25 (4), 2024, 1880-1892
Jurnal Pendidikan MIPA
e-ISSN: 2685-5488 | p-ISSN: 1411-2531
http://jurnal.fkip.unila.ac.id/index.php/jpmipa/

The Socioscientific Issues Approach in Chemistry Education: A Literature Study and Its Implication

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Abstract: Chemistry is often regarded as an unpopular subject among students, primarily because its learning process often disregards its relevance to students' everyday lives. Integrating socio-scientific issues (SSI) into chemistry education can bridge this gap by connecting chemistry concepts to students' real-life social experiences. Socio-scientific issues are socially relevant problems grounded in science that are inherently complex due to their intersection with multiple social factors, societal impacts, and the ethical dilemmas they often present. This study aims to explore the relationship between SSI-based chemistry learning, the relevance of chemistry education, students' social lives, and its benefits for students' learning. The research employs a Systematic Literature Review approach by analyzing 15 relevant articles retrieved from the ERIC and Scopus databases, selected based on established criteria and published within the last eight years. The findings from the reviewed literature indicate that incorporating SSI into chemistry education can enhance students' interest and motivation, improve their critical thinking and argumentation skills, and support their decision-making abilities.

Keywords: socioscientific issues, chemistry learning, and relevance model.

▪ INTRODUCTION

Chemistry is an unpopular subject among students, is considered difficult to learn, and is often overlooked in terms of social relevance for students' future (Zowada et al., 2018). A study showed that high school students in one of the public schools in East Java perceived chemistry as a difficult subject due to the lack of connecting the material with social relevance, where only 28% of students were aware of the role of chemistry in issues such as plastic waste management and air pollution, while chemistry learning is often focused on memorizing formulas and mathematical calculations without examples of real-life applications, thus making students lose motivation to explore chemistry because they feel that the subject has no direct contribution to their future or society (Ariani, 2024). Improving the relevance of science learning, particularly chemistry, has been debated for many years (Ke et al., 2020). In other words, science education should be woven into everyday life, involving students and community members so they can draw from their own experiences and gain practical benefits (Genisa et al., 2020). One way to integrate chemistry learning with social relevance is through contextualizing chemistry in socioscientific issues (SSI).

Socio-scientific issues (SSI) is one approach that is often suggested to improve the perception of relevance by incorporating them into the curriculum of science education, especially chemistry. The integration of SSI should be authentic, relevant, open to decision, debatable, and have a basis in the existing subject. Therefore, SSI can provide opportunities for students to build connections with other aspects of their lives, both for the present and for the future. In addition, SSI should also expand students' competencies which in turn will increase academic success. SSI encourages students to use scientific backgrounds in public policy engagement, thus improving their skills in chemistry and

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DOI: http://dx.doi.org/10.23960/jpmipa/v25i4.pp1880-1892
Received: 14 January 2025
Accepted: 19 January 2025
Published: 25 January 2025

critical thinking (Gulacar et al., 2020). These skills and thinking can be utilized by students to deal with problems in daily life with the community.

In SSI-based learning, students are led to solve environmental or social problems and present several scientific, social, and moral perspectives. Thus, in order to connect what students have learned in school with their daily problems, it is necessary to construct meaning (Sadler, 2009). The creation of meaning is the process of transferring individual knowledge from their learning to other conditions that are being faced. This transfer process is not only limited to the recall of knowledge owned, but also the use of applying knowledge or learned concepts to different situations (Bookhart, 2010). Thus, addressing these issues requires the use of higher-order thinking skills.

Students can think critically and creatively, especially in making decisions to solve a problem, if they have high-level thinking skills. These skills are known as High Order Thinking Skills (HOTS). Based on Bloom's taxonomy, these skills include analytical, evaluative, and synthesis thinking skills which fall into the HOTS category as knowledge transfer (Bookhart, 2010). These high-level thinking skills are in accordance with the application of SSI in learning where SSI in this learning teaches students to analyze a problem, double-check the selected sources, and create a solution to the problem (Qamariyah et al., 2021).

Higher-order thinking skills (HOTS) are crucial for developing students' abilities to face various challenges in real life. In the learning context, HOTS helps students not only absorb information but also analyze, evaluate, and create solutions to problems. This process strengthens students' critical and creative thinking skills, which are essential for addressing complex issues (Anderson & Krathwohl, 2001). By integrating HOTS in learning, students not only learn to memorize facts but also engage in deeper thinking and make more well-rounded decisions. Teaching based on HOTS encourages students to become active problem solvers, where they are trained to identify, evaluate, and formulate solutions to given problems. This HOTS-based learning also introduces more complex concepts, allowing students to develop sharper analytical and critical skills. In line with this, the implementation of SSI in education is increasingly relevant as it provides students the opportunity to analyze social and scientific issues that often require critical thinking and problem-solving involving multiple perspectives (Sadler, 2004).

The Socio-Scientific Issues (SSI) approach is closely related to the development of Higher Order Thinking Skills (HOTS), as it encourages students to think critically, analyze information comprehensively, and make decisions based on evidence within the context of complex social issues. According to Sadler (2004) and Zeidler et al. (2005), SSI integrates science education with real-world problems, such as environmental pollution, climate change, and waste management, requiring students to evaluate data, identify viable solutions, and consider their ethical and social implications. For instance, in chemistry learning, students may undertake a project to analyze the composition of biodegradable plastics and assess their environmental impact. This task not only facilitates an understanding of chemical concepts such as polymerization but also enhances critical thinking, problem-solving, and evidence-based decision-making skills. Moreover, the SSI approach fosters students' awareness of global issues, preparing them to become responsible and informed citizens. Therefore, HOTS and SSI complement each other in enhancing the quality of learning that focuses on developing critical and creative thinking skills.

In order to training individual high-level thinking skills, learning using SSI in chemistry raises the relevance model of chemical education to students' social lives so that it can build students' motivation and attitudes towards chemistry and increase students' interest in participating in chemistry learning (Eilks, Marks, & Stuckey, 2018). Although various studies have shown the importance of integrating Socio-Scientific Issues (SSI) in chemistry learning to increase social relevance and student learning motivation (Sadler, 2004; Zeidler et al., 2005), the application of this approach at the school level is still very limited. A study by Widiastuti and Setiawan (2019) revealed that most chemistry teachers in Indonesia still use conventional learning methods that focus on memorizing concepts and mathematical calculations, without linking the material to social issues such as environmental pollution, waste management, or renewable energy. This gap indicates that, although the SSI approach has proven effective globally, its application is still suboptimal at the secondary school level. Therefore, further review is needed regarding this SSI-based chemistry learning, its relation to the relevance of chemistry learning, students' social lives, and its usefulness in chemistry learning for students.

▪ METHOD

Research Design

This study is aqualitative research employing the Systematic Literature Review (SLR) method by synthesizing research articles on SSI-based chemistry learning, its relevance to students' social lives, and its benefits for chemistry education. The SLR method is conducted using a structured, consistent, and reliable approach to address specific research questions (Rosliana et al., 2022; Wardi et al., 2024).

Search Strategy

This study uses a search strategy that is guided by PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) with the stages of identification, screening, eligibility evaluation, and inclusion of relevant articles (Wardi et al 2024). The databases used in this study are ERIC and SCOPUS. Both databases are the main databases because they provide access to high-quality articles, broad coverage, and include relevant international journals (Mongeon & Paul-Hus, 2016). This research focuses on SSI-based chemistry learning and relevance to students' lives. The screening used the keywords socioscientific issues and chemistry learning. The screening steps carried out by researchers according to the PRISMA guidelines are presented in Figure 1.

Inclusion and Exclusion Criteria

The research analyzed in this article met the following criteria: (1) articles published within the last eight years, (2) articles containing the keywords Socio-Scientific Issues and Chemistry Learning, (3) articles published in national and international journals, (4) articles written in English, (5) research subjects consisting of students in formal education, (6) studies directly implementing SSI-based chemistry learning strategies to assess their impact on students, (7) studies utilizing SSI-contextualized learning models in chemistry education with specific objectives, (8) a focus on emphasizing the relevance of chemistry in everyday life through scientific literacy, and (9) the use of SSI-contextualized learning media to achieve specific learning goals.

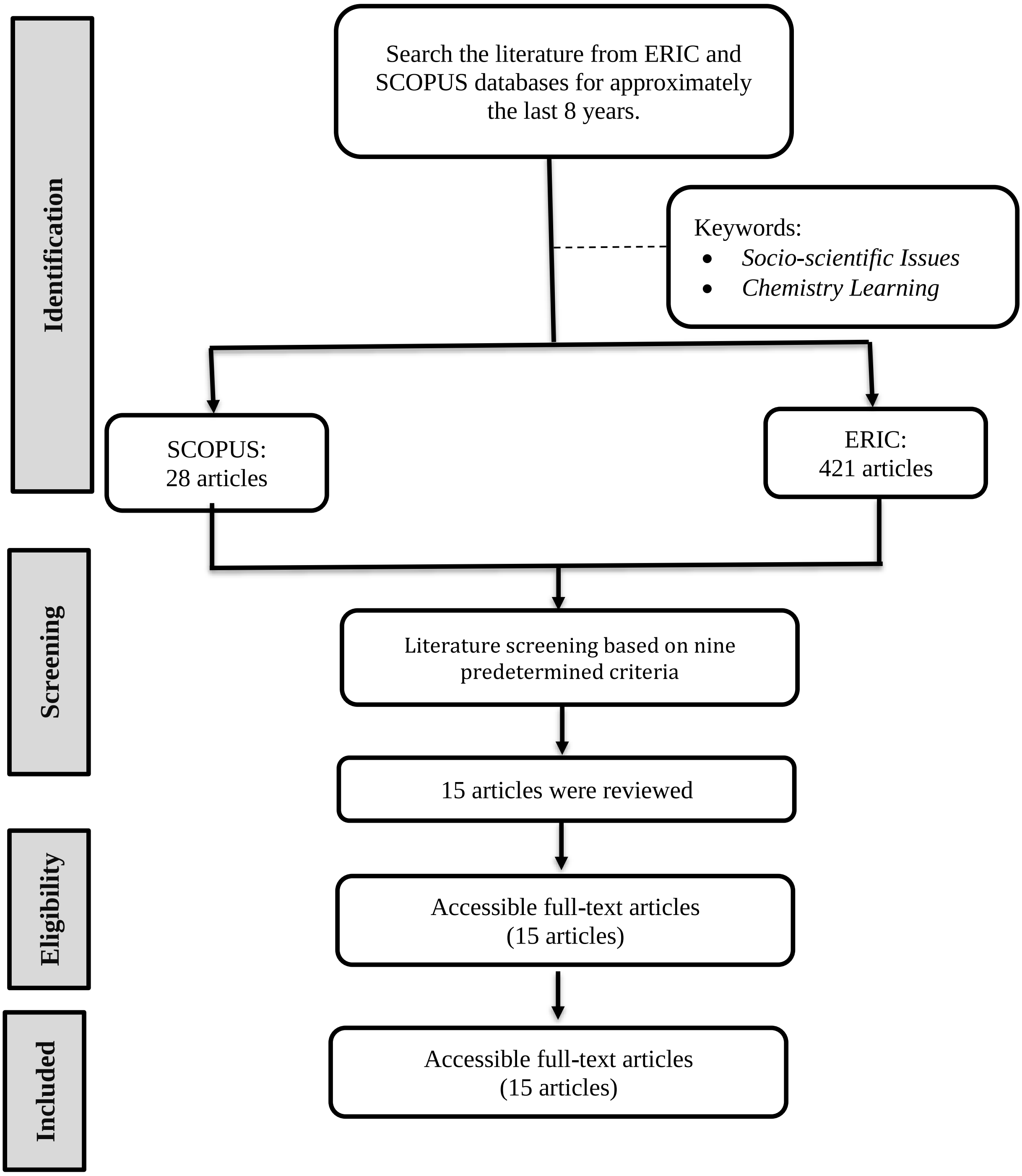

Figure 1. Article search flowchart

Data Analysis

The data analysis conducted was qualitative. The stages carried out are by reading the abstract and the results of the articles analyzed then grouping them into two large groups, namely learning that directly uses or integrates the SSI approach and learning that uses the SSI approach in the media. After being grouped, the benefits of using SSI in chemistry learning both directly and integrated with learning media were analyzed. This analysis produces a synthesis of the SSI approach in chemistry learning and can support further relevant research related to the SSI approach in chemistry learning.

▪ RESULT AND DISSCUSSION

SSI is a socioscientific issue that become a problem in people's lives and can be used as a foundation for students to relate to natural science (Putri et al., 2018). SSI engages students directly with social issues, offering them exciting learning experiences that connect to their daily lives (Irwanto et al., 2024). Socioscientific issues are included in complex societal dilemmas related to applying scientific principles and practices (Sakamoto et al., 2021). Thus, SSI is complex because it involves various aspects, causing controversy and ethical dilemmas.

The complex nature of this SSI can be seen from its vast scope because it is a social issue. For example, in the environment, there are issues regarding climate change and recycling of materials. (Koulougliotis et al., 2021). Regarding economics and the environment, the issue of hydraulic fracturing, which is the breaking of rocks to drain oil and gas trapped in wells, can be studied and explained in oil mining for processing and trading (Zowada et al., 2021). In the health sector, socioscientific issues can include topics such as the impact of heavy metals on human health (Effendi-Hasibuan et al., 2020). Its relationship with social activities causes SSI to be inseparable from ethical and moral dimensions. The scientific literacy of SSI can be used as an impetus for moral and ethical implications (Putri et al., 2018). Based on the findings of several journals, SSI has several dimensions. These SSI dimensions include economic, environmental, health, social, and ethical. The SSI dimensions in the analyzed articles are presented in Figure 2.

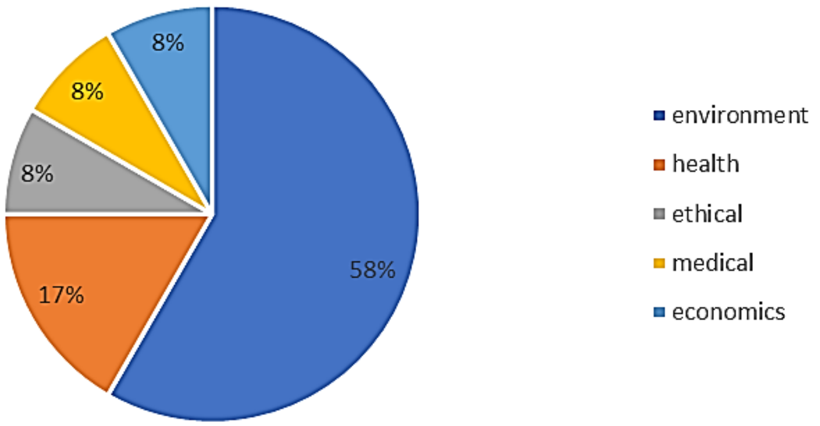

Figure 2. The SSI dimensions

The selection of SSIs for chemistry learning does not necessarily include all four dimensions of SSIs. As in the environmental dimension, green chemistry learning can be used with SSIs, namely climate change and material recycling (Koulougliotis et al., 2021). SSI plays a role in introducing green chemistry in secondary education by using socioscientific issues to teach specific chemistry content. Learning science, particularly chemistry, through SSI goes beyond just content knowledge and contextual comprehension (Eilks et al., 2021). Integrating contextual issues sparks students' curiosity, enthusiasm, and motivation, while also enhancing their argumentation skills, as demonstrated throughout the learning process. It also encourages their active involvement in discussing and debating social issues (Purwanto et al., 2022). Therefore, learning science, especially chemistry, using SSI will be very helpful to increase positive impacts in student learning, such as student skills and abilities.

The literature indicates that using the socioscientific issues approach, whether incorporated into learning strategies or media, affects student learning outcomes in various abilities and skills. The study results are presented in two tables, Table 1 and Table 2.

Table 1. Learning strategy with SSI

Article Title	Finding
Socioscientific Issues-Based Learning: The Effect on High School Students' Metacognitive Skills.	The research findings indicate that the use of SSIBL positively impacts the development of students' metacognitive skills, namely in the form of an increase. The emphasis in this research is on the potential of SSIBL which is integrated in various lessons, including chemistry. Implementing SSIBL provides students with authentic learning experiences, enhances their problem-solving and decision-making skills, and expands their knowledge.
Socio-critical and problem-oriented approach in environmental issues for students' critical thinking skills development in chemistry learning.	The findings of this study, namely in the form of students' critical thinking skills that increase with motivation, and students are involved in direct learning, support the problem-oriented socio-critical approach in chemistry learning. This approach is an applicable and contextual alternative in chemistry learning approaches to improve student activeness in class and critical thinking skills.
The Effectiveness of a SOIE Strategy Using Socioscientific Issues on Students' Chemical Literacy.	The findings of this study suggest that the SOIE strategy with SSI can enhance students' chemical literacy. The experimental group scored higher on average in each aspect compared to the control group.
Developing and Using Multiple Models to Promote Scientific Literacy in the Context of Socioscientific Issues.	Various models within the context of SSI deepen students' understanding of phenomena related to these issues, meanwhile, socio-scientific models assist students in applying scientific knowledge to wider social contexts and in reasoning about social interactions. In connecting disciplinary knowledge, especially chemistry, for decision-making in daily life problems, as well as having an important continuing impact in science teaching used in science literacy, this approach is important to implement.
An intervention study on students' decision-making towards consensus building on socioscientific issues.	A comparison of pre- and post-test results indicated an overall shift towards higher scores following the intervention. Students' arguments on socioscientific issues evolved from simply justifying their positions to proposing solutions. This finding suggests that the

Article Title	**Finding**
	teaching encouraged students' socioscientific decision-making toward consensus building.
The Effect of Implementation of Inquiry-based Learning with Socioscientific Issues on Students' Higher-Order Thinking Skills.	This study found that the experimental group had higher scores in Higher Order Thinking Skills. Furthermore, effect size analysis highlighted significant differences between the experimental and control groups. As a result, inquiry-based learning with socio-scientific issues can enhance students' higher-order thinking skills.
Probing Greek secondary school students' awareness of green chemistry principles infused in context-based projects related to socioscientific issues.	Integrating green chemistry principles into two context-based projects related to socioscientific issues increased students' environmental awareness and supported the development of skills crucial for responsible social citizenship.
Skills to argue: Using argument-based learning (AbL) and socioscientific issues to promote university students' argumentation skills in chemistry.	The finding of this study is that the argumentation scale of students with AbL and SSI has a significant difference with the argumentation scale of other class students (Tukey test; $p<0.05$). The use of TAP is a factor that produces scale differences. Therefore, it is good to engage students in learning that emphasizes argumentation training to develop students' argumentation skills in science.
Socioscientific issues as contexts for relevant education and a case on tattooing in chemistry teaching.	This study's findings indicate that science learning through SSIs extends beyond content and contextual understanding, fostering the growth of critical science literacy. Several case studies demonstrated the significant potential of this approach, showing a positive impact on students' motivation, perspectives on science, and overall appreciation of the lessons.
The Effectiveness of Problem-Based Learning (PBL) Models Based on Socioscientific Issues (SSI) to Improve the Ability.	The findings of this study demonstrate that using Problem-Based Learning (PBL) tools based on Socio-scientific Issues (SSI) is an effective approach to enhance science literacy skills on climate change topics, making it a viable option for science education.
Socioscientific issues (SSI) in reaction rates topic and its effect on the critical thinking skills of high school students.	The results of this study show that students' critical thinking skills between the two groups have significant differences. The group with SSI scored higher than those without. The results show that learning with SSI affects students' critical thinking skills.

Table 2. Learning media with SSI

Article Title	**Finding**
Integrating a sustainability-oriented socioscientific issue into the general chemistry curriculum: Examining the effects on student motivation and self-efficacy.	Integration of SSI in a general chemistry course on phosphate sustainability using Prezi showed positive acceptance of the digital material by students. As a result, there were no notable differences between

	men and women, but there were differences between ethnic groups.
Incorporating a Web-Based Hydraulic Fracturing Module in General Chemistry as a Socioscientific Issue That Engages Students.	The findings indicate positive perceptions when hydraulic fracturing is included in general chemistry education learning by illustrating its broad potential on ecological and social impacts. This is consistent with the findings of German secondary school chemistry teachers who use similar learning environments and related approaches.
The implementation of integrated science teaching materials based on socioscientific issues to improve students' scientific literacy for environmental pollution theme.	The results of this study indicate significant differences in the N-gain scores between the experimental and control groups, as well as in each indicator of content aspects and science competencies. These findings suggest that employing Integrated Science teaching materials with the SSI approach enhances both content knowledge and science competencies, presenting it as a valuable alternative for teaching Integrated Science.
The Effect of Socioscientific Topics on Discourse within an Online Game Designed to Engage Middle School Students in Scientific Argumentation.	The results show that socioscientific topics produce positive, supportive, and civilized collaborative discourse within an argumentation framework.

SSI in chemistry learning integrated into learning media, such as Socioscientific Issue-based science learning books for student learning reference (Yenni et al., 2017). Not only integrated in learning media, SSI can also be integrated in the learning model used, namely the integration of SSI in the problem-based learning model using the 4D model, where SSI will enter the problem orientation stage (Putri et al., 2018). In the research by Qamariyah et al. (2021), inquiry-based chemistry learning with SSI aims to advance students' critical thinking skills. Besides collaborating with learning models, SSI can also be included in cooperative chemistry learning strategies (jigsaw and two-stay-two-stray), which aim to improve student argumentation (Effendi-Hasibuan et al., 2020). Thus, chemistry learning with SSI can stand alone or be integrated, and it aims to achieve specific learning objectives. Based on the findings of the 15 journal articles that have been analyzed, learning chemistry with SSI has several impacts which are presented in Table 3.

Table 3. The impact of chemistry learning with SSI

No	Impact of SSI in chemistry learning	Number of Articles
1.	Improving metacognitive skills	1
2.	Increase student activeness in class	1
3.	Improve critical thinking skills	2
4.	Improve students' chemical literacy	1
5.	Improve student understanding	1
6	Encouraging students' socio-scientific decision-making towards consensus building	1
7.	Students' higher order thinking skills	1

8.	Increased student environmental awareness	1
9.	Development of skills that characterize socially responsible citizenship	1
10.	Developing students' argumentation skills	1
11.	Improving students' science literacy	2
12.	Students responded positively to digital materials related to SSI	1
13.	Positive perspectives on the material provided	1
14.	Improved aspects of science content and competence	1
15.	Positive, supportive, and civilized collaborative discourse within an argumentation framework	1

Based on Table 3, it provides a detailed overview of the various impacts of implementing Socio-Scientific Issues (SSI) in chemistry learning, particularly in enhancing critical skills and student engagement. SSI has been proven to improve metacognitive skills, critical thinking, and higher-order thinking, which are essential for understanding complex issues in chemistry and their societal implications. Zeidler et al. (2005) stated that SSI-based learning encourages students to think beyond traditional content by analyzing the ethical and social dimensions of scientific concepts. Furthermore, Table 3 illustrates improvements in students' chemical literacy and overall understanding, supporting the findings of Sadler (2004) that contextual learning helps bridge the gap between theoretical knowledge and real-world applications. These findings reinforce the importance of SSI as an effective approach to fostering deep learning in chemistry education.

Another significant impact of SSI is its ability to enhance student engagement while simultaneously developing social and environmental awareness. The use of SSI increases students' activeness in the classroom and their positive responses to digital materials, aligning with Sadler's (2004) research, which highlights that SSI makes science more relatable and engaging for students. Moreover, SSI fosters values such as environmental awareness and responsible citizenship, as demonstrated by its role in developing students' abilities to address pressing global challenges. Ratcliffe and Grace (2003) emphasized that SSI helps students connect classroom learning with broader societal issues, preparing them to become socially responsible individuals. This dual focus on cognitive and social development establishes SSI as a holistic approach to education.

The ability of SSI to improve argumentation skills and socio-scientific decision-making is another noteworthy benefit. By encouraging students to engage in collaborative discussions and consensus-building activities, SSI fosters respectful and supportive dialogue within the classroom (Ratcliffe & Grace, 2003). Table 3 also highlights how SSI enhances students' ability to analyze and discuss socio-scientific issues within an ethical and collaborative framework. These skills are vital for shaping critical and reflective thinkers who can navigate complex societal challenges. Thus, integrating SSI into chemistry education not only strengthens students' academic achievements but also equips them with the skills needed for active and informed participation in society. The specific skills that are needed include critical thinking skills, higher order thinking skills, and argumentation skills. Some of these skills are supported by the article findings presented in Figure 3.

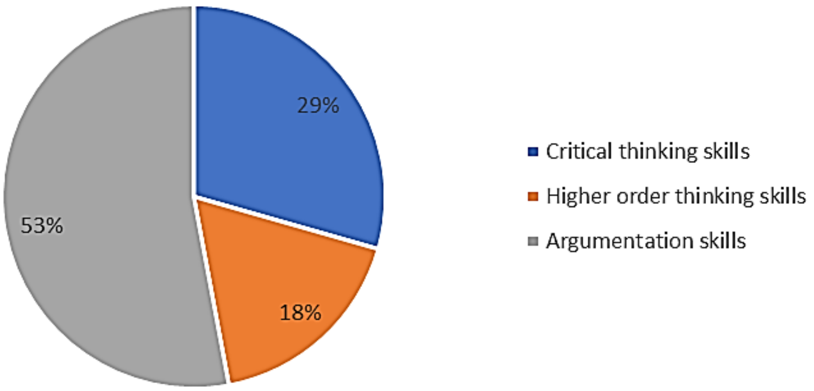

Figure 3. The impact of SSI in chemistry education

Chemistry learning with SSI can improve students' higher-order thinking skills because real-life problem scenarios are used in learning (Qamariyah et al., 2021). This is proven by using SSI-based learning books, which increases students' critical thinking compared to ordinary learning books (Yenni et al., 2017). Controversial issues, a key feature of SSI, can also motivate students to engage more actively in discussions and debates, helping to develop their critical thinking skills (Pratiwi et al., 2017). SSI in chemistry education can also enhance students' argumentation skills, which will aid them in making decisions and building consensus (Sakamoto et al., 2021). In addition, SSI, implemented in game-shaped chemistry learning media, has a good influence on students in preparing their scientific argumentation (Craig-Hare et al., 2017).

Through SSI, students are invited to analyze controversial issues related to science in a social context, thus encouraging them to think critically and actively participate in class discussions. Research shows that the application of SSI can improve students' critical thinking ability and science literacy, which contributes to strengthening their scientific argumentation skills (Purwandari, et al, 2024). Critical thinking skills and science literacy play an important role in strengthening students' scientific argumentation skills. Critical thinking allows students to evaluate claims and build arguments based on valid data, while science literacy helps them understand scientific concepts and apply them in everyday life. Research shows a positive relationship between science literacy and critical thinking skills, where improving science literacy contributes to strengthening students' critical thinking skills (Parinduri, et al, 2023). Thus, the simultaneous development of these two abilities can improve the quality of students' scientific argumentation.

Chemistry education using SSI can boost students' interest in studying chemistry (Ke et al., 2020). This can happen because the social issues raised in learning are relevant and feel close to students, making them more curious about learning about them. Students' motivation to study chemistry grew after SSI was incorporated into the general chemistry curriculum (Gulacar et al., 2020). In addition, learning with SSI can also improve the quality of learning in the chemistry classroom because SSI more than leads to content and contextual learning (Eilks et al., 2020). From some of these journal findings, learning with SSI can better understand students related to the material taught so that the quality of chemistry learning will improve.

Thus, learning chemistry with SSI helps explore student competencies, such as making students active in arguing, which will improve the quality of student argumentation and spur students to think critically because these socioscientific issues are controversial and relevant to their lives. Students' improved argumentation and critical thinking skills will help them make decisions, especially in problem-solving. In this regard, of course, students' higher-order thinking skills will also be honed. Socioscientific issues relevant to students' lives will make students more interested in knowing more about the problem and make them curious so that students are motivated and increase their interest in learning chemistry. In this regard, further and specific research is needed regarding the benefits of SSI in learning chemistry, both integrated into the model and the learning media used.

▪ CONCLUSION

Based on the review of several international journals, it is shown that SSI-based chemistry learning has various benefits. Chemistry learning based on socioscientific issues relevant to students' lives can increase students' motivation and interest in learning chemistry. This will certainly overcome the problem of chemistry not being popular among students and being considered difficult to learn because it is not relevant to their future. In addition, the controversial issues used will also certainly explore student competencies, such as skills in critical thinking, argumentation, and decision-making. These competencies are certainly competencies that are needed to support 21st-century skills.

Future research can be more specifically related to chemistry learning with SSI, such as using specific learning models to determine the effect of SSI on certain student skills. Future research can also emphasize future competencies, such as 21st-century skills, with the relevance of using this SSI. Future research can also discuss the impact of SSI-based chemistry learning on students' futures or careers. As technology develops, future research can also improve chemistry learning integrated with SSI-based technology. This is not only for students, but future research can also focus on teacher skills in integrating chemistry learning with SSI, which will undoubtedly impact students.

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