed., Springer, 2011, pp. 277–305.

E. Haryani, W. W. Cobern, B. A. S. Pleasants, and M. K. Fetters, "Analysis of teachers' resources for integrating the skills of creativity and innovation, critical thinking and problem solving, collaboration, and communication in the science classroom," *Jurnal Pendidikan IPA Indonesia*, vol. 10, no. 1, pp. 92–102, 2021, doi: 10.15294/jpii.v10i1.27084.

Ü. E. Uğur and S. Sungur, "Middle school students' perceptions about twenty-first-century learning practices in science classes: A multidimensional approach," *Hacettepe Egitim Dergisi*, vol. 36, no. 1, pp. 186–200, 2021, doi: 10.16986/HUJE.2020058877.

M. Tanti, B. Syefrinando, M. Daryanto, and H. Salma, "Students' self-regulation and motivation in learning science," *International Journal of Evaluation and Research in Education*, vol. 9, no. 4, pp. 865–873, 2020, doi: 10.11591/ijere.v9i4.20657.

U. Bossér, "Transformation of School Science Practices to Promote Functional Scientific Literacy," *Research in Science Education*, 2023, doi: 10.1007/s11165-023-10138-1.

R. Amos and R. Levinson, "Socio-scientifc inquiry-based learning: An approach for engaging with the 2030 Sustainable Development Goals through school science," *International Journal of Development Education and Global Learning*, vol. 11, no. 1, pp. 29–49, 2019, doi: 10.18546/IJDEGL.11.1.0.

D. L. Zeidler, "Socioscientific Issues: Theory and Practice," *Journal of Elementary Science Education*, vol. 2, no. Spring, p. 21, 2009.

H. Hestiana and D. Rosana, "The Effect of Problem Based Learning Based Sosio-Scientific Issues on Scientific Literacy and Problem-Solving Skills of Junior High School Students," *Journal of Science Education Research*, vol. 4, no. 1, Art. no. 1, Sep. 2020, doi: 10.21831/jser.v4i1.34234.

M. S. Topçu, E. Z. Muğaloğlu, and D. Güven, "Socioscientific issues in science education: The case of Turkey," *Kuram ve Uygulamada Egitim Bilimleri*, vol. 14, no. 6, pp. 2340–2348, 2014, doi: 10.12738/estp.2014.6.2226.

A. Z. Macalalag, J. Johnson, and M. Lai, "How do we do this: learning how to teach socioscientific issues," *Cult Stud of Sci Educ*, vol. 15, no. 2, pp. 389–413, Jun. 2020, doi: 10.1007/s11422-019-09944-9.

R. C. Rachmawati and E. Diningsih, "Pengenalan Sosio Scientific Issue secara Daring terhadap Kemampuan Penalaran Siswa,"

MPP, vol. 15, no. 1, pp. 31–36, Jun. 2021, doi: 10.26877/mpp.v15i1.7840.

N. Christenson, S.-N. Chang-Rundgren, and H.-O. Höglund, "Using the SEE-SEP model to analyze upper secondary students' use of supporting reasons in arguing socioscientifc issues," *Journal of Science Education and Technology*, vol. 21, no. 3, pp. 342–352, 2012, doi: 10.1007/s10956-011-9328-x.

J. Lewis and J. Leach, "Discussion of socio-scientifc issues: The role of science knowledge," *International Journal of Science Education*, vol. 28, no. 11, pp. 1267–1287, 2006, doi: 10.1080/09500690500439348.

R. Khishfe, "Nature of science and decision-making," *International Journal of Science Education*, vol. 34, no. 1, pp. 67–100, 2012, doi: 10.1080/09500693.2011.559490.

A. Solli, "Appeals to science: Recirculation of online claims in socioscientifc reasoning," *Research in Science Education*, vol. 51, no. Suppl 2, pp. 983–1013, 2021, doi: 10.1007/s11165-019-09878-w.

T. van der Leij, L. Avraamidou, A. Wals, and M. Goedhart, "Biology Students' Morality When Engaged With Moral Dilemmas in the Human-Nature Context," *Frontiers in Education*, vol. 6, 2021, doi: 10.3389/feduc.2021.729685.

T. Van Der Leij, L. Avraamidou, A. Wals, and M. Goedhart, "Supporting Secondary Students' Morality Development in Science Education," in *Studies in Science Education*, vol. 58, 2 vols., Routledge, 2022, pp. 141–181. doi: 10.1080/03057267.2021.1944716.

K. Ottander and S. Simon, "Learning democratic participation? Meaning-making in the discussion of socioscientifc issues in science education," *International Journal of Science Education*, vol. 43, no. 12, pp. 1895–1925, 2021, doi: 10.1080/09500693.2021.1946200.

I. Mahanani, S. Rahayu, and F. Fajaroh, "The Effect Of Inquiry Based Learning With Socioscientific Issues Context On Critical Thinking Skills And Scientific Explanation," *Jurnal Kependidikan*

Penelitian Inovasi Pembelajaran, vol. 3, no. 1, Art. no. 1, 2019, doi: 10.21831/jk.v3i1.20972.

A. K. Duraiappah *et al.*, *Reimagining Education: The International Science and Evidence-based Education Assessment*. New Delhi, India: UNESCO MGIEP, 2022.

IPBES, "The Global Assessment Report on Biodiversity and Ecosystem Services," IPBES, Bonn, Germany, 2019.

S. Reliantoro, "Isu Prioritas dan Subprioritas Lingkungan Hidup Didukung G20 EDM dan Organisasi Internasional." [Online]. Available: https://www.krjogja.com/yogyakarta/1242476844/sigit-reliantoro-isu-prioritas-dan-subprioritas-lingkungan-hidup- didukung-g20-edm-dan-organisasi-internasional

S. Ban and S. N. D. Mahmud, "Research and Trends in Socio-Scientific Issues Education: A Content Analysis of Journal Publications from 2004 to 2022," *Sustainability (Switzerland)*, vol. 15, no. 15, 2023, doi: 10.3390/su151511841.

A. Ezquerra, J. M. Ndabishibije, A. G. Campillejo, A. E. B. Villamor, and J. G. M. Ortega, "Trends in research on science in today's society: A systematic review," *Ensenanza de las Ciencias*, vol. 37, no. 3, pp. 31–47, 2019, doi: 10.5565/rev/ensciencias.2727.

D. Moher, A. Liberati, J. Tetzlaff, and D. G. Altman, "Preferred reporting items for systematic reviews and meta-analyses: The PRISMA statement," *International Journal of Surgery*, vol. 8, no. 5, pp. 336–341, 2010, doi: 10.1016/j.ijsu.2010.02.007.

A. D. Frost, A. Hróbjartsson, and C. H. Nejstgaard, "Adherence to the PRISMA-P 2015 reporting guideline was inadequate in systematic review protocols," *Journal of Clinical Epidemiology*, vol. 150, pp. 179–187, 2022, doi: 10.1016/j.jclinepi.2022.07.002.

J. Dolong, "Teknik Analisis Dalam Komponen Pembelajaran," *Jurnal Inspiratif Pendidikan*, vol. 5, no. 2, pp. 293–300, 2016, doi: 10.24252/ip.v5i2.3484.

M. W. Lidi, "Ragam Implementasi Materi Lokal Melalui Komponen-Komponen Pembelajaran Dalam Pembelajaran Sains,"

Jurnal Dinamika Sains, vol. 3, no. 1, pp. 10–19, doi: 10.37478/optika.v3i1.109.

D. Hodson, "Learning Science, Learning about Science, Doing Science: Different goals demand different learning methods,"

International Journal of Science Education, vol. 36, no. 15, pp. 2534–2553, 2014, doi: 10.1080/09500693.2014.899722.

H. P. Ginsburg and S. L. Golbeck, "Thoughts on the future of research on mathematics and science learning and education,"

Early Childhood Research Quarterly, vol. 19, no. 1, pp. 190–200, 2004, doi: 10.1016/j.ecresq.2004.01.013.

D. L. Zeidler, "Socioscientific issues as a curriculum emphasis: Theory, research, and practice," in *Handbook of research on science education*, vol. 2, N. G. Lederman and S. K. Abell, Eds., Routledge, 2014, pp. 697–726.

L. Leden, L. Hansson, and M. Ideland, "The mangle of school science practice: Teachers' negotiations of two nature of science activities at diferent levels of contextualization," *Science Education*, vol. 104, no. 5, pp. 5–26, 2020, doi: 10.1002/sce.21553.

A. M. Limbere, M. Munakata, E. J. Klein, and M. Taylor, "Exploring the tensions science teachers navigate as they enact their visions for science teaching: What their feedback can tell us," *International Journal of Science Education*, vol. 44, no. 12, pp. 1897–1915, 2022, doi: 10.1080/09500693.2022.2105413.

A. A. Ali Begam and A. Tholappan, "Psychomotor Domain of Bloom's Taxonomy in Teacher Education," *SHANLAX International Journal of Education*, 2018, doi: 10.5281/zenodo.1299766.

M. E. Hoque, "Three Domains of Learning: Cognitive, Affective and Psychomotor," *The Journal of EFL Education and Research*, vol. 2, 2016, [Online]. Available: www.edrc-jefler.org

M. Asholahudin, I. Syichabudin, and D. D. Solihin, "Peningkatan Kemampuan Dimensi Pengetahuan Konseptual Peserta didik melalui Penerapan Model Discovery Learning Terintegrasi media Pembelajaran KineMaster," 2021, [Online]. Available: http://Jiip.stkipyapisdompu.ac.id

A. Rahardjanto and R. Susilowati, "Study of Learning Strategy Integration of Science and Religion on the Development of Student Character," in *Advances in Social Science, Education and Humanities Research, volume 231. 5th International Conference on Community Development*, Atlantis Press, 2018.

W. Wartono, Y. F. Alfroni, J. R. Batlolona, and N. Mahapoonyanont, "Inquiry-Scaffolding Learning Model: Its Effect on Critical Thinking Skills and Conceptual Understanding," *Jurnal Ilmiah Pendidikan Fisika Al-Biruni*, vol. 8, no. 2, Art. no. 2, Oct. 2019, doi: 10.24042/jipfalbiruni.v8i2.4214.