

Integrating Socio-scientific Issues in Chemistry Learning to Enhance Critical Thinking Skills: Systematic Literature Review

Integrasi Isu Sosiosaintifik dalam Pembelajaran Kimia untuk Meningkatkan Keterampilan Berpikir Kritis: Sebuah Tinjauan Literatur Sistematis

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ABSTRACT

Background: 21st-century chemistry education requires the development of critical thinking skills to enable students to address complex social, scientific, and environmental issues. Integrating socio-scientific issues (SSI) into chemistry instruction has emerged as a promising approach to foster these competencies. Objective: This study aims to systematically examine the effect of SSI integration on students' critical thinking skills, identify the most effective learning models for SSI implementation, and analyze the challenges encountered in chemistry education. Methods: This study employed a Systematic Literature Review (SLR) by reviewing articles published between 2015 and 2025 from the ERIC, Google Scholar, and Scopus databases. Following predefined inclusion and exclusion criteria, 21 eligible studies were selected and analyzed using a narrative synthesis approach. Research Results: The findings indicate that SSI integration consistently enhances students' critical thinking skills, particularly in analysis, evidence evaluation, scientific argumentation, and data-driven decision-making. Problem-Based Learning and Inquiry-Based Learning were identified as the most effective and frequently used instructional models for SSI implementation, followed by case-based learning, argumentation, and project-based learning. Nevertheless, several challenges remain, including limited teacher readiness, insufficient learning resources, time constraints, and students' difficulties in constructing scientific arguments. Conclusion: Integrating SSI into chemistry learning is an effective strategy for improving students' critical thinking and scientific literacy. Its successful implementation requires adequate teacher competence, appropriate instructional materials, and supportive curriculum policies to maximize learning outcomes.

ABSTRAK

Latar Belakang: Pembelajaran kimia abad ke-21 menuntut pengembangan keterampilan berpikir kritis agar peserta didik mampu menghadapi berbagai persoalan sosial, ilmiah, dan lingkungan yang kompleks. Salah satu pendekatan yang dinilai relevan untuk mencapai tujuan tersebut adalah integrasi socio-scientific issues (SSI) dalam pembelajaran kimia. Tujuan: Penelitian ini bertujuan untuk mengkaji secara sistematis pengaruh integrasi SSI terhadap keterampilan berpikir kritis peserta didik, mengidentifikasi model pembelajaran yang paling efektif dalam penerapan SSI, serta menganalisis berbagai tantangan implementasinya dalam pembelajaran kimia. Metode: Penelitian ini menggunakan metode Systematic Literature Review (SLR) dengan menelaah artikel yang diterbitkan pada periode 2015–2025 dari basis data ERIC, Google Scholar, dan Scopus. Berdasarkan kriteria inklusi dan eksklusi yang telah ditetapkan, sebanyak 21 artikel dipilih dan dianalisis menggunakan pendekatan sintesis naratif. Hasil Penelitian: Hasil kajian menunjukkan bahwa integrasi SSI secara konsisten mampu meningkatkan keterampilan berpikir kritis peserta didik, terutama pada aspek analisis, evaluasi bukti, argumentasi ilmiah, dan pengambilan keputusan berbasis data. Model pembelajaran yang paling dominan dan efektif dalam mengintegrasikan SSI adalah Problem-Based Learning dan Inquiry-Based Learning, diikuti oleh pembelajaran berbasis kasus, argumentasi, dan proyek. Namun demikian, implementasi SSI masih menghadapi berbagai tantangan, antara lain kesiapan guru yang belum optimal, keterbatasan sumber belajar, keterbatasan waktu pembelajaran, serta kemampuan peserta didik dalam membangun argumentasi ilmiah. Kesimpulan: Integrasi socio-scientific issues dalam pembelajaran kimia merupakan strategi yang efektif untuk meningkatkan keterampilan berpikir kritis dan literasi sains peserta didik. Keberhasilan implementasinya memerlukan dukungan kompetensi guru yang memadai, ketersediaan bahan ajar yang sesuai, serta kebijakan kurikulum yang mendukung.

INTRODUCTION

21st-century education requires the development of higher-order thinking skills, including critical thinking, which is essential in facing increasingly complex social, scientific, and technological

challenges. One way to achieve this goal in science education is to integrate socio-scientific issues (SSI) into chemistry instruction. The integration of SSI not only facilitates the understanding of chemistry concepts but also teaches students to think critically in assessing and solving problems related to social issues. A study by (Fadly et al., 2022) found that the SOIE (Strengthening, Orientation, Investigation, Evaluation) learning strategy, when applied in the SSI context, can significantly improve students' chemistry literacy. This shows the importance of an SSI-based approach in improving the quality of chemistry learning and developing students' critical thinking skills (Fadly et al., 2022).

Along with developments in science education research, the trend of applying SSI is becoming increasingly popular, especially in chemistry education. SSI provides students with opportunities to debate and consider various perspectives on controversial scientific issues relevant to their lives. (Falah et al., 2024) note that SSI enables students not only to understand scientific concepts but also to make informed and ethical decisions in their daily lives. This study highlights the importance of integrating SSI into science learning to facilitate the development of better critical thinking skills (Falah et al., 2024).

However, even though various SSI-based learning models have been proven effective in improving students' critical thinking skills, challenges in their implementation remain. Some problems that arise include a lack of teacher readiness in implement SSI-based learning and limited teaching materials. (Redhana et al., 2021) note that to optimize chemistry learning, it is important to develop teaching materials that integrate chemistry concepts with current social issues. The use of teaching materials relevant to the social context can increase student motivation and help them see the direct relationship between science and everyday life (Redhana et al., 2021).

Therefore, the purpose of this systematic literature review is to explore and summarize studies examining the effect of SSI integration in chemistry learning on students' critical thinking development. This study is expected to provide deeper insights into the implementation of SSI in chemistry learning and to offer recommendations for developing more effective learning strategies to enhance students' critical thinking skills in the context of chemistry.

LITERATURE REVIEW

Critical Thinking Skills in Chemistry Education

Critical thinking skills are among the key competencies that students need to possess in the 21st century. In chemistry education, these skills encompass not only the ability to understand concepts but also the ability to analyze information, evaluate scientific evidence, construct logical arguments, and make decisions based on valid data (Redhana, 2019). Therefore, chemistry instruction needs to be designed not only to emphasize conceptual mastery but also to develop *higher-order thinking skills*.

(Redhana et al., 2021) explain that critical thinking disposition is an important aspect influencing students' ability to engage in scientific reasoning. Valid and reliable measurement of critical thinking disposition serves as a basis for evaluating the effectiveness of a learning model in improving critical thinking skills. Accordingly, chemistry education should be directed toward activities that stimulate processes of analysis, evaluation, reflection, and scientific problem-solving.

Various studies have demonstrated that active learning can improve students' critical thinking skills. (Selamat, 2018) found that a locally culturally based 7E learning model significantly improved critical thinking skills compared with conventional instruction. Similar findings were reported by (Widiandari & Redhana, 2021) who showed that case-based learning provided students with opportunities to identify problems, analyze evidence, and formulate solutions based on chemistry concepts. In addition, the use of argumentation-based textbooks was shown to improve students' critical thinking dispositions and scientific argumentation skills (Sudiana & Redhana, 2018). These findings indicate that critical thinking skills develop optimally through learning that is contextual, participatory, and student-centered.

Socio-Scientific Issues (SSI) in Chemistry Education

Socio-scientific issues (SSI) constitute a learning approach that utilizes social issues related to science as contexts for the learning process. These issues are generally complex and controversial and do not have a single definitive answer, thereby encouraging students to use scientific knowledge to analyze different perspectives before making decisions (Falah et al., 2024).

In chemistry education, the implementation of SSI connects chemistry concepts with various real-world problems, such as environmental pollution, climate change, industrial waste, plastic use, food safety, energy, and environmental sustainability. (López-Fernández et al., 2022) explain that SSI-based learning enables students to develop critical thinking skills through the analysis of different perspectives on plastic-use issues. Such activities encourage students to evaluate scientific evidence, construct arguments, and consider the social implications of the decisions they make.

In addition to improving critical thinking skills, SSI-based learning also contributes to the development of scientific and chemical literacy (Fadly et al., 2022) demonstrated that the SOIE (*Strengthening, Orientation, Investigation, and Evaluation*) strategy integrating SSI significantly improved students' chemical literacy through investigative activities, data interpretation, and contextual problem-solving. Recent research has also shown that SSI-based learning contributes to the development of students' collaboration and communication skills, thereby supporting the achievement of 21st-century learning competencies (Mellyzar et al., 2025).

Learning Models for Integrating SSI

The success of SSI implementation is strongly influenced by the learning model employed. Various studies indicate that *active learning* is one of the most appropriate approaches for integrating SSI because it provides students with opportunities to explore problems, engage in discussions, construct arguments, and make decisions based on scientific evidence.

Problem-Based Learning (PBL) is one of the most widely used models for SSI implementation because it focuses on solving real-world problems related to everyday life. Through PBL, students are trained to identify problems, seek scientific information, analyze alternative solutions, and formulate responsible decisions. In addition to PBL, *Inquiry-Based Learning* (IBL) is also widely implemented because it encourages students to conduct scientific investigations systematically, beginning with formulating questions and conducting investigations through to evaluating the results.

Other approaches that support SSI implementation include case-based learning, argumentation-based learning, and *Project-Based Learning* (PjBL). (Widiandari & Redhana, 2021) demonstrated that case-based learning can improve critical thinking skills through the analysis of contextual problems. (Sudiana & Redhana, 2018) emphasized that argumentation-based learning is effective in improving students' ability to formulate claims, provide evidence, and construct scientific reasoning. Meanwhile, green chemistry-based projects enable students to connect chemistry concepts with sustainability issues, making learning more meaningful (Redhana et al., 2021; Redhana & Suardana, 2021; Putri & Iriani, 2025).

Integration of SSI as a Strategy for Developing Critical Thinking Skills

Conceptually, the integration of SSI into chemistry education is a strategy that connects scientific knowledge with social contexts, enabling students not only to understand chemistry concepts but also to apply them in addressing various real-world problems. This process promotes the development of analytical skills, evidence evaluation, scientific argumentation, reflection, and decision-making, which constitute key components of critical thinking skills.

Findings from various *Systematic Literature Reviews* indicate that SSI-based learning consistently has a positive impact on improving students' critical thinking skills (Suardana et al., 2025; Falah et al., 2024). These findings are consistent with studies by (Casmini & Redhana, 2025; Liani & Redhana, 2025) which state that Challenge-Based Learning, STEM, and STEAM have characteristics similar to SSI, namely an orientation toward contextual problem-solving that requires students to think critically, creatively, and collaboratively.

Based on this theoretical review, it can be understood that the effectiveness of SSI integration is determined not only by the use of social issues as learning contexts but also by the learning model employed, the quality of instructional materials, teacher competence, and curriculum support. Therefore, SSI integration represents a relevant approach for developing critical thinking skills while simultaneously enhancing students' scientific literacy in chemistry education.

METHOD

Research Type

This study uses the Systematic Literature Review (SLR) method to identify, evaluate, and analyze relevant literature on integrating socio-scientific issues (SSI) in chemistry learning to improve students' critical thinking skills. SLR was chosen as the research method because of its systematic, structured nature, enabling researchers to obtain more comprehensive, objective conclusions through

an analysis of existing literature. This method provides a more transparent and replicable approach in research related to the integration of SSI in chemistry education. SLR enables the identification of trends, patterns, and gaps in existing research in this field, as well as guiding further research.

Research Question Formula (Research Question/RQ)

To focus the literature review, this study formulates the following three main questions.

Table 1. (Research Question)

No	Research questions	The analysis sought
1	How does the integration of social-scientific issues (SSI) in chemistry learning affect students' critical thinking skills?	Assessing the effect of SSI integration on students' critical thinking skills, both in terms of argumentation, problem solving, and other higher-order thinking skills. Relevant journals will be analyzed to examine the relationship between SSI-based teaching and the improvement of critical thinking skills in chemistry learning.
2	What learning model is most effective in integrating SSI to improve critical thinking skills in chemistry learning?	Identify learning models used in SSI-based chemistry learning, such as Problem-Based Learning (PBL), Inquiry-Based Learning (IBL), and other models. Then, analyze the effectiveness of each model in improving students' critical thinking skills.
3	What are the challenges faced in implementing SSI-based learning in chemistry education?	Analyzing the challenges that arise in the application of SSI in chemistry learning, such as difficulties in curriculum planning, limited resources, and teacher readiness in implementing SSI.

Research Procedures

This study uses the Systematic Literature Review (SLR) method to examine the literature on integrating socio-scientific issues (SSI) into chemistry learning to improve students' critical thinking skills. The literature search was conducted through reliable online databases such as ERIC, Google Scholar, SCOPUS, and SINTA. The keywords used in the search were "Socio-scientific Issues," "critical thinking in chemistry education," and "chemistry education with SSI." The search will begin in September and continue through December 2025. In select articles, inclusion and exclusion criteria were established to identify primary literature relevant to the research topic. These criteria are shown in the following table.

Table 2. Inclusion and exclusion criteria

Inclusion Criteria	Exclusion Criteria
1) Articles published between 2015 and 2025.	1) Articles that are not fully accessible.
2) Topics focusing on chemistry education and SSI integration.	2) Research using the Development method.
3) A journal focused on improving critical thinking skills in chemistry.	3) Article with an incomplete abstract.
4) Articles that use research methods relevant to SLR (quasi-experiments, experiments, or case studies).	4) Articles that are not relevant to the integration of SSI in chemistry.
5) Articles published in English or Indonesian.	5) Articles that focus on topics other than SSI-based chemistry learning.

After the inclusion and exclusion criteria were determined, the next step was to select articles by reading the titles, abstracts, and introductions to ensure their relevance to the research focus on the integration of social-scientific issues (SSI) in chemistry learning and its impact on students' critical thinking skills. The learning model used to integrate SSI in chemistry learning.

Measurement of critical thinking skills applied in research.

Findings related to the effectiveness of SSI integration in improving students' critical thinking skills.

Challenges and obstacles faced in implementing SSI in chemistry learning.

After the selected articles were analyzed, important data, including research titles, authors, publication years, research methods, main results, and relevance to the study topic, were extracted. The analysis was conducted using a narrative approach, systematically describing the findings in terms of patterns, trends, and research gaps identified in the existing literature.

RESULT AND DISCUSSION

The Effect of SSI Integration on Students' Critical Thinking Skills (RQ1) Improving Analytical and Evaluative Skills through SSI

The analysis shows that integrating social-scientific issues in chemistry learning consistently leads in significant improvements in students' critical thinking skills. Almost all of the studies analyzed (19 out of 21 articles) reported the development of higher-order cognitive skills, as indicated by an increase in students' ability to identify problems, analyze data, evaluate arguments, and make evidence-based decisions.

(Fadly et al., 2022) research confirms that the use of SOIE strategies that present SSI contexts, such as global warming, NO_x emissions, and the greenhouse effect, can improve chemistry literacy by enhancing data interpretation and investigation design skills. This improvement in literacy demonstrates a close relationship between SSI integration and critical thinking activities, as both require analytical and evaluative processes for chemical and social phenomena (Fadly et al., 2022).

(Lin & Wei, 2024) international study also shows that students' positions in SSI debates (affirmative, opposition, multi-standpoint) influence the quality of their arguments. Students in the affirmative and opposition positions demonstrate better abilities in constructing claims, evidence, and rebuttals. These findings reinforce that SSI-based learning can develop critical thinking structures through the process of scientific argumentation (Lin & Wei, 2024).

In addition, there is strong empirical evidence on the effectiveness of active learning in developing critical thinking skills, which is relevant to the characteristics of SSI learning.

Table 3. Empirical Evidence of the Effectiveness of Active Learning and Socio-scientific Issues (SSI) on Students' Critical Thinking Skills

Researchers	Research Findings
(Selamat, 2018)	The 7E learning model, grounded in local culture, significantly improves critical thinking skills compared to discovery learning. These results indicate that cultural context, which is also part of SSI, can improve students' analysis and evaluation of chemical phenomena.
(Sudiana & Redhana, 2018)	Argument-based textbooks have been proven to improve the disposition and critical thinking skills of junior high school students. These findings support the view that argumentation exercises, an essential component of SSI, are highly effective in strengthening critical thinking skills.
(Widiandari & Redhana, 2021)	Case study-based learning improves students' ability to identify chemistry problems and analyze evidence. The case-based approach is very similar to SSI practice.
(Redhana et al., 2021; Redhana & Suardana, 2021)	Green chemistry teaching materials and practicums improved learning outcomes and analytical skills. Although the focus is not on SSI, this approach still connects chemistry concepts to environmental issues, thereby increasing students' critical awareness of global issues.

Forms of Improving Students' Critical Thinking in SSI Learning

Based on the analysis, an increase in critical thinking skills occurred in various critical thinking indicators, including:

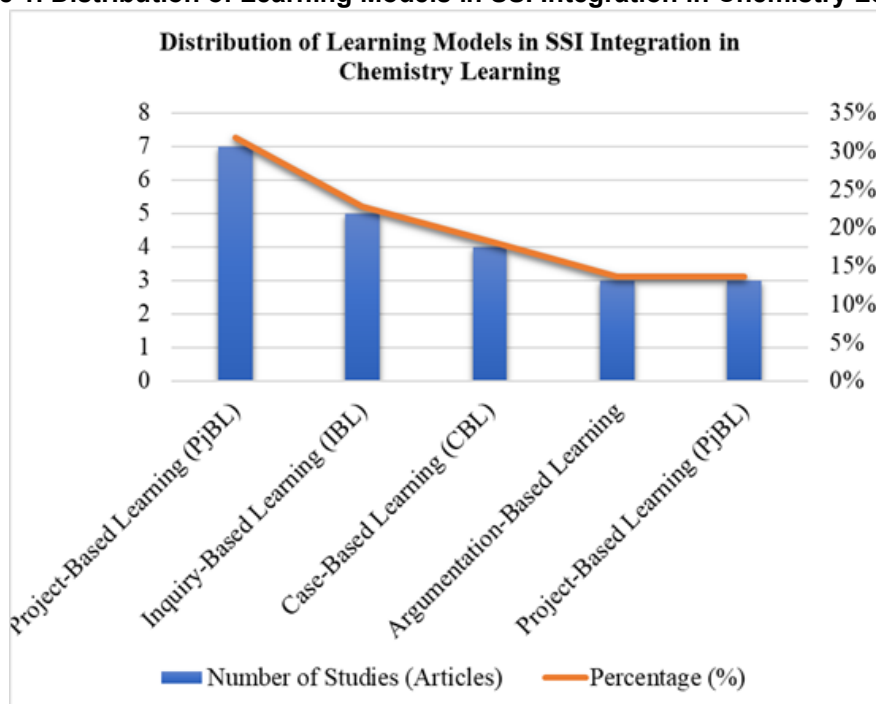
- ✓ Interpretation and analysis of chemical phenomena (Fadly et al., 2022; López-Fernández et al., 2022).
- ✓ Evaluate scientific evidence and arguments (Lin & Wei, 2024; Sudiana & Redhana, 2018).
- ✓ Preparation of claims, evidence, and logical reasoning
- ✓ Data-based decision making

- ✓ Strengthening conceptual understanding through social and environmental contexts

For example, (López-Fernández et al., 2022) research noted that students experienced an increase in critical analysis when involved in role-playing games about plastic issues. This perspective-based activity encouraged them to assess various viewpoints, construct arguments grounded in chemical concepts, and evaluate social impacts. These results confirm that chemistry learning integrated with SSI not only improves cognitive domain skills but also the affective domain in the form of greater sensitivity to social and environmental issues.

Effective Learning Models in SSI Integration (RQ2)

Figure 1. Distribution of Learning Models in SSI Integration in Chemistry Learning



Based on the distribution graph of learning models in the integration of Socio-scientific Issues (SSI) in chemistry learning, it can be seen that Problem-Based Learning (PBL) is the most dominant model used, with a total of 7 articles. The dominance of PBL indicates that this model is the most effective in integrating social and scientific issues, as it presents authentic problems that require students to conduct scientific investigations, analyze data, and make evidence-based decisions. This finding reinforces the results of previous studies which state that PBL plays a significant role in improving critical thinking, creativity, and problem-solving skills in the context of SSI.

Furthermore, Inquiry-Based Learning (IBL) ranked second with 5 articles. The use of IBL reflects the need for SSI learning that emphasizes the scientific investigation process, especially in examining issues such as environmental pollution, chemical toxicity, and energy efficiency. This model encourages students to formulate questions, conduct investigations, and evaluate findings systematically, thereby strengthening scientific process skills and scientific reasoning as the basis for critical thinking.

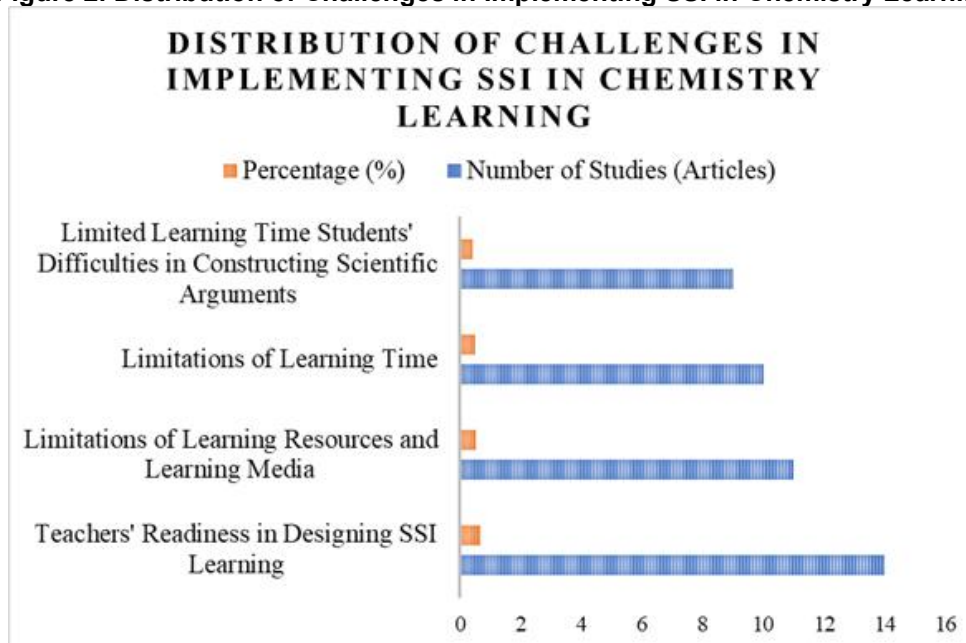
Case-Based Learning appeared in 4 articles and demonstrated its relevance in SSI learning that focuses on the analysis of real cases. Through this approach, students are trained to evaluate contextual events that are close to everyday life, such as environmental pollution, industrial waste, and the use of hazardous chemicals. This model is effective in developing the ability to evaluate evidence and construct logical and data-based scientific arguments.

Meanwhile, Argumentation-Based Learning and Project-Based Learning (PjBL) appear in 3 articles each. Although less frequent, these two models play a strategic role in SSI integration. Argumentation-Based Learning specifically supports the development of the ability to formulate claims, provide scientific justification, and consider various social perspectives. PjBL allows students to explore solutions to environmental problems through applied, context-based project activities, including those in green chemistry.

Overall, this graph shows that SSI integration in chemistry learning is dominated by active, student-centered models, particularly PBL and IBL. This confirms that SSI learning requires a pedagogical approach that not only emphasizes mastery of concepts but also the development of critical thinking skills, scientific argumentation, and responsible decision-making on social and environmental issues.

Key Challenges in SSI Implementation (RQ3)

Figure 2. Distribution of Challenges in Implementing SSI in Chemistry Learning



Based on the distribution graph of challenges in implementing Socio-scientific Issues (SSI) in chemistry learning, it is evident that teachers' readiness in designing SSI learning is the most dominant challenge, appearing in 14 of the 21 articles reviewed. This finding shows that although SSI is recognized as effective in improving critical thinking and scientific argumentation skills, many teachers still struggle in select issues relevant to students' developmental levels, design scientific discussion scenarios, and manage the dynamics of argumentation in the classroom argumentation. In addition, ensuring the use of valid scientific data sources is an essential factor that hinders optimal implementation of SSI.

The next challenge is the limited availability of learning resources and media, as reported in 11 articles. This condition indicates that the availability of structured, systematic SSI-based teaching materials remains limited in many schools. The lack of modules, worksheets, or learning media specifically designed to support socio-scientific issue-based learning means that teachers have to develop materials independently, which ultimately increases their workload and reduces the consistency of SSI implementation in the classroom.

Furthermore, limited learning time is a challenge that appears in 10 articles. SSI-based learning requires more time for discussion, investigation, and evaluation of scientific arguments. However, limited class hours in the curriculum structure often force teachers to simplify the learning process, thereby reducing the depth of issue exploration and the quality of scientific discussion.

Meanwhile, students' difficulties in constructing scientific arguments were reported in 9 articles. This challenge indicates that many students are not yet accustomed to expressing opinions scientifically, linking claims to relevant evidence, and constructing logical justifications and rebuttals. These findings emphasize the importance of providing scaffolding and continuous practice in argumentation in SSI learning so that students can optimally develop higher-order thinking skills.

Overall, this graph shows that the challenges of implementing SSI in chemistry learning are not only technical, but also pedagogical and structural. Therefore, systematic efforts are needed in the form of improving teacher competence, developing SSI-based learning resources, and adjusting learning strategies so that SSI integration can be implemented effectively and sustainably at the school level.

Conceptual Synthesis and Implications for Chemistry Learning

Based on a synthesis of 21 reviewed articles, integrating social-scientific issues (SSI) in chemistry learning has been proven effective in improving students' critical thinking skills, strengthening science literacy, connecting chemistry concepts to global issues, and building social and environmental awareness. SSI-based learning encourages students not only to understand chemistry concepts theoretically but also to relate them to real-world issues such as the environment, health, and sustainability, thereby stimulating their ability to analyze, evaluate, and make decisions based on scientific evidence. These findings are in line with (Selamat, 2018) research, which shows that the use of local cultural contexts in the 7E learning model can significantly improve students' critical thinking skills, as students learn chemistry through social phenomena that are close to their lives (Selamat, 2018).

In addition, learning that emphasizes scientific argumentation and evidence analysis, as developed in the argument-based textbook by (Sudiana & Redhana, 2018), has been shown to improve students' critical thinking dispositions and skills. Conceptually, SSI learning works optimally when supported by an active problem-based learning model, relevant and contextual teaching materials, teacher competence in managing discussions and arguments, and adequate curriculum support (Sudiana & Redhana, 2018).

This is reinforced by the results of research by (Widiandari & Redhana, 2021) which shows that case study-based learning provides space for students to critically and reflectively analyze real chemistry problems, as well as research by (Redhana et al., 2021; Redhana & Suardana, 2021) and Redhana and Suardana (2021), which confirm that context-based green chemistry teaching materials and practical work can improve students' conceptual understanding, learning outcomes, and sensitivity to sustainability issues. Thus, SSI not only functions as a learning context but also as a strategic means of building students' higher-order thinking skills and science literacy in chemistry learning (Redhana et al., 2021; Redhana & Suardana, 2021; Widiandari & Redhana, 2021).

Research Implications

Theoretically, the results of this SLR indicate that integrating SSI in chemistry learning strengthens the pedagogical foundations of social constructivism, in which science learning is understood as a process of constructing knowledge through interactions between scientific concepts and social contexts. Chemistry learning is no longer viewed as a mere transfer of knowledge, but rather as a reflective process involving argumentation, evaluation of evidence, and decision-making in dealing with socio-scientific issues. This approach is in line with the views of (Redhana et al., 2021; Sudiana & Redhana, 2018) who emphasize the importance of context-based and argumentation-based learning in developing students' critical thinking and science literacy skills.

In practical terms, these SLR findings imply that chemistry teachers need to be equipped to design problem-based and argument-based learning using relevant socio-scientific issues. The use of contextual teaching materials, such as green chemistry modules and environmental case studies, needs to be optimized to enable students to relate chemistry concepts to real-world problems critically. Research by (Widiandari & Redhana, 2021; Selamat, 2018; Wayan et al., 2023) shows that active learning involving investigation, experimentation, and contextual discussion can significantly improve students' critical thinking and science process skills (Selamat, 2018; Wayan et al., 2023; Widiandari & Redhana, 2021). From a policy perspective, this study's results indicate the need for curriculum support that provides explicit space for integrating SSI in chemistry learning. The curriculum needs to be designed flexibly so that teachers have the time and freedom to develop discussions, arguments, and reflections based on socio-scientific issues. This policy support is important to ensure that chemistry learning can contribute significantly to the development of 21st-century skills, including critical thinking, science literacy, and socio-environmental awareness, as emphasized in the studies by (Redhana et al., 2020; Suardana et al., 2024).

CONCLUSION AND SUGGESTION

Conclusion

1. The integration of socio-scientific issues (SSI) into chemistry education has been proven effective in improving students' critical thinking skills, particularly in the areas of analytical skills, evaluation of scientific evidence, scientific argumentation, and data-driven decision-making.
2. The most effective learning models for integrating SSI are Problem-Based Learning (PBL) and Inquiry-Based Learning (IBL), while case-based learning, argumentation-based learning, and

Project-Based Learning (PjBL) also demonstrate positive contributions to the development of critical thinking skills.

3. The implementation of SSI in chemistry education still faces several challenges, including teachers' readiness to design SSI-based learning, limited learning resources and instructional materials, limited instructional time, and students' difficulties in developing scientific arguments.
4. Successful implementation of SSI requires support in the form of enhanced teacher competencies, the development of contextual learning materials, and curriculum policies that support the sustainable integration of social and scientific issues into chemistry education.

Suggestions

1. Chemistry teachers are encouraged to systematically integrate socio-scientific issues (SSI) into learning by implementing active, student-centered learning models, such as Problem-Based Learning (PBL) and Inquiry-Based Learning (IBL).
2. The development of SSI-based instructional materials, learning media, and assessment tools needs to be strengthened to make learning more contextual and support the development of students' critical thinking skills.
3. Educational institutions and policymakers should provide support through the development of more flexible curricula and the provision of continuous professional development programs to enhance teachers' competencies in implementing SSI-based learning.
4. Future research is recommended to expand the scope of the review by including more articles from international databases, exploring SSI implementation across various chemistry topics, and developing more comprehensive and validated instruments for assessing critical thinking skills.

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