HYDROGEN
JURNAL KEPENDIDIKAN KIMIA
https://e-journal.undikma.ac.id/index.php/hydrogen/index

February 2026. 14(1)
e-ISSN: 2656-3061
p-ISSN: 2338-6487
pp. 162-172

Socio-Scientific Issues in Chemistry Education for Improving 21st Century Skills: A Systematic Literature Review

Heppy Okmarisa*, Dwi Eka Sabila, Deswita Maharani, Nurmala Sari
Chemistry Education Study Program, Faculty of Tarbiyah and Teacher Training, Sultan Syarif Kasim Riau State Islamic University, Pekanbaru, Indonesia
*Corresponding Author e-mail: heppyokmarisa91@gmail.com

Article History
Received: 30-12-2025
Revised: 07-02-2026
Published: 28-02-2026

Keywords: 21st-Century Skills; Chemistry Education; PRISMA Framework; Socio-Scientific Issues (SSI); Systematic Literature Review.

Abstract
This Systematic Literature Review (SLR) investigates the integration of Socio-Scientific Issues (SSI) in chemistry education to foster 21st-century skills. Using the PRISMA framework, 15 empirical studies published between 2020 and 2025 were analyzed from Google Scholar, SINTA, and Scopus. The findings indicate that SSI-based learning significantly impacts various student competencies, with the highest distribution of improvement observed in Critical Thinking (38%) and Science Literacy (31%), followed by Argumentation (13%). Additionally, Problem Solving, Creative Thinking, and Higher Order Thinking Skills (HOTS) each contributed 6% to the reported outcomes. The integration of real-world issues, such as green chemistry and polymer waste, proved effective in bridging abstract chemistry concepts with social-environmental responsibility. This study concludes that SSI serves as a vital catalyst for transforming chemistry pedagogy. Future research should focus on developing standardized assessment instruments to measure the long-term retention of these skills.

How to Cite: Okmarisa, H., Eka Sabila, D., Maharani, D., & Sari, N. (2025). Socio-Scientific Issues in Chemistry Education for Improving 21st Century Skills: A Systematic Literature Review. *Hydrogen: Jurnal Kependidikan Kimia*, *14*(1), 162-172. https://doi.org/10.33394/hjkk.v14i1.19111

https://doi.org/10.33394/hjkk.v14i1.19111

INTRODUCTION

In order for students to be able to handle complex global issues, modern chemistry learning requires more than just an understanding of concepts but also the development of critical thinking skills, creativity, collaboration, communication, scientific literacy, and social responsibility (Wahyuni et al., 2025). One approach that is widely recommended is to incorporate SSI into chemistry learning. Socio-scientific issues (SSI) are social issues rooted in science and laden with ethical, economic, and environmental aspects, such as plastic pollution, renewable energy, climate change, and food security (Högström et al., 2025).

Various recent studies confirm that SSI-based learning is able to connect chemistry concepts with real life, thereby increasing interest, motivation, and relevance of learning for students. (Mongkau et al., 2024). This approach is in line with the 21st-century skills framework, which emphasizes contextual learning, problem solving, and student participation in science-based public decision-making processes (Dewi & Yahdi 2025). However, despite these advancements, chemistry is frequently taught using traditional, teacher-centered methods that rely heavily on rote memorization. Consequently, the subject is often perceived as abstract and disconnected from social reality (Sinambela et al., 2025), leaving students' 21st-century skills suboptimal and underdeveloped (Sinambela et al., 2025, Maimunah, 2025). This discrepancy highlights the urgent need for a systematic mapping of how SSI is utilized to effectively bridge this gap.

A number of empirical studies show that the application of SSI in chemistry learning effectively improves students' critical thinking, argumentation, problem solving, chemistry literacy, and social awareness skills (Sari et al., 2024). Various learning models such as guided

inquiry, problem-based learning, project-based learning, and real-life case contexts are used to integrate SSI into chemistry topics such as salt hydrolysis, environmental chemistry, polymers, and chemistry in everyday life (Mukti & Widjajanti, 2025). On the other hand, several systematic studies have emerged on SSI research trends in science and chemistry education, mapping the most frequently studied topics, learning models, and skill aspects, particularly scientific argumentation, problem solving, and critical thinking (Munawwarah, 2025).

There is also a systematic review related to 21st-century skills in general in science learning that highlights the role of constructivist approaches (inquiry, PBL, PjBL, contextual learning) in improving learning achievement as well as the 4Cs and scientific literacy, although it does not specifically place SSI as the main focus (Mere, 2023)(Ahiri, 2025). The literature shows that studies on SSI in chemistry education and studies on 21st-century skills have developed rapidly in recent years (Purwandari et al., 2024). However, most systematic studies still focus on general trends in the use of SSI in science or chemistry without explicitly linking them to a comprehensive framework of 21st-century skills (Dewi & Yahdi 2025).

The scientific uniqueness of this article lies in its attempt to compile a comprehensive mapping that explains the 21st-century skills developed, the chemistry materials used, and evidence of the effectiveness of socio-scientific issue (SSI)-based chemistry learning on these skills based on recent publications. The need for such systematic mapping is crucial as previous reviews often focus on general trends without specific alignment to the 21st-century competency framework (Dewi & Yahdi 2025).

Based on these identified gaps in the literature, this systematic literature review formulates three main research questions: (1) which 21st-century skills are the primary focus of development in SSI-based chemistry learning research; (2) what chemistry materials or topics are applied to foster these skills; and (3) how effective is SSI-based chemistry learning in improving the various skill indicators reported in recent studies. Consistent with these questions, this article aims to identify and categorize the 21st-century skills developed through SSI-based learning, as well as to inventory the chemistry topics utilized in these interventions.

The selection of this review theme is driven by the critical need to bridge the gap between abstract chemistry theory and the practical implementation of 21st-century skills. By synthesizing diverse empirical findings, this study offers a strategic roadmap for educators to transform chemistry classrooms into dynamic spaces for the development of global citizenship and scientific literacy.

METHOD

This study employs the Systematic Literature Review (SLR) method, designed to identify, evaluate, and interpret research findings regarding the implementation of Socio-Scientific Issues (SSI) in chemistry education and its impact on 21st-century skills. The review follows the PRISMA 2020 (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) protocol to ensure transparency and the quality of the synthesized results (Page et al., 2021). The selection process consists of four main stages: identification, screening, eligibility, and inclusion of final articles (Haddaway et al., 2018)(Dinter et al., 2021). This method was specifically chosen to identify, select, and analyze relevant scientific articles on the application of SSI in chemistry learning at the Senior High School

Data Collection the process begins with defining the research objectives, followed by a structured literature search conducted between November 13 and December 12, 2025, using the Google Scholar, Sinta, and Scopus databases. A combination of keywords was used, including *"Socio-Scientific Issues," "SSI," "Chemistry Education," and "21st Century Skills."* The search was limited to publications released between 2020 and 2025. This specific five-year timeframe was selected to capture the most recent pedagogical shifts in SSI implementation and to ensure the findings reflect the current post-pandemic educational landscape.

Inclusion and Exclusion Criteria To ensure relevance, inclusion criteria were strictly defined as follows: (1) articles discussing the integration of SSI into chemistry learning; (2) studies focusing on the development of 21st-century skills; (3) publications released between 2020 and 2025; (4) research samples involving High School (SMA) stu-

dents; and (5) articles published in Sinta-accredited national journals or Scopus-indexed international journals. Conversely, articles were excluded if they: (1) were purely theoretical reviews without empirical data; (2) focused on tertiary education (university level); or (3) lacked clear instrumentation for assessing skill outcomes

Data Analysis Abstracts were reviewed to capture core ideas, followed by full-text readings for clarification. Data extraction was facilitated using Microsoft Excel to organize a coding matrix. The coding process involved systematically categorizing data into smaller analytical units using variable elements such as research objectives, methods, and results (Yuendita & Rohaeti, 2025). A thematic analysis was then applied to synthesize these units. This SLR approach is instrumental in synthesizing various relevant research findings to present more comprehensive and balanced conclusions regarding the influence of SSI on student competencies (Arham & Dimyati, 2024 ; Krath et al., 2021). After a multi-stage selection process, 15 articles were identified as eligible for final analysis.

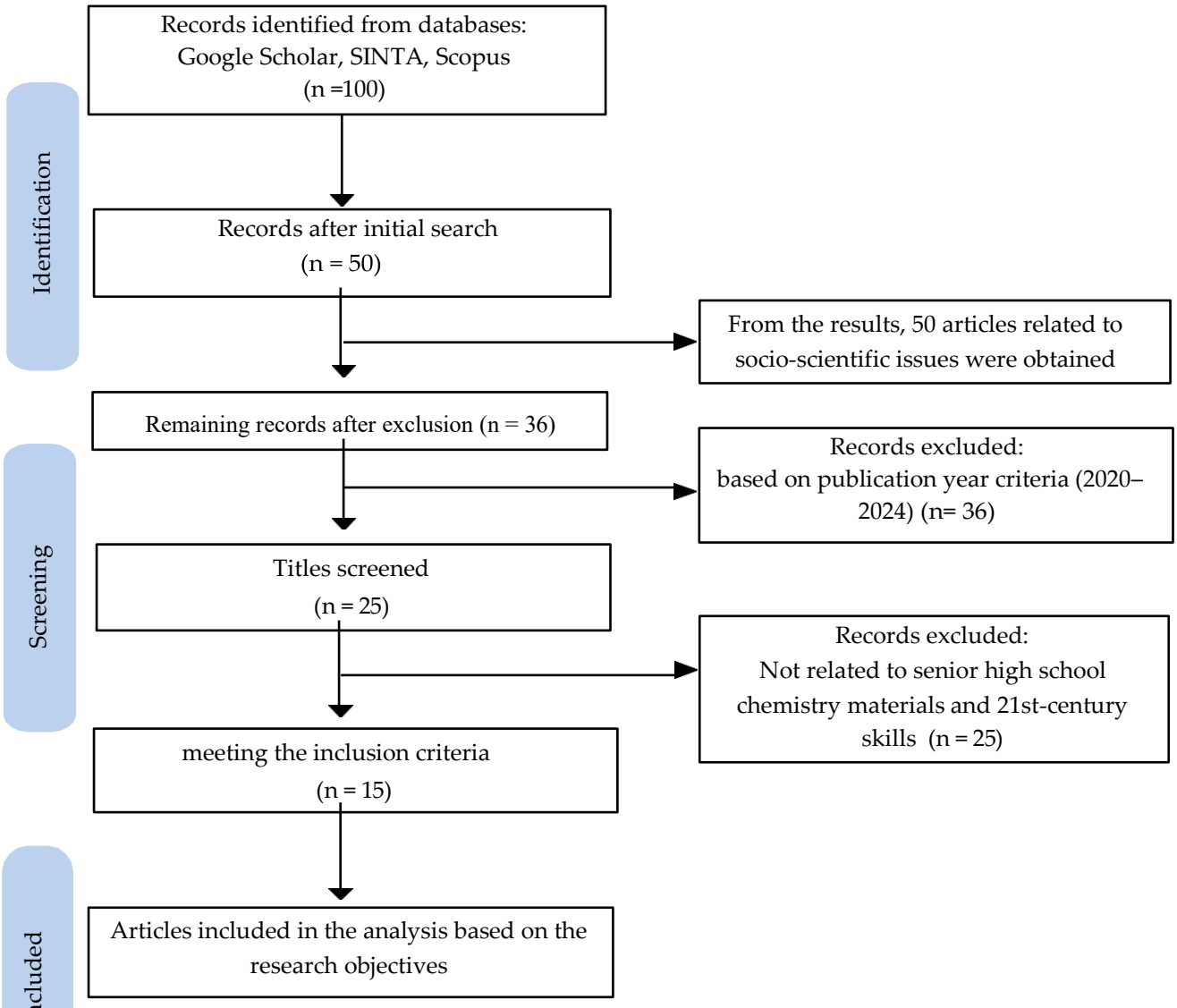

Figure 1. PRISMA Diagram of Article Screening

RESULTS AND DISCUSSION

Results

This study began by searching for and selecting articles from national and international journals through specific databases. Articles were searched using keywords relevant to the research topic. Initially, 100 articles with similar themes were found, but after selection, only 15 articles were considered most relevant to the research needs. The selected articles focused on in-depth discussions of socio-scientific issues that support 21st-century skills in chemistry learning and the details are shown in Table 1.

Table 1. Results of Journal Article Review

No.	Author & Year	Socio-Scientific Issue (SSI)	Chemistry Material	Enhanced 21st Century Skills	Key Findings (Impact/ Effectiveness)
1.	Wuri Utami Dea Sismawarni, Usman, Nur Hamid, Pintaka Kusumaningtyas (2020)	The issue of plastic waste incineration and motor vehicle fuel combustion	Basic Laws of Chemistry.	higher-order thinking skills/HOTS	The statistical analysis results show that the t-value = 3.072 > t-table = 1.673 (α= 0.05).
2.	Pintaka Kusumaningtyas , Rezky Oktafiani, Mukhamad Nurhadi, Sekar Sulistyaningwarni (2020)	The issue of sour fruit taste is linked to vitamin C content; the issue of lemon infused water for health; the issue of alkaline water to neutralize body acid and remove toxins.	Acid–Base.	Critical thinking	The results of statistical analysis using the t-test (calculated value, 3.153 > table value, 1.66)
3.	Rizka Azkia, Teguh Wibowo (2024)	Issues surrounding the impact of fuel consumption, the fire at the Pertamina Plumpang depot, and oil spills at sea.	petroleum and the environment	Critical Thinking	8 students in the very high category and 1 in the high category; average critical thinking skills of 86.47%.
4.	Mara del Mar López-Fernández, Francisco González-García, Antonio Joaquín Franco, Mariscal (2022)	Plastic issues: high production and consumption, limited fossil raw materials, low recycling rates, non-biodegradability, and microplastic problems in various ecosystems.	Polymer (plastic)	Critical thinking and evidence-based argumentation	Significant improvement in understanding of chemistry concepts and vision; correct answers about microplastic formation increased from 33.3% to 76.2%, and about the presence of plastic in the ocean from 72.2% to 90.5% after the intervention.
5.	Agung Purwanto , Yuli Rahmawati , Novia Rahmayanti , Alin Mardiah , Risky Amalia (2021)	The issues raised were environmental problems related to water pollution from waste, acid rain, and the impact of coal mining, which causes water and soil to become acidic.	Acids and Bases.	Critical thinking	Effectively improved students' critical thinking skills to a good level across all indicators, with the strongest improvement in problem identification and concept understanding, accompanied by increased motivation and engagement in learning.

No.	Author & Year	Socio-Scientific Issue (SSI)	Chemistry Material	Enhanced 21st Century Skills	Key Findings (Impact/ Effectiveness)
6.	Afifa Purwandari, Sukma Ayu Deaningtyas, Nur Izzah Faradillah, Sevi Anjelika Putrikundia, Oktavia Sulistina (2024)	Controversial chemical and scientific issues such as climate change, bio-fuels, petro-leum, water quality, food coloring, and vaccination.	SSI-based chemistry learning.	Science Literacy	Studies show that SSI-based chemistry learning improves students' scientific literacy, especially their ability to explain phenomena, investigate, and draw scientific conclusions.
7.	NurAida Afrilya, Neti Afrianis, Nurhadi (2022)	The issue of adulterated gasoline sales and various problems related to petro-leum use affect-ing engine per-formance, emis-sions, and the environment.	Crude oil	Science literacy	n-gain science literacy in the experimental class was 0.7352 (high category) and in the control class was 0.6729 (medium), t-count was -22.942 with |t-count| > t-table 2.0301 (α 0.05).
8.	Syafira Rachmatyah Ulliva, A.K. Prodjosantoso (2025)	The issue of excessive salt and sugar consumption in daily life and its consequences for public health.	Chemical bond	Science literacy	The MANOVA test and between-subjects test showed significance < 0.001 with a practical contribution of approximately 0.441.
9.	Cahya Anggita Safitri, Yuli Hartati, Nurlaili (2021)	Issues of energy use, heat trans-fer in everyday life, and contro-versial scientific issues in society;	Thermochemistry	Argumentatio n	The average pretest score of 45.69 (fair ca-tegory) increased to a posttest score of 62.41 (good category), with an N-gain of 0.30.
10.	Elsa Hanifah, Setiono, Gina Nuranti (2021)	The impact of the Work From Home (WFH) policy during the Covid-19 pandemic on the environ-ment, such as increased elec-tricity consum-ption, CO_2 emissions from power plants, and increased plastic waste from online shopping and delivery.	Environmental change/ environmental balance	Problem solving skills	The SSI model in the experimental class produced a moderate gain in problem-solving skills (average 0.62) and differed significantly from the control class (gain 0.26, low category) based on the Wilcoxon test.

No.	Author & Year	Socio-Scientific Issue (SSI)	Chemistry Material	Enhanced 21st Century Skills	Key Findings (Impact/ Effectiveness)
11.	Putri Nadlifah Tiara Nita, Ella Izzatin Nada (2024)	Air pollution, global warming, batik waste in the context of green chemistry.	Green Chemistry	Creative Thinking	PBL-SSI effectively stimulates creative thinking; t-test p 0.001 and effect size 0.708 (moderate), with the experimental class having a higher average creative score than the control class.
12.	Medina Fasya Salsafitri, Risa Rahmawati Sunarya, Imelda Helsy, Iis Dahriah. (2025)	The problem of conventional petroleum-based plastic waste that is difficult to decompose, and environmentall y friendly bioplastic alternatives from agricultural waste (sugarcane bagasse).	Green chemistry and biopolymers/ bioplastics	Scientific argumenta-tion	The average ability to complete the worksheets reached a score of 91 in the "very good" category. The majority of oral arguments were at level 2 (claims with evidence), while written arguments averaged level 3 (claims with evidence and weak rebuttals; 22 out of 36 students were at level 3).
13.	Tania Damayanti Mukti & Endang Widjajanti L.F.X (2025)	The use of KNO3 and ZA fertilizers in agriculture, the use of KCN fish poison in the sea, and the use of fluoride in toothpaste in relation to environmental and health impacts.	Salt hydrolysis	Chemistry literacy and Higher Order Learning Skills (HOLS)	Chemistry literacy; in most SSI contexts, ≥75–89% of students were in the fair to very good category, with the exception of the ZA context, which was still dominated by the poor category (64%).
14.	Aida Hajijah, Mariam Nasution, Nur Azizah Putri Hasibuan, Lelya Hilda, Najah Yousef Baroud (2025)	Scientific social issues relevant to stoichiomet-ry, such as environmental pollution, food safety, and the use of chemicals in everyday life (e.g., waste, food additives, energy)	Stoichiometry	Critical Thinking	The independent t-test showed no significant difference in the pretest ($p = 0.335 > 0.05$) but there was a significant difference in the posttest ($p = 0.027 < 0.05$).

No.	Author & Year	Socio-Scientific Issue (SSI)	Chemistry Material	Enhanced 21st Century Skills	Key Findings (Impact/ Effectiveness)
15.	Dinda Nur Azizah, Dedi Irwandi, dan Nanda Saridewi (2021)	The issue of acid rain and other environ-mental prob-lems involving acidic/alkaline substances in the environ-ment	Acid Base	Science Literacy	The results of the independent sample t-test show a sig value < 0.05 at a significance level of 5%.

Discussion

Based on the results of the analysis of the reviewed articles, the range of years of publication of socioscientific issue-based chemis-try learning research (SSI) shows a fairly clear variation. The years 2025 and 2021 are the periods with the number of articles relatively more than any other year, each contributing several articles to this study. This indicates that in these two periods there was an increase in researchers' attention to the application of SSI in Chemistry learning, along with the increasing demands for 21st century skills development in the curriculum. Meanwhile, in certain years there were relatively fewer publications, which indicates fluctuations in research interest or publication limitations in the period, although the topic of SSI-based learning remains relevant and actual.

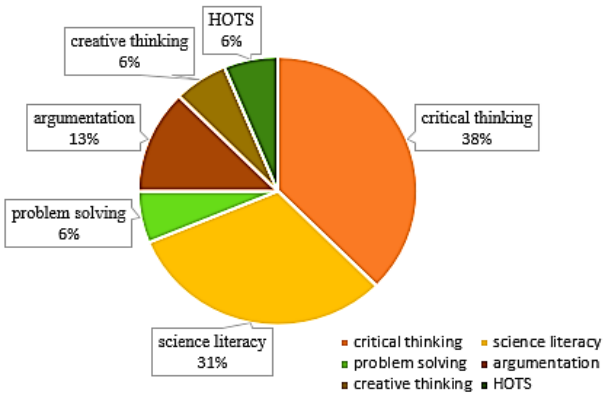

Figure 2. Distribution of 21st Century Skills

In the last five years, research on SSI-based chemistry learning is dominated at the SMA/MA level. This dominance can be attributed to the characteristics of learners at that level who are at the stage of formal cognitive development, so they are better equipped to understand the relationship between chemical concepts, social issues, and environmental impacts. SSI-based learning at this level aims not only to strengthen mastery of concepts, but also to train critical thinking skills, scientific literacy, decision making, and awareness of social and environmental problems faced by the community.

Based on the mapping of materials used in the articles analyzed, it was found that acid–base materials and environmental chemistry were the topics most often integrated with socioscientific issues. This material is widely associated with real issues such as acid rain, water pollution, industrial waste, and environmental balance. Furthermore, Petroleum and energy materials, as well as polymers/plastics and microplastics are also quite dominant in use, given the high relevance of these issues to global problems such as the energy crisis, marine pollution, and plastic waste management.

Other materials such as green chemistry, biopolymers/bioplastics, stoichio-metry, chemical bonding, thermochemistry, and the Basic Laws of chemistry appear with lower frequency, but still show strong potential to be developed in the context of SSI when associated with the right issues. The dominance of contextual and applicative materials shows that SSI-based chemistry learning tends to be more effectively applied to topics that have a direct connection with everyday life and community problems. Thus, the selection of chemicals relevant to socioscientific issues is an important factor in supporting the success of SSI-based learning to develop 21st century skills and form learners who have scientific, social, and environmental awareness.

21st Century Skills Development Focus in SSI-Based Chemistry Learning

Based on the analysis of the 15 reviewed arti-cles, 21st-century skills developed through SSI-based chemistry learning can be grouped into sev-eral main categories, including critical thinking,

scientific and chemical literacy, higher-order thinking skills (HOTS), scientific argumentation, creativity, and problem solving. Among these competencies, critical thinking and scientific literacy emerge as the most dominant and consistently developed skills. Studies that integrate socioscientific issues such as global warming, environmental pollution, microplastics, petroleum-related problems, and everyday health issues consistently report significant improve-ments in students' critical thinking abilities (Utami et al., 2020)(Purwanto et al., 2022). This finding reflects the inherent characteristics of SSI, which are contextual, controversial, and multidimen-sional, thereby encouraging students to analyze complex problems, evaluate multiple perspectives, and make decisions based on scientific evidence. Similar results were reported by (Benek, 2022) who found that socio-scientific STEM activities significantly enhanced students' cognitive skills, particularly critical thinking and problem solving, as indicated by statistically significant differences between pretest and posttest scores.

In addition to cognitive skills, SSI-based chemistry learning also supports the develop-ment of *Information, Media, and Technology Skills*, which include information literacy, media lite-racy, and digital or computer technology literacy. These skills are essential in the context of rapid technological advancement and the abundance of information, as they enable students to critically evaluate information sources, use digital media responsibly, and adapt to technological changes (Benek, 2022). Furthermore, SSI-based learning contributes to the enhancement of *Life and Career Skills*, such as flexibility and adaptability, entrepreneurship and self-management, social and intercultural competence, productivity and responsibility, as well as leadership and accountability. Alongside critical thinking and scientific literacy, supporting skills such as HOTS, scientific argumentation, creativity, and problem solving also show significant development when SSI is systematically integrated into chemistry learning, indicating that SSI provides a holistic contribution to students' readiness for real-life situations and future work environments (Sari et al., 2024)

Chemistry Materials or Topics in SSI-Based Learning

In Chemistry learning is not only teaching theoretical concepts and formulas but must also involve an understanding of social issues related to science. The socio-scientific issues (SSI) approach in chemistry learning aims to develop critical thinking skills, scientific thinking, reasoning, creative thinking, problem-solving and awareness of the ethical and social implications of science. However, the implementation of SSI in the context of chemistry education faces various challenges (Dewi & Yahdi, 2025).

SLR results show that SSI-based chemistry learning has been applied to a variety of materials or chemistry topics, both on basic concepts and applied concepts. The most commonly used materials include acid–base, Petroleum, environmental chemistry, polymers/plastics, stoichiometry, chemical bonding, thermochemistry, Basic Laws of chemistry, green chemistry, and biopolymers or bioplastics. Acid-base materials and environmental chemistry are the most dominant topics because they have direct links to real issues such as acid rain, water pollution, industrial waste, and environmental balance. Some issues contain the concept of acid-base material and can be explained through SSI as a learning context, such as acid rain, ocean acidification, global availability of clean water, water pollution, and food sovereignty in acidic soil. Thus, acid-base material was chosen to be taught through the SSI learning context in the PBL Model to develop students' chemical literacy skills (Putri et al., 2025).

Meanwhile, Petroleum materials, polymers, and green chemistry are widely associated with sustainability issues, energy crisis, and plastic waste problems. This shows that contextual and applicative chemistry topics are easier to integrate with SSI to develop 21st century skills. The variety of materials used also indicates that the SSI approach is flexible and can be applied to various chemical concepts. Thus, the SSI is not limited to a specific topic, but can be adapted according to the characteristics of the material and the objectives of Skill Development to be achieved.

The Effectiveness of SSI-Based Chemistry Learning Towards 21st Century Skills

In terms of effectiveness, all reviewed articles report that SSI-based chemistry learning has a positive impact on improving students ' 21st century skills. The effectiveness was shown through various indicators, such as an increase in

pretest–posttest scores, n-gain values in the medium to high category, statistically significant test results, and an increase in the level of argumentation and the quality of problem solving. SSI-based learning is proven to be effective because it places students at the center of active, critical, and reflective learning. Students are not only required to understand chemical concepts, but also to relate them to social, environmental, and health issues, so that the learning process becomes more meaningful. Thus, SSI-based chemistry learning can be viewed as a relevant and potential approach in supporting the achievement of 21st century educational goals.

CONCLUSION

Based on the results of the Systematic Literature Review of 16 relevant research articles, it can be concluded that socioscientific issue-based chemistry (SSI) learning has a significant contribution in developing the skills of 21st century learners. The integration of real issues that are contextual, multidimensional, and controversial has been proven to encourage students' cognitive involvement in greater depth, so that chemistry learning is not only oriented to mastering concepts, but also to strengthening high-level thinking skills. The most dominant 21st century skills developed through SSI-based learning are critical thinking and science/ chemistry literacy, followed by scientific argumentation skills, problem solving, creativity, and higher-order thinking skills. The characteristics of SSI that require issue analysis, evaluation of scientific evidence, and data-based decision making are the main factors that support the development of these skills.

In terms of Materials, Chemistry topics that are most often integrated with SSI are acid–base, environmental chemistry, Petroleum, and polymers/plastics, because they have a direct relationship with social and environmental problems faced by the community. This shows that the effectiveness of SSI-based learning is strongly influenced by the selection of chemicals that are contextual and relevant to students ' daily lives. Overall, socioscientific issue-based chemistry learning can be viewed as an effective, relevant, and potentially major approach in supporting the achievement of 21st century educational goals. This approach not only strengthens the understanding of chemical concepts, but also forms learners who have scientific awareness, critical thinking skills, and social and environmental responsibility.

RECOMMENDATION

Based on the findings in this Systematic Literature Review, several recommendations can be proposed for the development of learning and subsequent research. First, chemistry teachers are advised to integrate socioscientific issues more systematically in the learning process, especially in contextual and applicable chemistry materials, such as acid–base, environmental chemistry, Petroleum, and polymers. SSI integration needs to be designed through student-centered learning models, such as problem-based learning, project-based learning, and inquiry, so that 21st century skill development can take place optimally.

Second, the development of SSI-based learning tools needs to be accompanied by assessment instruments capable of comprehensively measuring 21st century skills, not only limited to critical thinking and scientific literacy, but also includes creativity, scientific argumentation, collaboration, and problem solving. This is important to obtain a fuller picture of the impact of SSI-based learning on student competence.

Third, further research is recommended to expand the context of the study, both in terms of educational level, variety of chemicals, and variations of socioscientific issues raised. In addition, research with stronger experimental designs and more in-depth quantitative and qualitative data reporting is needed so that the effectiveness of SSI-based chemistry learning on 21st century skills can be proven more comprehensively and sustainably.

BIBLIOGRAPHY

Afrilya, N. A., & Afrianis, N. (2020). Pengaruh Penerapan Pendekatan Socio Scientific Issues terhadap Kemampuan

Literasi Sains Siswa pada Materi Minyak Bumi. *Jurnal Riset Pendidikan Kimia*, 12(1), 10–18. https://doi.org/10.21009/JRPK.121.02

Ahiri, Y. (2025). Systematic Literature Review: Pengaruh Model Pembelajaran Pjbl (Project-Based Learning) Terhad

ap Keterampilan Berpikir Kritis Mahasiswa. *Edusaintek: Jurnal Pendidikan, Sains Dan Teknologi*, 12(3), 1566–1582. https://doi.org/10.47467/edusaintek.v12i3.6124

Arham, B., & Dimyati, M. (2024). Systematic Literature Review (SLR) : Explorations flood systems theory and appr
opriate modeling Brenda. Journal of Smart Agriculture and Environmental Technology. 2(2), 67–80. https://doi.org/10.60105/josaet.2024.2.2.67-80

Azizah, D. N., Irwandi, D., & Saridewi, N. (2021). Pengaruh Model Pembelajaran Problem Based Learning Berkonte
ks Socio Scientific Issues Terhadap Kemampuan Literasi Sains Siswa pada Materi Asam Basa. *Jurnal Riset Pendidikan Kimia*, 11(1), 12–18. https://doi.org/10.21009/JRPK.111.03

Benek, I. (2022). The effects of socio-scientific STEM activities on 21st century skills of middle school students. *Participatory Educational Research (PER)*, *9*(March), 25–52. https://doi.org/http://dx.doi.org/10.17275/per.22.27.9.2

Dewi, Citra Ayu & Yahdi. (2025). Research Trends on Socio-Scientific Issues in Chemistry Learning: A Systematic
Review. Jurnal Pendidikan MIPA. (6). 457-475. http://dx.doi.org/10.23960/jpmipa/v26i1.pp457-475

Dinter, R. Van, Tekinerdogan, B., & Catal, C. (2021). Automation of systematic literature reviews: A systematic
literature review. *Information and Software Technology*, 136, 106589. https://doi.org/10.1016/j.infsof.2021.106589

Haddaway, N. R., Macura, B., Whaley, P., & Pullin, A. S. (2018). ROSES RepOrting standards for Systematic Evide
nce Syntheses: pro forma, flow-diagram and descriptive summary of the plan and conduct of environmental systematic reviews and systematic maps. *Environmental Evidence*, 7(1), 1-8. https://doi.org/10.1186/s13750-018-0121-7

Hajijah, A., Nasution, M., Azizah, N., Hasibuan, P., Hilda, L., Ali, S., Ahmad, H. (2025). Fostering Critical Thinking
through Socio-Scientific Issue Based Problem-Based Learning in Stoichiometry Instruction. *JTK: Jurnal Tadris Kimiya*, 1, 35–44. https://doi.org/10.15575/jtk.v1i1.35412

Hanifah, E., Setiono, & Nuranti, G. (2021). Pengaruh Model Socio-Scientific Issue Terhadap Keterampilan Memeca
cahkan Masalah Menggunakan Aplikasi Powtoon pada Materi Perubahan Lingkungan. *BIODIK: Jurnal Ilmiah Pendidikan Biologi*, 7(4), 18–28. https://doi.org/10.22437/bio.v7i4.15112

Högström, P., Gericke, N., Wallin, J., & Bergman, E. (2025). Teaching Socioscientific Issues: A Systematic Review.
Science & Education, 34(5). https://doi.org/10.1007/s11191-024-00542-y

Krath, J., Schurmann, L., & Korflesch, H. F. O. (2021). Revealing the theoretical basis of gamification: a systematic
review and analysis of theory in research on gamification, serious games and game-based learning. *Computers in Human Behavior*, *125*, 1–34. https://doi.org/10.1016/j.chb.2021.106963.

Kusumaningtyas, P., Rezky, O., Nurhadi, M., & Sulistyaningwarni, S. (2024). Pengaruh Isu Sosiosaintifik Dalam
Model Discovery Learning Terhadap Keterampilan Berpikir Kritis Siswa Pada Materi Asam Basa. *ORBITAL: Jurnal Pendidikan Kimia*, 4(1), 64–74. https://doi.org/10.19109/ojpk.v4i1.15632

López-Fernández, M. M., González García, F., & A. J. F.-M. (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, 3435–3442. https://doi.org/10.1021/acs.jchemed.2c00223

Maimunah, N. J. (2025). Meningkatkan Keterampilan Abad 21 Dengan Model Project Based Learning Pada Pembel
ajaran Pendidikan Agama Islam Di Smk Muhammadiyah 5. *Edification Journal*, 8(1), 79–100. https://doi.org/10.37092/ej.v8i1.1199

Medina Fasya Salsafitri, Risa Rahmawati Sunarya, Imelda Helsy, I. D. (2025). Socioscientific Issues As A Pedagogic
al Approach To Foster Scientific Argumentation In Bioplastic Production Using Sugarcane Bagasse. *Lantanida Journal*, 13(1), 124–142. https://doi.org/10.22373/lj.v13i1.30333

Mere, K. (2023). Systematic Literature Review: Penerapan Model Project Based Learning untuk Meningkatkan Kete
rampilan Berpikir Kreatif Siswa. *Journal on Education*, 6(1), 5655–5661. https://doi.org/10.31004/joe.v6i1.3742

Mongkau, J. G., Daniel, R., & Pangkey, H. (2024). Kurikulum Merdeka: Memperkuat Keterampilan Abad 21 untuk
Generasi Emas. *Journal on Education*, 6(4), 22018–22030. https://doi.org/10.31004/joe.v6i4.6231

Mukti, T. D., & Widjajanti, E. (2025). Guided Inquiry with socio - scientific issues approach in Improving Student
Chemical Literacy Skills. *Jurnal Pendidikan Indonesia*, 14(1), 55. https://doi.org/10.23887/jpiundiksha.v14i1.84489

Munawwarah, Z. A. (2025). Membangun Literasi Kimia Kritis : Kajian Literatur Sistematis. *Jurnal Pendidikan Ilmu*
Pengetahuan Alam (JP-IPA), 6(2), 276–288. https://doi.org/10.32665/jpipa.v6i2.2841

Nadlifah, P., Nita, T., & Nada, E. I. (2024). Efektivitas Model Problem Based Learning Berbasis Socio Scientific Issue

Terhadap Keterampilan Berpikir Kreatif Siswa Materi Kimia Hijau. *Jurnal Riset Pendidikan Kimia*, 14(2), 136–143. https://doi.org/10.21009/JRPK.142.08

Page, M. J., Mckenzie, J. E., et al. (2021). The PRISMA 2020 statement: an updated guideline for reporting systematic

reviews. *BMJ*, 372(n71). https://doi.org/10.1136/bmj.n71

Purwandari, A., Deaningtyas, S. A., Faradillah, N. I., Putrikundia, S. A., & Sulistina, O. (2024). Peran Pendekatan

Socio-Scientific Issue (SSI) Dalam Meningkatkan Scientific Literacy Pada Pembelajaran Kimia. *UNESA Journal of Chemical Education*, 13(2), 118–128. https://doi.org/10.26740/ujced.v13n2.p118-128

Purwanto, A., Rahmawati, Y., & Rahmayanti, N. (2022). Socio-Critical And Problem-Oriented Approach In Enviro

nmental Issues For Students' Critical Thinking Skills Development In Chemistry Learning. *Journal of Technology and Science Education*, 12(1), 50–67. https://doi.org/10.3926/jotse.1341

Putri, A. J. H., Susilowati, E., & Mulyani, S. (2025). Socio-Scientific Issue Application in the PBL Model : Is that Effective in Improving Chemical Literacy ? *Jurnal Inovasi Pendidikan IPA*, *11*(1), 296–307. http://dx.doi.org/ 10.21831/jipi.v11i1.77351

Rizka Azkia, T. W. (2024). Analisis Keterampilan Berpikir Kritis Siswa pada Pembelajaran Kimia Bermuatan SSI

(Socio Scientific Issue). *MIPA Insight*, 1(1), 49–58. https://doi.org/10.5281/zenodo.10543210

Safitri, C. A., & Hartati, Y. (2021). Peningkatan keterampilan argumentasi siswa pada materi Termokimia dalam

konteks Socio-scientiffic Issues melalui model pembelajaran kooperatif Tipe Team Assisted Individualiza

Individualization. *Prosiding Seminar Nasional KPK*, 4, 1–6.

Sari, D. R., Saputro, S., & Maret, U. S. (2024). A Systematic Review on Integrating SSI into Science Education. *Educat*

ional Studies and Research Journal (ESRJ), 2(1). https://doi.org/10.61100/esrj.v2i1.102

Sinambela, Y., Sitorus, N., & Gobal, R. (2025). Persepsi Mahasiswa Terhadap Relevansi Mata Kuliah Kimia Terapan

Dalam Industri Grafika. *IQRO: Journal of Islamic Education*, 8(1), 36–48. https://doi.org/10.30605/iqro.v8i1. 4012

Ulliva, S. R., & Prodjosantoso, A. K. (2025). Development of Student Worksheets Based On Socio-Scientific Issues:

Its Influence On Chemical Literacy and Students' Scientific Attitudes. *Indonesian Journal of Educational Development (IJED)*, 6(1), 451–464. https://doi.org/10.59672/ijed.v6i2.4760

Utami, W., Sismawarni, D., Hamid, N., & Kusumaningtyas, P. (2020). Pengaruh Penggunaan Isu Sosiosaintifik

dalam Model Pembelajaran Berbasis Masalah Terhadap Keterampilan Berpikir Tingkat Tinggi Siswa. *Jambura Journal of Educational Chemistry*, 2(1), 10–17. https://doi.org/10.34312/jjec.v2i1.4589

Wahyuni, M. T., Tsalasa, R., Rodhiah, A., & Fadillah, M. (2025). Strategi Peningkatan Keterampilan Abad ke-21

Siswa SD dengan Memanfaatkan Aliran Filsafat Rekonstruksionisme. *JEMARI: Jurnal Edukasi Madrasah Ibtidaiyah*, 7(2), 88–103. https://doi.org/10.35931/jemari.v7i2.4512

Yuendita, D., & Rohaeti, E. (2025). Research Trends on the Integration of Ethnoscience in the Learning of Chemistry

as the Development of Chemical Literacy: A Systematic Review. *Jurnal Pendidikan Sains Indonesia*, 8, 210–222. https://doi.org/10.24815/jpsi.v13i1.38541