



Improving students' chemical literacy skills through experiential learning on global warming concepts

Sunartri ^{1,*} , Antuni Wiyarsi ² , Bambang Susilo ¹ 

¹ Master Program of Chemistry Education, Universitas Negeri Yogyakarta, Yogyakarta, Indonesia

² Department of Chemistry Education, Universitas Negeri Yogyakarta, Yogyakarta, Indonesia

*Corresponding author

Abstract

Improving chemical literacy is an important task in learning in the global and sustainable development era. However, chemistry learning at schools still tends to focus on mastering theoretical concepts. Therefore, a learning model that is able to provide meaningful and contextual learning experience is needed, one of which is the experiential learning model. The experiential learning model is considered capable of facilitating students in constructing knowledge and developing chemical literacy skills. This study aims to analyze students' chemical literacy skills before and after learning using the experiential learning model on the topic of global warming, as well as analyzing their improvement. This study employed a quasi-experimental method with a one-group pretest–posttest design and was conducted in two public senior high schools in Sleman Regency, Indonesia, with a sample of 144 Grade X students. Data were collected using chemical literacy tests that had been validated theoretically and empirically. The data were analyzed using a paired t-test and N-gain scores. The results showed a significant difference between pretest and posttest scores, with an improvement in chemical literacy skills in the medium category. These findings indicate that the application of the experiential learning model is effective in improving students' chemical literacy skills on global warming topics.

Keywords: chemical literacy skills, experiential learning, global warming

How to cite: Sunartri, Wiyarsi, A., & Susilo, B. (2026). Improving students' chemical literacy skills through experiential learning on global warming concepts. *International Journal on Education Insight*, 7(1), 99-108. <https://doi.org/10.12928/ije.v7i1.15846>

Article history: Received 13/02/2026, Accepted 28/02/2026, Published 01/03/2026

Correspondence address: Program Studi Magister Pendidikan Kimia, Universitas Negeri Yogyakarta, Jalan Colombo No. 1, Karangmalang, Yogyakarta 55281 Indonesia. E-mail: sunartri0074fmipa.2023@student.uny.ac.id

© 2026 Sunartri, Antuni Wiyarsi, Bambang Susilo

INTRODUCTION

Global warming is an increasingly crucial environmental issue in the 21st century. The impact not only disrupts ecosystem stability, but also triggers social, economic, and public health changes around the world. Studies have shown that the increase in the earth's average temperature is mainly caused by human activities, such as the burning of fossil fuels, deforestation, industrialization, and land-use changes (Ibarra-Rius & Pons, 2024; Scafetta, 2024). These activities produce greenhouse gases including carbon dioxide (CO₂) and methane (CH₄) that reinforce the greenhouse effect in the atmosphere (Rezaporaghdam & Hidalgo-García, 2024; Sulistyono, 2020). The accumulation of these gases triggers climate change which is characterized by extreme weather, rising sea levels, and declining biodiversity (Andarini & Sudarti, 2023). The Intergovernmental Panel on Climate Change (IPCC) also affirms that human activity is a major factor in climate change that is taking place today (Kovach et al., 2024).

Global warming is a complex problem that cannot be solved only through a scientific and technical approach. However, it requires the collaboration of various social, economic, political, and ethical perspectives to produce sustainable solutions (Röper & Kohl, 2024; Zhao et al.,

2024). This condition places education as a strategic sector in preparing the younger generation to be able to understand, study, and play an active role in finding solutions to these global challenges. Science learning, especially at the secondary school level, is required not only to emphasize understanding of concepts, but also to encourage the development of science literacy and concern for the environment.

The global warming issue is an example of Socio-Scientific Issues (SSI) which is very relevant in the field of chemistry. This topic has a strong connection with chemical concepts such as the combustion process, the carbon cycle, the greenhouse effect, and gas emissions (Atabey & Topcu, 2017; Widiyawati, 2020). SSI-based learning provides students with the opportunity to connect scientific concepts with real context while understanding the social and environmental impacts of an issue. A number of studies have proven that the SSI approach can improve science literacy through the ability to interpret scientific evidence, evaluate arguments, and make data-driven decisions (Badeo & Duque, 2022; Ban & Mahmud, 2023; Wiyarsi & Çalik, 2019). In addition, direct involvement in real issues also contributes to fostering environmental awareness (Edsand & Broich, 2020; Thor & Karlsudd, 2020).

Global warming as a context of SSI allows chemistry teachers to present more applicable and meaningful learning. Through activities such as discussion, debate, and problem-solving, students are invited to examine issues from various perspectives, understand the relationship between science and social life, and consider the long-term impact of human activities on the environment (Araya et al., 2024; Auliah et al., 2025; Yaumi et al., 2019). This kind of learning not only enriches the learning experience, but also shapes learners into critical, reflective, and responsible individuals.

In Indonesia, the Merdeka Curriculum provides a wider space for the integration of environmental and social issues in the learning process. This approach emphasizes the relevance of the subject matter to the real lives of students, including discussions about climate change and global warming that are relevant to the context of students' lives (Kementerian Pendidikan Kebudayaan Riset dan Teknologi, 2024; Vioreza et al., 2023). In addition, the Independent Curriculum emphasizes the development of 21st century skills, such as critical thinking, collaboration, problem-solving, and science literacy as essential competencies for students (Devian et al., 2023). Learning is designed to be more experiential to learning through experimental activities, field projects, and scientific discoveries that allow learners to actively build understanding (Bell, 2010; Ridwan et al., 2023).

In chemistry learning outcomes, students are expected to understand scientific processes related to global warming, such as the reactions that produce CO₂, the role of deforestation in increasing greenhouse gas concentrations, and the environmental and social impacts of climate change (Ministry of Education and Culture, 2024). Students are also invited to learn about other issues related to climate change, such as food security and human health (Mirzabaev et al., 2023). This approach is consistent with constructivist theory which emphasizes that knowledge is built through direct experience and reflection (Piaget, 1972; Sarkar et al., 2022). One of the models that is considered to be able to optimize the learning process based on environmental issues is Experiential Learning, because this model provides opportunities for students to experience real phenomena directly so that science concepts can be understood through concrete experiences and deep reflection (Hayati, 2020).

The experiential learning model places direct experience as the core of learning, so that students can understand phenomena concretely (Susiloningsih et al., 2023). Kolb (1984) explains that this model includes four stages, namely concrete experience, reflection, abstract conceptualization, and active experimentation. Through this stage, students are given the opportunity to observe, reflect, build concepts, and apply these concepts in new situations (Shehu et al., 2024; Susanti et al., 2023). In the discussion of global warming, Experiential Learning can be carried out through activities such as greenhouse effect experiments, air quality

observations, analysis of ambient temperature changes, or environmental mitigation projects such as tree planting. In addition, action-based activities such as waste processing, biogas production, and ecoenzyme production can also be a means of learning that allows students to understand the relationship between human activities, greenhouse gas emissions, and efforts to reduce the impact of global warming directly.

Various studies show that experiential learning is able to strengthen the understanding of scientific concepts because students experience the phenomena they learn for themselves (Conchas et al., 2023). In addition, this model supports the development of critical thinking because learners are trained to analyze information and draw conclusions based on evidence (Hamilton & Klebba, 2011). Experiential learning has strong relevance to the development of chemical literacy. Chemical literacy includes the ability to understand chemical concepts and use them in real-life situations, including the skills to analyze chemical issues in society and make science-based decisions (Cigdemoglu & Geban, 2015; Shwartz, Ben-zvi, et al., 2006). However, some studies report that the chemical literacy of students in Indonesia is still low (Yuliaty, 2017; Prasemmi et al., 2021), which is also seen in the 2022 PISA achievements (OECD, 2023). Therefore, a learning model is needed that not only strengthens the mastery of concepts, but is also able to relate them to real-life contexts so that chemical literacy develops more comprehensively.

The issue of global warming requires very adequate chemical literacy because students must understand the chemical mechanisms underlying global warming, such as the carbon cycle or the impact of gas emissions. Students who have good chemical literacy will be able to assess the impact of human activities, compare alternative solutions, and make decisions that favor environmental sustainability (Rahmawati et al., 2023). Students must also be able to see issues from a social and ethical perspective (Sevian et al., 2018; Shwartz et al., 2013).

SSI-based learning has been shown to improve students' chemical literacy (Prodjosantoso et al., 2024). Topics such as global warming allow students to engage in the analysis of real issues, weigh scientific evidence, and formulate solutions. Thus, incorporating SSI in chemistry learning is an effective strategy to improve students' understanding. Although the Experiential Learning model and the SSI approach have proven to be effective, research integrating the two on global warming is still limited in Indonesia. Given that global warming is a topic in the curriculum, empirical studies are needed to assess the effectiveness of this learning strategy. This research is expected to make a theoretical and practical contribution. Theoretically, research can expand the study of the integration of Experiential Learning and SSI in chemistry learning. In practical terms, the results of the research can serve as a guideline for teachers in designing learning that is more contextual and relevant to global challenges, while supporting the development of curricula that are responsive to environmental issues and 21st century skills.

Based on this urgency, as well as the limited research that specifically integrates the Experiential Learning model and SSI's approach to global warming materials in the context of chemistry learning in Indonesia, an empirical study is needed that is able to assess the effectiveness of these learning strategies in more depth. Thus, the questions focused on the research are: (1) How did students' chemical literacy skills improve before and after participating in the experiential learning model on global warming as a SSI? and (2) How much did students' chemical literacy skills improve after participating in the Experiential Learning model on global warming?

RESEARCH METHOD

This study employed a quantitative approach with a quasi-experimental design to examine the effect of the Experiential Learning model on students' chemical literacy skills in the context of global warming as a socio-scientific issue (SSI). The research design applied was a one-group pre-test–post-test design (Creswell & Plano Clark, 2017). The study involved four experimental

classes consisting of 144 Grade X students from two public senior high schools in Sleman Regency, namely two classes from SMA Negeri 1 Pakem and two classes from SMA Negeri 1 Cangkringan. The selection of schools was conducted using convenience sampling, based on school accessibility and willingness to participate in the study. After the schools were selected, the sample classes were determined using random sampling, with the class serving as the unit of randomization. The primary research instrument was a chemical literacy test consisting of 15 designed to measure students' skills to apply chemical concepts in the context of climate change and environmental issues. To enhance clarity and provide a comprehensive overview of the methodological process, a flowchart diagram illustrating the research stages is presented in Figure 1.

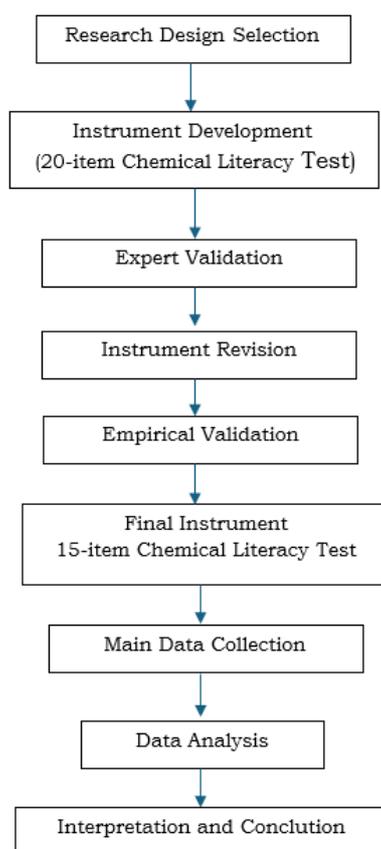


Figure 1. Flowchart of instrument development and empirical validation process

The chemical literacy skills test instrument consisted of open-ended questions developed based on six topics related to global warming. Each topic was contextualized with environmental issues relevant to students' local conditions, enabling students to connect real-life experiences with the chemistry concepts learned. The development of the test items was based on four aspects of chemical literacy proposed by Shwartz et al. (2006), namely the chemical aspect in the context, the aspect of chemical content knowledge, Higher Order Learning Skills (HOLS), and affective aspects. The instrument was piloted with 282 students outside the research sample. Construct validity was evaluated using Confirmatory Factor Analysis (CFA), and the results indicated that all items met the required validity criteria. Reliability analysis was conducted to examine the internal consistency of the instrument, yielding a Cronbach's alpha coefficient of 0.83, which falls into the very good category. The research data were analyzed using a paired t-

test to determine differences in students' chemical literacy skills before and after the intervention, as well as normalized gain (N-gain) analysis to measure the magnitude of improvement. Prior to inferential analysis, the data were tested for normality. If the normality assumption was satisfied, a paired t-test was applied; however, if the data were not normally distributed, the Wilcoxon signed-rank test was employed as a nonparametric alternative.

RESULTS AND DISCUSSION

Results

This study was conducted to analyze differences in chemical literacy skills before and after learning using the experiential learning model on the topic of global warming, employing a paired t-test. Before the implementation of the instructional intervention, a pre-test was administered, followed by a post-test to measure students' chemical literacy skills. Because the assumptions for parametric testing were not met, the data were analyzed using a nonparametric statistical test, namely the Wilcoxon Signed-Rank Test. The results of the analysis are presented in Table 1.

Table 1. Wilcoxon signed-rank test chemical literacy score results

Comparison	N	Mean Rank	Sum of Ranks	Z	Asymp. Sig. (2-tailed)
Posttest – Pretest	144	72.50	10,440.00	-10.480	0.000

Based on the results of the Wilcoxon Signed-Rank Test on students' chemical literacy scores in the experimental group, a Z value of -10.480 was obtained with an Asymp. Sig. (2-tailed) value of 0.000, which is less than 0.05. This indicates a statistically significant difference between pre-test and post-test scores. The effect size was calculated using the formula (1).

$$r = \frac{Z}{\sqrt{n}} \quad (1)$$

It yields a value of 0.87, which indicates a large effect. These results demonstrate a significant improvement in students' chemical literacy scores after the implementation of the experiential learning model. Furthermore, the positive mean rank value of 72.50 indicates that the majority of students experienced an increase in scores following the learning intervention. Therefore, the experiential learning model has a positive effect on improving students' chemical literacy.

Learning using the experiential learning model resulted in greater improvement in students' chemical literacy skills. This is evidenced by the average N-gain score of the experimental group, which was 0.52, compared to 0.29 in the control group. A description of the average chemical literacy scores of Grade X students in the experimental group is presented in Table 2.

Table 2. Average pretest and posttest scores of chemical literacy skills

Groups	n	Pretest	Posttest	N-gain	Category
Experiment	144	58.37	80.11	0.52	Medium

Discussion

The results of the Wilcoxon Signed-Rank Test showed a significant increase between the pretest and posttest scores of students' chemical literacy skills. The high positive mean rank value indicates that the increase in chemical literacy skills occurred consistently in most students, not just in a few individuals. This finding indicates that learning with the experiential learning model is able to provide a relatively even and inclusive learning experience in developing chemical literacy, regardless of differences in students' initial abilities. The achievement of this increase in chemical literacy is inseparable from the structure of activities in the Experimental Student

Worksheet (LKPD) which implements the four main stages of experiential learning by Kolb (1984), namely concrete experience, reflective observation, abstract conceptualization, and active experimentation.

Concrete experience stage

Students are invited to observe extreme weather phenomena, the production of eco-enzymes, and the management of organic waste through videos and direct observation in their surroundings. These activities provide authentic experiences that stimulate scientific awareness and the ability to connect real phenomena with chemical concepts such as greenhouse gas formation reactions and fermentation processes.

Reflective operation stage

Reflective observation stage guides students to reflect on their experiences and identify the relationship between human activities, greenhouse gas emissions, and their impact on the environment. This stage strengthens interpretive and evaluative skills in chemical literacy as stated by Shwartz et al. (2006), that the ability to understand chemical issues requires critical reflection on the relationship between scientific concepts and their social context.

Abstract conceptualization stage

Students connect their reflections with theoretical concepts, such as the chemical reactions of hydrocarbon combustion, photosynthesis, and fermentation. This activity fosters the ability to apply chemical concepts to scientific explanations of the phenomenon of global warming.

Active experimentation stage

Active experimentation stage provides opportunities for students to design real actions to mitigate global warming, such as making eco-enzymes or compost and other innovations based on the students' ideas. This stage encourages students to apply chemical concepts creatively and solution-oriented, so that they can do it independently.

A series of Experiential Learning activities comprising the stages of concrete experience, reflective observation, abstract conceptualization, and active experimentation are presented in Figure 2.



(a)



(b)



(c)



(d)

Figure 2. Concrete experience (a), reflective observation (b), abstract conceptualization (c), and active experimentation (d).

In the concrete experience phase, students work in groups to gain authentic learning experiences through field observations and hands-on practice. Each group visits a different environmental management-based location. Group 1 conducted observations at Omah Maggot Jogja, Group 2 visited Kampung Iklim, Group 3 visited a biogas production site, Group 4 studied eco-enzyme production, and Group 5 observed the organic fertilizer production process. In addition to observing the ongoing processes, students also participated directly in product manufacturing practices at each location. This phase aims to provide real, contextual experiences related to climate change and environmental management issues.

In the reflective observation phase, students reflect on their experiences through structured classroom discussions. Each group presents the results of their observations and practices and then discusses them with other groups. Through this process, students analyze field findings, identify similarities and differences between practices, and develop collaborative understanding.

Next, in the abstract conceptualization stage, students relate these empirical experiences to relevant chemical concepts, such as decomposition reactions, fermentation, waste management, renewable energy, and the principles of environmental chemistry. At this stage, the teacher acts as a facilitator, helping guide discussions and correct misconceptions so that the concepts developed align with scientific principles. This process enables students to develop a more systematic conceptual understanding based on real-world experiences.

The final stage, active experimentation, is realized through the design and implementation of concrete actions by students as a form of application of the concepts they have understood. Students design simple activities aimed at reducing the impact of global warming on the surrounding environment. This stage emphasizes the application of knowledge in everyday life contexts, so that learning does not stop at conceptual understanding but progresses to reflective and responsible action.

Overall, the four stages demonstrate a systematic experiential learning cycle that connects real-world exposure with scientific meaning-making. The integration of real experiences, scientific reflection, and concept application makes this student worksheet function as a constructivist tool for building high-level chemistry literacy. This is in line with the findings of (Bloom & Fuentes, 2019) that Experiential Learning is effective in improving environmental literacy through direct involvement with real phenomena, critical reflection on issues, integration between scientific knowledge and social context, and the development of attitudes as energy and environment-conscious learners. Additionally, the eco-enzyme and biogas context in the worksheet provides space for learners to relate chemistry concepts to actual environmental issues, in line with the view of (Hanifha et al., 2023) that science and chemistry literacy develops when learners can apply scientific concepts to make decisions about real phenomena in life.

Experiential learning provides space for students to build understanding through direct interaction with real phenomena, so that the chemistry concepts learned become easier to understand, meaningful, and sustainable. Thus, the significant improvement in chemistry literacy scores shows that learning through Experiential Learning-based worksheets has successfully fostered students' ability to identify, analyze, and solve chemistry problems in the context of global warming in a scientific and meaningful way.

CONCLUSION

Based on the results of the study, the chemical literacy skills of students before participating in experiential learning on global warming as SSI were relatively low to moderate, as evidenced by the students' limited ability to explain scientific concepts, interpret data, and relate chemical concepts to contextual problems. After participating in experiential learning, students' chemical literacy skills improved significantly, as seen in the increase in posttest scores compared to

pretest scores in most chemical literacy indicators. The magnitude of the improvement was moderate, based on the results of the n-gain study. These results indicate that the experiential learning model is effective in improving students' ability to understand the concept of global warming in a contextual manner, analyze science-based issues, and make decisions based on scientific considerations.

ACKNOWLEDGEMENT

We express our deepest gratitude to the principal of SMA Negeri 1 Pakem and the principal of SMA Negeri 1 Cangkringan for granting permission to conduct an empirical study of the instrument trials and for providing research access and supporting facilities that greatly assisted in completing this research.

DECLARATION

Author contribution

All authors contribute in the research and/or writing the paper, and approved the final manuscript.

Sunartri Conceptualizing the research idea, leading the investigation, setting up the methodology, analyzing data, and writing the first draft.

Antuni Wiyarsi Assisting the investigation, reviewing the validity of the methodology, enriching the data analysis, and co-writing the revised draft.

Bambang Susilo Assisting the investigation, reviewing the validity of the methodology, enriching the data analysis, and co-writing the revised draft.

Funding

This research received no specific funding from any institution, whether public, commercial, or private.

Conflict of interest

All authors declare that they have no competing interests.

Ethics declaration

We as authors acknowledge that this work has been written based on ethical research that conforms with the regulations of our institutions and that we have obtained the permission from the relevant institutes when collecting data. We support the International Journal on Education Insight (IJEI) in maintaining the high standards of personal conduct, practicing honesty in all our professional practices and endeavors.

The use of artificial intelligence

We do not use any generative AI tools to write any part of this paper.

Additional information

Not available.

REFERENCES

- Andarini, S. Y., & Sudarti, S. (2023). Analisis efek global warming terhadap perubahan iklim. *Jurnal Phi: Jurnal Pendidikan Fisika dan Fisika Terapan*, 9(2), 31–38. <https://doi.org/10.22373/p-jpft.v9i2.15549>
- Araya, A., Barquilla, M., Canlita, E., Bagaloyos, J., & Pitiporntapin, S. (2024). Development and implementation of SSI-based module in promoting decision making skills of STEM strand learners. *Journal of Innovation, Advancement, and Methodology in STEM Education*, 1(3), 170–179.
- Atabey, N., & Topcu, M. S. (2017). The development of a socioscientific issues-based curriculum unit for middle school students: Global warming issue. *International Journal of Education in Mathematics, Science and Technology*, 5(3), 153–169. <https://doi.org/10.18404/ijemst.296027>
- Auliah, A., Allo, E. L., Fadly, D., Islawati, I., Halisah, N., & Rahma, R. (2025). Improving students' understanding of chemistry concepts and environmental sensitivity through the implementation of the project-based learning (PBL) model based on the socio-scientific issue (SSI) approach. *East Asian Journal of Multidisciplinary Research (EAJMR)*, 4(9), 4499–4514. <https://doi.org/10.55927/eajmr.v4i9.377>

- Badeo, J. M., & Duque, D. A. (2022). The effect of socio scientific issues (SSI) in teaching science: A meta analysis study. *Journal of Technology and Science Education*, 12(2), 291–302. <http://www.jotse.org/index.php/jotse/article/view/110/142>
- Ban, S., & Mahmud, S. N. D. (2023). Research and trends in socio-scientific issues education: A content analysis of journal publications from 2004 to 2022. *Sustainability (Switzerland)*, 15(15), 1–20. <https://doi.org/10.3390/su151511841>
- Bell, S. (2010). Project-based learning for the 21st century: Skills for the future. *A Journal of Educational Strategies, Issues and Ideas*, 83(2), 36–43. <https://doi.org/10.1080/00098650903505415>
- Bloom, M., & Fuentes, S. Q. (2019). Experiential learning for enhancing environmental literacy regarding energy: A professional development program for inservice science teachers. *EURASIA Journal of Mathematics, Science and Technology Education*, 15(6). <https://doi.org/10.29333/ejmste/103571>
- Cigdemoglu, C., & Geban, O. (2015). Improving students' chemical literacy levels on thermochemical and thermodynamics concepts through a context-based approach. *Chemistry Education Research and Practice*, 16(2), 302–317. <https://pubs.rsc.org/en/content/articlehtml/2015/rp/c5rp00007f>
- Conchas, D. M., Montilla, A. R. Y., Romblon, K. D. C., Torion, M. P., Reyes, J. J. R. R., & Tinapay, A. O. (2023). Assessing the experiential learning and scientific process skills of senior high school STEM students: A literature review. *International Journal of Multidisciplinary Research and Publications*, 6(2), 81–90.
- Creswell, J. W., & Plano Clark, V. L. (2017). *Designing and Conducting Mixed Methods Research* (3rd ed.). SAGE Publication.
- Devian, L., Neviyarni, & Murni, I. (2023). Konsep merdeka sebagai landasan pendidikan di era kurikulum merdeka belajar. *Didaktik: Jurnal Ilmiah PGSD FKIP Universitas Mandiri*, 9(2), 1974–1993. <https://doi.org/10.36989/didaktik.v9i2.918>
- Edsand, H. E., & Broich, T. (2020). The impact of environmental education on environmental and renewable energy technology awareness: Empirical evidence from Colombia. *International Journal of Science and Mathematics Education*, 18(4), 611–634. <https://doi.org/10.1007/s10763-019-09988-x>
- Hamilton, J. G., & Klebba, J. M. (2011). Experiential learning: A course design process for critical thinking. *American Journal of Business Education (AJBE)*, 4(12), 1–12. <https://doi.org/10.19030/ajbe.v4i12.6608>
- Hanifha, S., Erna, M., Noer, A. M., & Talib, C. A. (2023). Socioscientific issue-based undergraduate student worksheets on scientific literacy and environmental awareness. *Jurnal Pendidikan IPA Indonesia*, 12(4), 504–513. <https://doi.org/10.15294/jpii.v12i4.45817>
- Hayati, R. S. (2020). Pendidikan lingkungan berbasis experiential learning untuk meningkatkan literasi lingkungan. *Humanika*, 20(1), 63–82. <https://doi.org/10.21831/hum.v20i1.29039>
- Ibarra-Rius, N., & Pons, Á. M. (2024). Representation of climate change and global warming in comics: From apocalyptic fiction to educational tool. *European Journal of Cultural Studies*, 1–18. <https://doi.org/10.1177/13675494241264449>
- Kementerian Pendidikan Kebudayaan Riset dan Teknologi. (2024). *Capaian Pembelajaran pada Pendidikan Anak Usia Dini, Jenjang Pendidikan Dasar, dan Jenjang Pendidikan Menengah pada Kurikulum Merdeka*. Badan Standar, Kurikulum, dan Asesmen Pendidikan, Kementerian Pendidikan, Kebudayaan, Riset, dan Teknologi.
- Kolb, D. A. (1984). *Experiential Learning: Experience as the Source of Learning and Development* (Second). Prentice Hall.
- Kovach, D., Kullolli, B., Djaparova, S., Mikhnevych, L., & Myskovets, I. (2024). Legal aspects of environmental sustainability and climate change: The role of international and national legislation. *Journal of Environmental Law and Policy*, 4(2), 149–179. <https://doi.org/10.33002/jelp040206>
- Mirzabaev, A., Bezner Kerr, R., Hasegawa, T., Pradhan, P., Wreford, A., Cristina Tirado von der Pahlen, M., & Gurney-Smith, H. (2023). Severe climate change risks to food security and nutrition. *Climate Risk Management*, 39. <https://doi.org/10.1016/j.crm.2022.100473>
- Piaget, J. (1972). *The Psychology of the Child*. Basic Books.
- Prodjosantoso, A. K., Heryati, D. P., & Putri, A. S. (2024). The effectiveness of integrated socio-scientific issues jigsaw model to improve students' chemistry literacy and communication skills. *International Journal of Religion*, 5(11), 494–503. <https://doi.org/10.61707/aqge9p29>
- Rahmawati, Y., Erdawarti, E., Hadiana, D., Ridwan, A., & Veronica, N. (2023). Developing students' chemical literacy through the integration of dilemma stories into a steam project on petroleum topic. *Journal of Technology and Science Education*, 14(2). <https://doi.org/10.3926/jotse.2221>

- Rezapouraghdam, H., & Hidalgo-García, D. (2024). Urban development and climate change: Implications for educational tourism destination planning. *Water Air Soil Pollut*, 235(319), 1–26. <https://doi.org/10.1007/s11270-024-07125-1>
- Ridwan, I. M., Kaniawati, I., Suhandi, A., Ramalis, T. R., & Novia, N. (2023). A decades of climate change education in experiential learning - A bibliometric study and research agenda. *Journal of Engineering Science and Technology*, 18(3), 81–88.
- Röper, N., & Kohl, S. (2024). Bookkeepers of catastrophes: The overlooked role of reinsurers in climate change debates. *Global Environmental Change*, 89, 1–12. <https://doi.org/10.1016/j.gloenvcha.2024.102931>
- Sarkar, S., Verma, R., & Singh, S. (2022). Faculty and students' perceptions on experiential learning based anatomy dissection hall sessions for medical undergraduates. *Advances in Medical Education and Practice*, 13(1), 543–554. <https://doi.org/10.2147/AMEP.S359140>
- Scafetta, N. (2024). Impacts and risks of "realistic" global warming projections for the 21st century. *Geoscience Frontiers*, 15(2), 1–25. <https://doi.org/10.1016/j.gsf.2023.101774>
- Sevian, H., Dori, Y. J., & Parchmann, I. (2018). How does STEM context-based learning work: What we know and what we still do not know. *International Journal of Science Education*, 40(10), 1095–1107. <https://doi.org/10.1080/09500693.2018.1470346>
- Shehu, B. P., Gjelaj, M., Konjufca, J., Arenliu, A., & Hoxha, R. (2024). Classroom-based experiential learning: Experiences from Kosovo primary schools. *Journal of Experiential Education*, 1–21. <https://doi.org/10.1177/10538259241282788>
- Shwartz, Y., Ben-zvi, R., & Hofstein, A. (2006). Chemical literacy: What does this mean to scientists and school teachers? *Journal of Chemical Education Research*, 83(10), 1557–1561. <https://doi.org/10.1021/ed083p1557>
- Shwartz, Y., Ben-Zvi, R., & Hofstein, A. (2006). The use of scientific literacy taxonomy for assessing the development of chemical literacy among high-school students. *Chemistry Education Research and Practice*, 7(4), 203–225. <https://doi.org/10.1039/B6RP90011A>
- Shwartz, Y., Dori, Y. J., & Treagust, D. F. (2013). *How to outline objectives for chemistry education and how to assess them in teaching chemistry - A studybook: A practical guide and textbook for student teachers, teacher trainees and teachers*. Sense Publishers.
- Sulistiyono. (2020). Pemanasan global (global warming) dan hubungannya dengan penggunaan bahan bakar fosil. *Jurnal Forum Teknologi*, 2(2), 47–56.
- Susanti, S., Muaza, M., & Supian, S. (2023). Implementation of the Pancasila student profile strengthening project (P5) as an effort to strengthen the character of students. *Jurnal Indonesia Sosial Teknologi*, 4(10), 1795–1808. <https://doi.org/10.59141/jist.v4i10.766>
- Susiloningsih, E., Sumantri, M. S., & Marini, A. (2023). Experiential learning model in science learning: Systematic literature review. *Jurnal Penelitian Pendidikan IPA*, 9(9), 550–557. <https://doi.org/10.29303/jppipa.v9i9.4452>
- Thor, D., & Karlsudd, P. (2020). Teaching and fostering an active environmental awareness design, validation and planning for cction-oriented environmental education. *Sustainability*, 12(8), 1–17. <https://doi.org/10.3390/SU12083209>
- Vioreza, N., Hilyati, W., & Lasminingsih, M. (2023). Education for sustainable development: Bagaimana urgensi dan peluang penerapannya pada Kurikulum Merdeka? *EUREKA: Journal of Educational Research and Practice*, 1(1), 34–47. <https://doi.org/10.56773/eureka.v1i1>
- Widiyawati, Y. (2020). Global warming & climate change: Integration of socio scientific issues to enhance scientific literacy. *Journal of Physics: Conference Series*, 1511(1), 1–12. <https://doi.org/10.1088/1742-6596/1511/1/012071>
- Wiyarsi, A., & Çalik, M. (2019). Revisiting the scientific habits of mind scale for socio-scientific issues in the Indonesian context. *International Journal of Science Education*, 41(17), 2430–2447. <https://doi.org/10.1080/09500693.2019.1683912>
- Yaumi, Y., Madlazim, M., & Taufikurohmah, T. (2019). Development of science learning material with socio-scientific issues (SSI) on climate change materials to improve science literacy of junior high school students. *Jurnal Penelitian Pendidikan IPA*, 4(2), 56–63.
- Zhao, X., Li, Y., Li, Z., & Huo, F. (2024). Future projection of extreme precipitation using a pseudo-global warming method: A case study of the 2013 alberta flooding event. *Weather and Climate Extremes*, 46, 1–10. <https://doi.org/10.1016/j.wace.2024.100721>