International Journal of Religion
2025
Volume: 6| Number 1 | pp. 326 – 338
ISSN: 2633-352X (Print) | ISSN: 2633-3538 (Online)
ijor.co.uk
DOI: https://doi.org/10.61707/a5j1yr60

The Role of Socioscientific Issues (SSI) in Chemistry Education and the Challenges of Implementing Socioscientific Issues (SSI) in Indonesia: A Systematic Literature Review

Oleh: Danang Priyadi[1], Muhammad Ibnu Mas'ud[2], Eli Rohaeti[3]

Abstract

The increasingly complex global challenges, such as climate change and social injustice, demand that science education integrate social and ethical perspectives. This research aims to examine the role of the application of socioscientific issues (SSI) in chemistry education and the challenges of its implementation in Indonesia. Using the systematic literature review (SLR) method, this study reviews 36 journals related to SSI in chemistry education. The analysis results show that the SSI-based approach has the potential to enhance students' understanding of chemical concepts and critical thinking skills, as well as to shape character and social awareness. However, challenges such as teacher readiness and resource limitations still hinder its implementation in Indonesia. Strategies to overcome these challenges include enhancing teacher training and developing contextual curricula. The application of SSI in chemistry education can improve the quality of education and prepare students to face social and environmental challenges in the future.

Keywords: *Roles, Challenges, Socioscientific Issues, Chemistry Learning*

INTRODUCTION

The era of globalization has brought advancements in science and technology that affect various aspects of human life, including in the field of education (Avsar Erumit & Akerson, 2023). The challenges faced by the global community in the context of education today are becoming increasingly complex and interconnected. Issues such as climate change, social injustice, and health crises have become major challenges that require a deep understanding of science and technology (Apollo & Mbah, 2021; Stacey et al., 2018; Prentice et al., 2024). This knowledge must be applied in ethical and responsible decision-making. Therefore, science education must go beyond merely mastering scientific concepts by integrating relevant social and ethical perspectives (Ammon et al., 2022). This effort is crucial to equip the younger generation with the skills needed to create innovative and sustainable solutions to global challenges. Therefore, an educational approach that connects science with social issues becomes very relevant (Kruit et al., 2024).

Chemistry is closely related to everyday life, so various environmental issues can be connected to chemistry education. Issues such as waste management, the use of hazardous chemicals, and the energy crisis can be made significant learning contexts (Yacout & Hassouna, 2016; Khare et al., 2023; Boonanunt et al., 2024). An approach that links learning with real societal issues helps students understand scientific concepts while also fostering awareness of the importance of environmental preservation. Socio-scientific issues serve as a strong foundation for developing scientific understanding that is relevant to everyday life because the approach of linking learning with real issues in society helps students to comprehend scientific concepts while also fostering awareness of the importance of environmental conservation (Kärkkäinen et al., 2017; Rahmawati et al., 2023).

The socio-scientific issues-based learning approach allows students to connect their scientific knowledge with real-world problems faced by society, such as the impact of technology on the environment, science-based decision-making, and public health issues. Through this approach, students can be encouraged to develop important skills such as critical thinking, decision-making, and complex problem-solving (Viehmann et al., 2024; López-Fernández et al., 2022). Learning based on socio-scientific issues is not only socially relevant but also

[1] Universitas Negeri Yogyakarta

[2] Universitas Negeri Yogyakarta

[3] Universitas Negeri Yogyakarta

provides a context that enriches students' learning experiences. As a result, students not only become recipients of information but also actively participate in the learning process, encouraging them to become responsible and competitive citizens in the global era (Georgiou & Kyza, 2023).

In general, socio-scientific issue-based learning can be applied in various disciplines to encourage students to understand the relationship between science, technology, society, and the environment (STSE). In science education, this approach allows students to explore the impact of science on everyday life by considering moral and ethical aspects (Ammon et al., 2022). When specifically applied to chemistry education, socio-scientific issues such as chemical waste management, the utilization of renewable energy, and the impact of chemicals on health can be the main focus. This approach not only strengthens the understanding of chemical concepts but also encourages students to develop awareness of social and environmental responsibilities arising from the application of chemistry (Susilawati et al., 2021).

The socioscientific issues (SSI) approach has developed as one of the effective strategies in science education. This approach focuses on controversial issues that have social impacts and require scientific understanding for ethical decision-making. SSI provides students with the opportunity to develop critical thinking skills, scientific ethics, and the ability to solve complex problems (Viehmann et al., 2024). In chemistry education, the SSI approach offers great potential to bridge abstract concepts with real-world applications (Passos Sá et al., 2013). For example, issues such as waste management, the use of renewable energy, and the impact of chemicals on health become relevant topics to be studied through the SSI approach. Thus, chemistry education is not only oriented towards theoretical understanding but also towards practical applications that benefit society (Dishadewi et al., 2020).

Over the past decade (2014–2024), research related to socioscientific issues (SSI) in chemistry education has shown a significant upward trend. This reflects a growing awareness of the importance of connecting chemistry education with relevant social issues, such as the environment, health, and technology. Based on the background that has been previously explained, a systematic and comprehensive study is needed to identify the role of SSI in chemistry education, evaluate its impact, and uncover the challenges and opportunities of its implementation. Therefore, the author is interested in conducting research that reviews various articles on SSI in chemistry education. This study aims to deeply understand how SSI can be effectively applied to enhance students' understanding, critical thinking skills, and social awareness, as well as to provide strategic recommendations for the development of a more contextual and globally relevant chemistry curriculum.

RESEARCH METHOD

This research uses the systematic literature review method to explore the role of socioscientific issues (SSI) in chemistry education. This method aims to understand how SSI can contribute to improving students' understanding of chemical concepts, developing critical thinking skills, and enhancing social awareness. In addition to the role of SSI, this research also analyzes the challenges faced in its implementation, particularly in the context of chemistry education in Indonesia. The focus is to understand the role of SSI as a contextual learning approach relevant to global issues, as well as to evaluate best practices in its implementation.

Here is an overview of the stages of article selection using the PRISMA method in this SLR research:

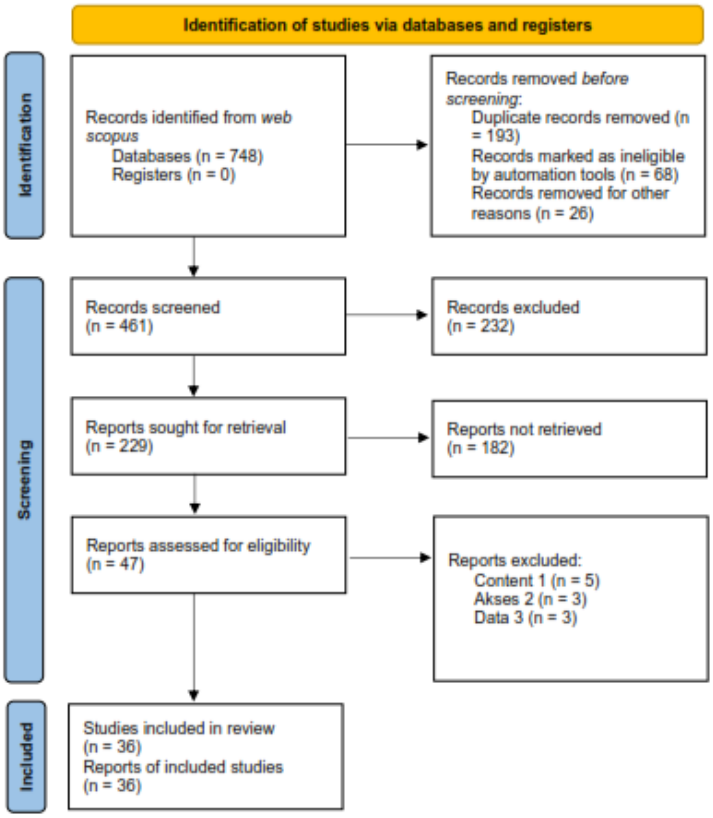

Figure 1. Article Selection Mechanism

The literature selection process begins with the collection of articles using the Scopus website. The collected articles were selected based on inclusion criteria that included the relevance of the topic to the application of socioscientific issues (SSI) in chemistry and education, as well as publications from the last ten years (2014-2024). Articles that do not meet the inclusion criteria, such as those that do not focus on chemistry and chemistry education or do not cover socio-scientific issues, are excluded from further analysis. Qualified literature is then screened to ensure the quality of methodology and the accuracy of research results. Here are the guidelines for inclusion and exclusion criteria in selecting the journals to be analyzed:

Table 1. List of Inclusion and Exclusion Criteria Guidelines for Journal Selection

Criteria Inclusion	Criteria Exclusion
An article that focuses on the application of SSI in chemistry learning.	Articles that only discuss SSI outside the context of chemistry education.
Articles that can be accessed	Article not accessible
Full article	Articles that do not include empirical data or implementation descriptions.

After data collection, the selected articles were analyzed using thematic analysis and narrative synthesis methods (Yanto et al., 2024). This process involves grouping articles based on topics, methodologies, and key findings related to the application of socioscientific issues (SSI) in chemistry and learning. Literature evaluation is conducted to ensure the relevance and quality of the studies, as well as to identify SSI opportunities in supporting more effective chemistry learning. From this selection process, 36 relevant journals were identified that will be further discussed in the analysis, providing in-depth insights into how SSI can be integrated into the chemistry curriculum and its impact on student understanding. Here is the list of reviewed journals that can be seen in Table 2:

Table 2. List of reviewed articles

No	Code	Writer	Focus on socioscientific issues (SSI)
1	A1	(Boonanunt et al., 2024)	SSI's approach to integrating social issues with chemistry learning.
2	A2	(Sulistina & Samudra Mutiara Hasanah, 2024)	SSI development through augmented reality (AR) technology.
3	A3	(L et al., 2024)	Implementation of SSI in chemistry education learning to improve social and character aspects.
4	A4	(Maciejowska, 2024)	Implementation of SSI through MOOC and blended learning in the context of chemistry learning.
5	A5	(Cabello et al., 2024)	The socioscientific issues (SSI) approach is applied through teaching contextual and responsive as well as the use of podcasts as pedagogical tools
6	A6	(Hanifha et al., 2023)	Socioscientific issues (SSI) approaches are applied to improve scientific literacy and environmental awareness.
7	A7	(Ambrogi & Eilks, 2023)	Socioscientific issues (SSI) approach applied through chemistry learning
8	A8	(Fitria et al., 2023)	The socioscientific issues (SSI) approach is applied to develop students' argumentation skills in the context of environmental, societal, and economic dimensions.
9	A9	(Martins do Vale et al., 2023)	The socioscientific issues (SSI) approach applied to analyze the argumentative cycle in student texts with a focus on social and scientific dimensions
10	A10	(Rahayu & Rosawati, 2023)	Instrument test based on socioscientific issues (SSI)
11	A11	(Rahmawati et al., 2023)	Socioscientific issues (SSI) approach applied in chemistry learning
12	A12	(G. Silva & Queiroz, 2023)	QSC (Questioning, Scaffolding, Collaboration) strategy in learning chemistry
13	A13	(Lee & Jiin, 2022)	Semantic mapping strategies are applied to help students understand the relationships between concepts.
14	A14	(Suparman et al., 2022)	Instrument for measuring students' attitudes towards socioscientific issues (SSI)
15	A15	(Rietz et al., 2022)	The socioscientific issues (SSI) approach applied
16	A16	(Arif et al., 2022)	The socioscientific issues (SSI) approach applied to study the influence of literacy environments on public and civil servants towards clean production in the river area
17	A17	(Mendonça & Vargas, 2022)	QSC (Questioning, Scaffolding, Collaboration) contribution used to expand thinking in moral considerations in context ethics among relativism culture
18	A18	(Zidny & Eilks, 2022)	An environmentally friendly extraction method (microwave) was applied in chemistry learning using an online learning management system (SPADA) and Google Meet during the pandemic
19	A19	(Saija et al., 2022)	OE3C-based approach to local socioscientific issues (SSI).
20	A20	(Occelli et al., 2022)	learning based on socioscientific issues (SSI).
21	A21	(Rietz et al., 2021)	The socioscientific issues (SSI) approach is applied to teach argumentation in the context of socio-scientific issues.
22	A22	(Nida et al., 2021)	Socioscientific issues (SSI) approach applied to chemistry education
23	A23	(Wahyuni et al., 2021)	Socioscientific issues (SSI) approach applied in the EDI-SSI learning model
24	A24	(Rahayu, 2021)	Socioscientific issues (SSI) approach applied in the learning model
25	A25	(Davis, 2021)	Socioscientific issues (SSI) approach applied in adult learning
26	A26	(Bambut & Rahayu, 2020)	Socioscientific issues (SSI) approach applied through collaborative argumentation patterns in group learning
27	A27	(Zamakhsyari & Rahayu, 2020)	Socioscientific issues (SSI) approach used as a context in solving unstructured problems
28	A28	(Rahayu et al., 2018)	Socioscientific issues (SSI) approach applied in inquiry-based chemistry learning
29	A29	(Morales-Doyle, 2018)	Approach/socioscientific issues (SSI) applied to examine the relationship between science learning and social agency
30	A30	(Bernard & Albert, 2018)	Socioscientific issues (SSI) approach applied in biology learning
31	A31	(S.-Y. Chen & Liu, 2018)	Socioscientific issues (SSI) approaches are applied using web technology to teach argumentation related to environmental issues
32	A32	(Rahayu, 2017)	Using SSI to enhance 21st-century skills
33	A33	(Itzek-Greulich & Vollmer, 2017)	Use of social and scientific issues in learning contexts.
34	A34	(Blonder et al., 2016)	Comparison of RRI dimensions with SSI studies.
35	A35	(RR da Silva et al., 2015)	Discussion of the social and environmental impacts of sunscreen use.
36	A36	(Belova et al., 2015)	SSI on climate change and decision-making.

RESULTS AND DISCUSSION

The Role of SSI Integration in Chemistry Learning

Based on the literature analysis conducted, it was found that the socioscientific issues (SSI) approach is an effective strategy for integrating science with relevant social issues. Findings from various articles indicate that this approach not only focuses on understanding scientific concepts but also encourages students to reflect on the social, ethical, and environmental impacts of the scientific decisions they study. Thus, SSI has proven to

play an important role in equipping students with the skills necessary to face real-world challenges, particularly in the context of chemistry education. As for the details regarding the list of article groupings on SSI, they can be seen in the following Table 4:

Table 4. List of Grouping of Articles on SSI

Group SSI Discussion	Article Code	Amount	%
Development and Implementation of SSI in Chemistry Learning	A1, A3, A4, A7, A13, A23, A24, A25, A28, A29, A30	11	31%
Developing Critical Thinking and Argumentation Skills	A8, A9, A16, A19, A27, A32	6	17%
Use of Technology for SSI Learning	A2, A12, A18, A31	4	11%
SSI Evaluation and Impact	A10, A14, A16, A34	4	11%
Developing Student Engagement and Social Awareness	A5, A6, A11, A16, A19, A20,	7	19%
Issue Environment and Sustainability	A18, A22, A35, A36	4	11%
Total		36	100%

Development and Implementation of SSI in Chemistry Education

The development and implementation of the socioscientific issues (SSI) approach in chemistry education is a strategic step aimed at linking chemical concepts with relevant and current issues (Boonanunt et al., 2024). This approach emphasizes the importance of integrating chemistry theory with practical applications in the context of everyday life (Bernard & Albert, 2018). The introduction of topics such as waste management, the use of renewable energy, and the impact of chemicals on health provides students with the opportunity to see how chemistry functions in solving problems faced by society (Ambrogi & Eilks, 2023).

In this context, SSI not only serves as a tool for teaching chemistry concepts but also as a method to enhance student engagement in the learning process. Linking the subject matter with real-world issues makes students more motivated and active in learning (Rahayu, 2021; Boonanunt et al., 2024). They are encouraged to conduct research, engage in discussions, and collaborate in solving complex problems, which in turn can enhance their understanding of the subject matter (Rahayu et al., 2018).

Literature analysis shows that the application of SSI in chemistry education can enhance students' conceptual understanding (Lee & Jiin, 2022). The integration of relevant social issues allows students not only to learn chemistry theory but also to apply it in a broader context (Wahyuni et al., 2021; Rahayu, 2021). This helps students develop critical and analytical thinking skills, which are very important in facing scientific and social challenges in the future (Maciejowska, 2024).

In addition, the SSI approach also provides space for students to explore various perspectives and solutions to the issues faced. In this way, students learn to appreciate the complexity of problems and the importance of a multidisciplinary approach in finding solutions (Morales-Doyle, 2018; Rahayu et al., 2018). Therefore, the development and implementation of SSI in chemistry education not only enrich the students' learning experience but also prepare them to become more critical and innovative thinkers in facing real-world challenges (L et al., 2024; Davis, 2021).

Here is Table 5 presenting the categorization of articles on environmental and sustainability issues in the context of socioscientific issues (SSI):

Table 5. List of SSI Development and Implementation Article Groupings

Group	Article Code	Information Grouping
Integration of Social Issues in Chemistry Learning	A1	Integration of issues social
	A3	Integration of issues social
	A7	Integration of issues social
Learning Models and Strategies in SSI	A4	Learning model
	A13	Learning strategies
	A23	Learning model
	A24	Learning model
	A25	Learning model

Implementation of SSI in Inquiry-Based Learning	A28	Learning based on investigation
	A29	Learning based on investigation
	A30	Learning based on investigation

Development of Critical Thinking and Argumentation Skills

The socioscientific issues (SSI) approach plays a crucial role in developing students' critical thinking and argumentation skills, which are very important in the context of 21st-century education (Rahayu, 2017). In this category, there are six articles that discuss how SSI can be used to train students in developing critical thinking skills and evidence-based arguments, as well as considering various perspectives on controversial issues. The critical thinking and argumentation skills developed through SSI contribute to the character formation of students (Fitria et al., 2023). The involvement in discussions that encompass ethical values and social responsibility teaches students to consider the impact of their decisions on others and the environment. This helps them become more empathetic and responsible individuals, capable of making positive contributions to society (Fitria et al., 2023; Martins do Vale et al., 2023).

Additionally, SSI also encourages students to think critically about the information they receive (Rahayu, 2017; Zamakhsyari & Rahayu, 2020; Saija et al., 2022). In an era of abundant information, the ability to evaluate the accuracy and credibility of information sources becomes very important (Saija et al., 2022). Through the analysis of socio-scientific issues, students are trained to identify bias, evaluate arguments, and distinguish between facts and opinions (Fitria et al., 2023). These skills are not only beneficial in an academic context but also in everyday life, where students must make informed decisions about issues that affect them and society (Arif et al., 2022).

Overall, the SSI approach in chemistry education not only strengthens students' scientific understanding but also equips them with critical thinking and argumentation skills necessary to face complex challenges in the modern world. Students are engaged in discussions about controversial issues while being guided to construct evidence-based arguments, thereby shaping a generation with strong scientific knowledge as well as critical thinking and responsible decision-making skills (Zamakhsyari & Rahayu, 2020). Literature analysis shows that these critical thinking and argumentation skills are crucial for preparing students to face real-world challenges, where decisions often involve scientific and ethical considerations.

Here is Table 6 presenting the categorization of articles on environmental and sustainability issues in the context of socioscientific issues (SSI):

Table 6. List of Grouping of Articles on Developing Critical Thinking and Argumentation Skills

Subgroup	Article Code
Development Skills Argumentation	A8
	A9
	A16
Learning Models for Critical Thinking Skills	A19
	A27
	A32

The Use of Technology for SSI Learning

The use of technology in socioscientific issues (SSI) education offers significant new opportunities to enhance student engagement and the effectiveness of the learning process. The use of technology such as augmented reality (AR) and online learning platforms allows students to explore social and scientific issues interactively and more engagingly (Sulistina & Samudra Mutiara Hasanah, 2024; G. Silva & Queiroz, 2023; Zidny & Eilks, 2022; Rietz et al., 2021). This technology allows students to not only receive information passively but also actively participate in their learning. Through AR, for example, students can see visual representations of complex concepts, helping them better understand the relationship between theory and practice (Sulistina & Samudra Mutiara Hasanah, 2024).

In this study, there are four articles that delve deeply into the use of technology in the context of SSI. The articles provide diverse insights on how technology can be integrated into learning to enhance student engagement. Moreover, technology provides students with access to explore a wider and more diverse range of information. They can access various resources, including articles, videos, and discussion forums, which enrich their learning experience (G. Silva & Queiroz, 2023). The availability of this access encourages students to conduct more in-depth research and develop a comprehensive understanding of the issues discussed. In addition, this access also allows students to deepen their understanding of certain topics and stay informed about the latest developments in the fields of science and technology (S.-Y. Chen & Liu, 2018). Thus, technology not only enriches students' learning experiences but also helps them become more independent and proactive learners (Sulistina & Samudra Mutiara Hasanah, 2024).

Overall, the integration of technology in SSI-based learning provides a more interactive and engaging learning experience for students. This approach not only enhances students' motivation and interest in chemistry learning but also prepares them to become individuals who are better equipped to face challenges in an increasingly complex and interconnected world (Sulistina & Samudra Mutiara Hasanah, 2024). Therefore, the role of technology is crucial in enhancing the effectiveness of SSI in science education, creating a generation that not only possesses deep scientific knowledge but also the skills needed to make positive contributions to society (S.-Y. Chen & Liu, 2018).

Here is Table 7 presenting the categorization of articles on environmental and sustainability issues in the context of socioscientific issues (SSI):

Table 7. List of Article Groupings Use of Technology for SSI Learning

Subgroup	Article Code	Theme
Use Augmented Reality (AR) Technology	A2	AR technology
Learning Strategies Based on Technology	A12	Learning strategies
Use of Technology in Online Learning	A18	Online learning
Using Web Technologies for Argumentation	A31	Web technology

Evaluation and Impact of SSI

The evaluation and impact of the socioscientific issues (SSI) approach in learning are very important for understanding its effectiveness. This evaluation process includes the use of SSI-based test instruments and the measurement of students' attitudes towards socio-scientific issues, which can provide deep insights into how students respond to and apply the knowledge they have gained (Suparman et al., 2022). Systematic evaluation allows educators to identify aspects of teaching that require improvement and to design more effective strategies for teaching SSI (Hernández-Villafaña & Luna, 2023).

Based on the analysis of the article, there are several studies that discuss the instruments used to measure SSI. These instruments include various forms of evaluation, such as SSI-based tests designed to assess students' conceptual understanding, as well as attitude assessments that measure students' responses to socio-scientific issues (Suparman et al., 2022; Rahayu & Rosawati, 2023). Some articles also highlight the importance of the validity and reliability of the instruments, ensuring that the evaluation tools used can provide accurate and useful data. The selection of the appropriate instruments enables educators to be more effective in evaluating students' academic understanding as well as measuring the impact of learning on their social awareness (Abdelrahman, 2020).

In addition, several articles also discuss the impact of implementing SSI in the context of scientific literacy. This approach not only enhances students' understanding of scientific concepts but also helps them develop the ability to read, analyze, and evaluate scientific information. Thus, students become more capable of understanding and participating in discussions related to complex scientific issues (Arif et al., 2022).

With proper evaluation, educators can assess not only students' academic understanding but also the impact of learning on their social awareness and responsibility towards the issues faced by society (Arif et al., 2022). Literature analysis shows that the SSI approach is not only beneficial for enhancing students' academic understanding but also indirectly contributes to the formation of a more caring attitude towards social and environmental issues. Thus, the evaluation and impact of the SSI approach become key to ensuring that students not only acquire scientific knowledge but also the skills and attitudes necessary to contribute positively to society. Effective evaluation can help create a more responsive and relevant learning environment, thereby maximizing the benefits of the SSI approach in education (Blonder et al., 2016).

Here is Table 8 presenting the categorization of articles on environmental and sustainability issues in the context of socioscientific issues (SSI):

Table 8. List of SSI Evaluation and Impact Article Groupings

Subgroup	Article Code	Theme
Instrument Evaluation SSI-Based	A10	Instrument evaluation
	A14	Instrument evaluation
The Impact of SSI Implementation in Learning	A16	Impact SSI implementation
	A34	Impact SSI implementation

Development of Student Engagement and Social Awareness

Student involvement in socioscientific issues (SSI) learning is crucial for building strong social awareness (Hanifha et al., 2023). This approach encourages students to actively engage in issues that affect their communities, such as social justice, public health, and ethics in science. Through contextual and responsive teaching methods, students can understand the relevance of their learning in everyday life. For example, when students are invited to analyze the impact of health policies or ethical issues in scientific research, they not only learn about scientific concepts but also understand how these issues affect society at large (Cabello et al., 2024; Saija et al., 2022).

This involvement also creates opportunities for students to collaborate with their peers on projects related to social issues. Through group discussions and project-based activities, students can share perspectives and experiences, which in turn enriches their understanding of the complexities of the issues faced by society (Saija et al., 2022). The aspect of collaboration among students is very important in this context, because through cooperation, they learn to appreciate different perspectives and develop effective communication skills (Occelli et al., 2022). For example, in a project that discusses social justice issues, students can be divided into small groups to conduct research, formulate solutions, and present their findings. This process not only enhances their understanding of the subject matter but also builds trust and responsibility among group members (Cabello et al., 2024).

Literature analysis shows that student involvement in social issues not only enhances their understanding of the subject matter but also shapes their character and positive social values (Belova et al., 2015). Students who are involved in SSI learning tend to develop empathy, a sense of responsibility, and awareness of their roles as members of society. The social awareness that emerges from SSI learning encompasses a deeper understanding of social dynamics, injustices, and the challenges faced by various groups in society. As a result, students learn to become individuals who are more sensitive to broader social issues, not just those related to the environment (Belova et al., 2015; Rietz et al., 2022; Rahmawati et al., 2023).

Furthermore, student involvement in social issues can motivate them to take real action outside the classroom. For example, students who learn about social justice might be inspired to participate in awareness campaigns or volunteer activities in their community. Learning does not stop in the classroom but also extends to actions that can have a positive impact on society in this way (Ferrari & Chapman, 2014; Cabello et al., 2024). Therefore, the SSI approach not only serves to enhance academic knowledge but also to shape individuals who are more socially aware and active in creating positive change in their environment (Rietz et al., 2022). Student engagement in SSI learning becomes key to building a generation that not only has strong scientific knowledge

but also a commitment to important social issues (Böttcher & Meisert, 2013; Belova et al., 2015; Occelli et al., 2022).

Here is Table 9 presenting the categorization of articles on environmental and sustainability issues in the context of socioscientific issues (SSI):

Table 9. List of Grouping of Articles on Developing Student Engagement and Social Awareness

Subgroup	Article Code	Theme
Approach Contextual and Responsive	A5	Involvement student
	A19	Involvement student
Environmental Literacy and Social Awareness	A6	Literacy environment
	A15	Awareness social
	A36	Awareness social
Student Involvement in Social Issues	A11	Involvement student
	A20	Involvement student

Environmental and Sustainability Issues

Environmental and sustainability issues are the main focus in the socioscientific issues (SSI) approach, considering the global challenges currently faced, such as climate change, biodiversity loss, and pollution. There are four articles that discuss SSI in this context, providing in-depth insights into how education can be directed to address environmental issues. This approach invites students to explore the impact of human activities on the environment, as well as the importance of sustainable decision-making in social and scientific contexts (Sanchez et al., 2024). Discussion of issues such as natural resource management allows students to understand how daily actions, such as energy use, water consumption, and waste management, contribute to larger environmental problems (Belova et al., 2015; R. R. da Silva et al., 2015; Rahayu et al., 2018; Nida et al., 2021).

Contextual learning invites students to analyze data and information related to environmental issues, so they can see the direct relationship between science and sustainability practices. For example, in learning about climate change, students can study how greenhouse gas emissions from industrial and transportation activities affect global temperatures and extreme weather. Understanding this relationship, students not only learn about scientific concepts but also become aware of their responsibilities as individuals and members of society in preserving the environment (R. R. da Silva et al., 2015).

Literature analysis shows that education focused on environmental issues not only raises students' awareness but also prepares them to become active agents of change in society (Nida et al., 2021). Students who engage in SSI learning tend to develop a proactive attitude towards environmental issues, such as participating in recycling programs, waste reduction campaigns, or conservation initiatives. Additionally, they also learn to think critically about existing policies and practices, as well as consider more sustainable alternatives (Belova et al., 2015; Rahayu et al., 2018; Wang et al., 2018).

Thus, the SSI approach that emphasizes environmental issues and sustainability plays a crucial role in shaping a generation that not only has strong scientific knowledge but also a commitment to creating positive change (Nida et al., 2021). Education that integrates environmental issues into the curriculum helps students understand the complexity of the challenges faced by this planet and encourages them to take responsible actions (Rahayu et al., 2018). The active involvement of students in sustainability issues enables them to become future leaders who can tackle global challenges with innovative and sustainable solutions (Mkhitaryan & Sargsyan, 2024).

Here is Table 10 presenting the categorization of articles on environmental and sustainability issues in the context of socioscientific issues (SSI):

Table 10. List of Grouping of Articles on Environmental and Sustainability Issues

Subgroup	Article Code	Theme
Impact Environment and Sustainability	A35	Impact environment
	A36	Sustainability
Implementation of SSI in Environmental-Based Learning	A28	Learning based on environment
	A22	Chemistry and sustainability education

Challenges of SSI Implementation in Chemistry Education in Indonesia

Although the socioscientific issues (SSI) approach offers many advantages in enhancing students' understanding and critical thinking skills, its implementation in chemistry education still faces several significant challenges (Cabello et al., 2024). Based on the analysis of the article conducted, one of the main obstacles identified is the readiness of teachers to integrate social issues into the chemistry curriculum. Many teachers feel less confident and do not have adequate skills to manage discussions involving complex and controversial issues. This may be due to a lack of adequate professional training in teaching SSI, as well as uncertainty about how to connect chemistry material with relevant social issues (Bernard & Albert, 2018; Nielsen, 2020; L. Chen & Xiao, 2021).

These concerns often make teachers hesitant to adopt the SSI approach in their teaching. They may feel uncomfortable discussing topics that could spark debate, such as climate change, the use of hazardous chemicals, or ethics in scientific research. This uncertainty can hinder productive discussions in the classroom, which should be one of the key components of SSI-based learning (Bambut & Rahayu, 2020). Without proper support and training, teachers may prefer to stick to more comfortable traditional teaching methods, even though they are less relevant to the challenges faced by students today (Metwally, 2021).

Moreover, the limitation of learning resources is also a common obstacle encountered in the implementation of SSI (Cabello et al., 2024). Many schools may not have access to relevant teaching materials or the resources needed to support issue-based learning. For example, the lack of access to technology, such as augmented reality devices or digital platforms, can limit students' ability to engage in interactive and engaging learning. In addition, teaching materials that do not cover current socio-scientific issues can make it difficult for teachers to relate chemistry concepts to relevant social contexts (Sulistina & Samudra Mutiara Hasanah, 2024).

These limitations can result in an inadequate learning experience for students, which in turn can reduce the effectiveness of the SSI approach. Without adequate resources, students may not be able to access the information needed to understand complex issues, and classroom discussions may not be as productive as expected (Cabello et al., 2024). Therefore, it is important for educational institutions to provide the necessary support, both in the form of training for teachers and access to relevant resources (Choi & Lee, 2021; Mang et al., 2021).

Overall, the challenges in implementing SSI in chemistry education include teacher readiness and the limitations of learning resources (Cabello et al., 2024; Bernard & Albert, 2018; Bambut & Rahayu, 2020). Collaborative efforts between curriculum developers, educational institutions, and the government are crucial to ensure that teachers receive the necessary training and support to effectively integrate SSI (Nielsen, 2020; L. Chen & Xiao, 2021; Metwally, 2021). Overcoming these obstacles allows for a more effective implementation of the SSI approach, thereby providing students with more meaningful and relevant learning experiences, and preparing them to become more critical and responsible individuals in facing social and environmental issues in the future.

CONCLUSION

This research emphasizes the importance of integrating socioscientific issues (SSI) into chemistry education to connect chemical concepts with relevant social issues, such as environmental and health problems. This approach has several important roles, including enhancing students' critical thinking skills and argumentation abilities, encouraging the development of active engagement in learning, and increasing social awareness of global issues. In addition, SSI also helps students understand the relationship between chemistry concepts and environmental and sustainability issues, making learning more contextual and meaningful. However, the implementation of SSI-based learning still faces challenges, especially in terms of teacher readiness and the

limited availability of supporting resources. Many teachers feel less confident and not skilled enough to guide discussions on complex issues, which can affect the success of implementing SSI in the classroom.

REFERENCES

Abdelrahman, R. M. (2020). Metacognitive Awareness and Academic Motivation and Their Impact on Academic Achievement of Ajman University Students. Heliyon, 6(9), e04192. https://doi.org/10.1016/j.heliyon.2020.e04192

Ambrogi, P., & Eilks, I. (2023). Lessons Learned from a Case Study on Teaching The Socioscientific Issue of Ethanol, Used as An Ingredient of Sanitizers, to Promote Students' Learning of and About Chemistry During The COVID-19 Pandemic. Chemistry Teacher International, 5(4), 481–492. https://doi.org/10.1515/cti-2023-0028

Ammon, S., Kljagin, A., Rettschlag, J., & Vortel, M. (2022). The Berlin Ethics Certificate: Conceptualizing Interdisciplinarity as a Core Building Block of Ethics in Engineering Education. Towards a New Future in Engineering Education, New Scenarios That European Alliances of Tech Universities Open Up, 913–924. https://doi.org/10.5821/conference-9788412322262.1422

Apollo, A., & Mbah, M. F. (2021). Challenges and Opportunities for Climate Change Education (CCE) in East Africa: A Critical Review. Climate, 9(6), 93. https://doi.org/10.3390/cli9060093

Arif, M., Behzad, H. M., Tahir, M., & Changxiao, L. (2022). Environmental Literacy Affects Riparian Clean Production Near Major Waterways and Tributaries. Science of The Total Environment, 834, 155476. https://doi.org/10.1016/j.scitotenv.2022.155476

Avsar Erumit, B., & Akerson, V. L. (2023). Contemporary Efforts Involving Globalization and Science Teacher Education (pp. 29–45). https://doi.org/10.1007/978-3-031-46073-9_3

Bambut, K. E. N., & Rahayu, S. (2020). The Patterns Of Discussion In Teaching Argumentation Skills In Chemistry Learning. 020003. https://doi.org/10.1063/5.0000529

Belova, N., Eilks, I., & Feierabend, T. (2015). The Evaluation of Role-Playing in The Context of Teaching Climate Change. International Journal of Science and Mathematics Education, 13(S1), 165–190. https://doi.org/10.1007/s10763-013-9477-x

Bernard, M.-C., & Albert, M. (2018). Intégration D'enjeux Relatifs au Vivant en Classe : Points De Vue D'enseignants et D'enseignantes en Biologie au Québec. RDST, 18, 79–102. https://doi.org/10.4000/rdst.2016

Blonder, R., Zemler, E., & Rosenfeld, S. (2016). The Story of Lead: a Context for Learning about Responsible Research and Innovation (RRI) in The Chemistry Classroom. Chemistry Education Research and Practice, 17(4), 1145–1155. https://doi.org/10.1039/C6RP00177G

Boonanunt, S., Jomnum, S., & Chancharoenrith, S. (2024). Chemistry in Everyday Life: A Context-Based Course for High School Students Incorporating Household Application Topics with Explanatory Writing Assignments. Journal of Chemical Education, 101(6), 2372–2380. https://doi.org/10.1021/acs.jchemed.3c00992

Böttcher, F., & Meisert, A. (2013). Effects of Direct and Indirect Instruction on Fostering Decision-Making Competence in Socioscientific Issues. Research in Science Education, 43(2), 479–506. https://doi.org/10.1007/s11165-011-9271-0

Cabello, V., Zúñiga, C. G., Amador Valbuena, C., Manrique, F., Albarrán, M. J., & Moncada-Arce, A. (2024). "We are not Being Taught Sustainable Citizenship!" LUMAT: International Journal on Math, Science and Technology Education, 12(2). https://doi.org/10.31129/LUMAT.12.2.2135

Chen, L., & Xiao, S. (2021). Perceptions, Challenges and Coping Strategies of Science Teachers In Teaching Socioscientific Issues: A Systematic Review. Educational Research Review, 32, 100377. https://doi.org/10.1016/j.edurev.2020.100377

Chen, S.-Y., & Liu, S.-Y. (2018). Reinforcement of Scientific Literacy through Effective Argumentation on an Energy-related Environmental Issue. EURASIA Journal of Mathematics, Science and Technology Education, 14(12). https://doi.org/10.29333/ejmste/95171

Choi, Y., & Lee, H. (2021). Exploring the Effects of Implementing a Research-Based SSI Program on Students' Understanding of SSI and Willingness to Act. Asia-Pacific Science Education, 7(2), 477–499. https://doi.org/10.1163/23641177-bja10033

Davis, P. (2021). Green Chemistry in the Third Age: Engaging Older Adults in Learning about Sustainability. Proceedings of International Conference of the Learning Sciences, ICLS, 1051–1052.

Dishadewi, P., Wiyarsi, A., Prodjosantoso, A. K., & Nugraheni, A. R. E. (2020). Chemistry-based socio-scientific issues (SSis) as a learning context: an exploration study of biofuels. Journal of Physics: Conference Series, 1440(1), 012007. https://doi.org/10.1088/1742-6596/1440/1/012007

Ferrari, J. R., & Chapman, J. G. (2014). Educating Students to Make a Difference. Routledge. https://doi.org/10.4324/9781315827674

Fitria, R., Wiyarsi, A., Rosyidah, D. M., & Arifa, M. F. (2023). Analysis of Students'Argumentation skill towards Socio-scientific Issues in Chemistry Learning. 2023 The 5th World Symposium on Software Engineering (WSSE), 159–163. https://doi.org/10.1145/3631991.3632015

Georgiou, Y., & Kyza, E. A. (2023). Fostering Chemistry Students' Scientific Literacy for Responsible Citizenship through Socio-Scientific Inquiry-Based Learning (SSIBL). Sustainability, 15(8), 6442. https://doi.org/10.3390/su15086442

Hanifha, S., Erna, M., Noer, A. M., & Talib, C. A. (2023). Scientific Literacy and Environmental Awareness through Undergraduate Student Worksheets Based on Socioscientific Issues. Jurnal Pendidikan IPA Indonesia, 12(4), 504–513. https://doi.org/10.15294/jpii.v12i4.45817

Hernández-Villafaña, A. D., & Luna, E. (2023). Metaevaluación Del Sistema De Evaluación Docente en Una Universidad Pública Mexicana. Education Policy Analysis Archives, 31. https://doi.org/10.14507/epaa.31.7501

Hugerat, M. (2020). Incorporating Sustainability into Chemistry Education by Teaching through Project-Based Learning (pp. 79–96). https://doi.org/10.1021/bk-2020-1344.ch007

Itzek-Greulich, H., & Vollmer, C. (2017). Emotional and Motivational Outcomes of Lab Work In The Secondary Intermediate Track: The Contribution of A Science Center Outreach Lab. Journal of Research in Science Teaching, 54(1), 3–28. https://doi.org/10.1002/tea.21334

Kärkkäinen, S., Keinonen, T., Kukkonen, J., Juntunen, S., & Ratinen, I. (2017). The Effects of Socio-Scientific Issue Based Inquiry Learning on Pupils' Representations of Landscape. Environmental Education Research, 23(8), 1072–1087. https://doi.org/10.1080/13504622.2016.1177711

Khare, P., Tiwari, S. K., & Bala, L. (2023). Chemical Sustainability for a Nontoxic Environment – A Healthy Future. In Biotechnology in Environmental Remediation (pp. 269–283). Wiley. https://doi.org/10.1002/9783527839063.ch14

Kruit, P. M., Bredeweg, B., & Nieuwelink, H. (2024). Enhancing Students' Argumentation Skills, Content Knowledge, and Nature of Science Understanding Through a Web-Based Educational Instrument in The Context of Socio-Scientific Issues. International Journal of Science Education, 1–20. https://doi.org/10.1080/09500693.2024.2348824

L, A., Alimin, Copriyadi, Rery, & Sofni. (2024). Pre-Service Chemistry Teachers' Attitude Of Socioscientific Issues And Characters As Citizens. Journal Pendidikan IPA Indonesia, 3(3), 411–422. https://doi.org/10.15294/0zr2eg90

Lee, & Jiin, S. (2022). The Effects of Implementing Semantic Mapping Reading Strategy in Science Class On High School Students' Science Text Reading Ability. Journal of the Korean Chemical Society, 66(5), 376–389. https://doi.org/10.5012/jkcs.2022.66.5.376

López-Fernández, M. del M., González-García, F., & Franco-Mariscal, A. J. (2022). How Can Socio-scientific Issues Help Develop Critical Thinking in Chemistry Education? A Reflection on the Problem of Plastics. Journal of Chemical Education, 99(10), 3435–3442. https://doi.org/10.1021/acs.jchemed.2c00223

Maciejowska, I. (2024). Implementation of The Course "Good Chemistry: Methodological, Ethical and Social Implications" – A Case Study. Chemistry Teacher International. https://doi.org/10.1515/cti-2024-0019

Mang, H. M. A., Chu, H.-E., Martin, S. N., & Kim, C.-J. (2021). An SSI-Based STEAM Approach to Developing Science Programs. Asia-Pacific Science Education, 7(2), 549–585. https://doi.org/10.1163/23641177-bja10036

Martins do Vale, W. K., Tavares Santos Batinga, V., & Do Nascimento Firme, R. (2023). Análise De Textos Argumentativos Produzidos Pelos Licenciandos De Química Sobre A Questão Sociocientífica Utilização De Agrotóxicos Nas Lavouras Brasileiras. Investigações Em Ensino de Ciências, 28(2), 218–239. https://doi.org/10.22600/1518-8795.ienci2023v28n2p218

Mendonça, P. C. C., & Vargas, I. B. (2022). Práticas Epistêmicas E Abordagem Qsc Com O Foco No Ensino Explícito De Ética E Moral. Investigações Em Ensino de Ciências, 27(2), 294–311. https://doi.org/10.22600/1518-8795.ienci2022v27n2p294

Metwally, E. (2021). The Impact of Social Support on First Year Teacher Development. In Trauma Informed Classrooms (pp. 149–168). BRILL. https://doi.org/10.1163/9789004465367_006

Mkhitaryan, I., & Sargsyan, L. (2024). Fostering environmental consciousness among university students. E3S Web of Conferences, 585, 04003. https://doi.org/10.1051/e3sconf/202458504003

Morales-Doyle, D. (2018). Students as Curriculum Critics: Standpoints with Respect to Relevance, Goals, and Science. Journal of Research in Science Teaching, 55(5), 749–773. https://doi.org/10.1002/tea.21438

Nida, S., Marsuki, M. F., & Eilks, I. (2021). Palm-Oil-Based Biodiesel in Indonesia: A Case Study on a Socioscientific Issue That Engages Students to Learn Chemistry and Its Impact on Society. Journal of Chemical Education, 98(8), 2536–2548. https://doi.org/10.1021/acs.jchemed.1c00244

Nielsen, J. A. (2020). Teachers and Socioscientific Issues – An Overview of Recent Empirical Research (pp. 13–20). https://doi.org/10.1007/978-3-030-40229-7_2

Occelli, M., Garcia Romano, L., & Valeiras, N. (2022). Aprendizaje Colaborativo De Cuestiones Sociocientíficas en Ambientes Virtuales: Estudio De Una Experiencia De Formación Docente. Revista de Educación a Distancia (RED), 22(70). https://doi.org/10.6018/red.518511

Passos Sá, L., Cláudia Kasseboehmer, A., & Linhares Queiroz, S. (2013). Casos investigativos de caráter sociocientífico: aplicação no ensino superior de Química. Educación Química, 24, 522–528. https://doi.org/10.1016/S0187-893X(13)72523-0

Prentice, C. M., Vergunst, F., Minor, K., & Berry, H. L. (2024). Education outcomes in the era of global climate change. Nature Climate Change, 14(3), 214–224. https://doi.org/10.1038/s41558-024-01945-z

Rahayu, S. (2017). Promoting The 21st Century Scientific Literacy Skills Through Innovative Chemistry Instruction. 020025. https://doi.org/10.1063/1.5016018

Rahayu, S. (2021). Chemistry for Life: How To Analyze and Construct Socioscientific Cases For Chemistry Instruction? 020012. https://doi.org/10.1063/5.0043177

Rahayu, S., & Rosawati, E. E. (2023). The Development of Higher-Order Thinking Skills (HOTS) Assessment Instrument in Chemistry Using Socioscientific Issues Context: A Preliminary Trial. 030009. https://doi.org/10.1063/5.0118624

Rahayu, S., Setyaningsih, A., Astarina, A. D., & Fathi, M. N. (2018). High School Students' Attitudes about Socioscientific Issues Contextualized in Inquiry-based Chemistry Instruction. Proceedings of the 2nd International Conference on Education and Multimedia Technology, 80–84. https://doi.org/10.1145/3206129.3239436

Rahmawati, Y., Akbar, M. J., Budi, S., & Ridwan, A. (2023). Exploring value-based learning environment for sustainable development in education: Integration of socio-scientific issues in chemistry learning. 040006. https://doi.org/10.1063/5.0106206

Rietz, L., Jönsson, A., & Lundström, M. (2021). Students' use of Justifications in Socioscientific Argumentation. Nordic Studies in Science Education, 17(3), 247–264. https://doi.org/10.5617/nordina.8203

Rietz, L., Jönsson, A., & Lundström, M. (2022). Elevers Upplevelser Av Ett SNI-Fall Och Dess Betydelse för Elevers Roll Som Demokratiska Samhällsmedborgare. Nordic Studies in Science Education, 18(2), 181–198. https://doi.org/10.5617/nordina.8762

Saija, M., Rahayu, S., Fajaroh, F., & Sumari, S. (2022). Enhancement of High School Students' Scientific Literacy Using Local-Socioscientific Issues in OE3C Instructional Strategies. Jurnal Pendidikan IPA Indonesia, 11(1), 11–23. https://doi.org/10.15294/jpii.v11i1.33341

Sanchez, J. M., Picardal, M., Fernandez, S., & Caturza, R. R. (2024). Socio-Scientific Issues in Focus: A Meta-analytical Review of Strategies and Outcomes in Climate Change Science Education. Science Education International, 35(2), 119–132. https://doi.org/10.33828/sei.v35.i2.6

Silva, R. R. da, Machado, P. F. L., Rocha, R. J. da, & Silva, S. C. F. (2015). The Light and the Sunscreens: A Social-Theme. Revista Virtual de Química, 7(1). https://doi.org/10.5935/1984-6835.20150011

Silva, G., & Queiroz, S. (2023). Promovendo E Identificando A Sensibilidade Moral De Licenciandos Em Química. Educación Química, 34(3), 89–101. https://doi.org/10.22201/fq.18708404e.2023.3.82112

Stacey, O., De Lazzari, G., Grayson, H., Griffin, H., Jones, E., Taylor, A., & Thomas, D. (2018). A Review of the Existing Literature on Globalization of Science Curricula (pp. 5–21). https://doi.org/10.1007/978-3-319-71532-2_2

Sulistina, O., & Samudra Mutiara Hasanah. (2024). Improving Chemical Literacy Skills: Integrated Socio-Scientific Issues Content in Augmented Reality Mobile. International Journal of Interactive Mobile Technologies (IJIM), 18(05), 135–147. https://doi.org/10.3991/ijim.v18i05.47923

Suparman, A. R., Rohaeti, E., & Wening, S. (2022). Development of Attitude Assessment Instruments Towards Socio-Scientific Issues in Chemistry Learning. European Journal of Educational Research, volume-11-(volume-11-issue-4-october-2022), 1947–1958. https://doi.org/10.12973/eu-jer.11.4.1947

Susilawati, S., Aznam, N., Paidi, P., & Irwanto, I. (2021). Socio-Scientific Issues as a Vehicle to Promote Soft Skills and Environmental Awareness. European Journal of Educational Research, volume-10-(volume-10-issue-1-january-2021), 161–174. https://doi.org/10.12973/eu-jer.10.1.161

Viehmann, C., Fernández Cárdenas, J. M., & Reynaga Peña, C. G. (2024). The Use of Socioscientific Issues in Science Lessons: A Scoping Review. Sustainability, 16(14), 5827. https://doi.org/10.3390/su16145827

Wahyuni, E. S., Rahayu, S., & Yahmin. (2021). The effect of socioscientific issues embedded in explanation-driven inquiry (EDI) learning model on high school students' conceptual understanding of reaction rate. 040034. https://doi.org/10.1063/5.0041638

Wang, H.-H., Hong, Z.-R., Liu, S.-C., & Lin, H.-S. (2018). The Impact of Socio-scientific Issue Discussions on Student Environmentalism. EURASIA Journal of Mathematics, Science and Technology Education, 14(12). https://doi.org/10.29333/ejmste/95134

Yacout, D. M. M., & Hassouna, M. S. (2016). Identifying Potential Environmental Impacts of Waste Handling Strategies in Textile Industry. Environmental Monitoring and Assessment, 188(8), 445. https://doi.org/10.1007/s10661-016-5443-8

Yanto, C. H., Biantoro, N. R., Fathur, M., & Pratama, D. (2024). Utilization of Artificial Intelligence (AI) Technology in the Field of Education : A Systematic Literature Review. JURNAL REIN. 1(1), 2–7.

Zamakhsyari, & Rahayu, S. (2020). Fostering Ill-Structured Problem-Solving Skills Of Chemistry Students Using Socioscientific Issues As Learning Contexts. 020027. https://doi.org/10.1063/5.0000533

Zidny, R., & Eilks, I. (2022). Learning about Pesticide Use Adapted from Ethnoscience as a Contribution to Green and Sustainable Chemistry Education. Education Sciences, 12(4), 227. https://doi.org/10.3390/educsci12040227

Zowada, C., Belova, N., & Eilks, I. (2021). Enhancing Education for Sustainable Development Through Geographical Perspectives in Chemistry Teaching. International Journal of Science and Mathematics Education, 19(1), 87–109. https://doi.org/10.1007/s10763-019-10043-y