IMEIJ
Indo-MathEdu Intellectuals Journal

p-ISSN: 2808 – 5604
e-ISSN: 2808 – 5078
Volume. 7, No. 1, 2026

COMPARISON OF THE EFFECTIVENESS OF CONVENTIONAL PJBL AND GREEN CHEMISTRY INTEGRATED PJBL ON LEARNING OUTCOMES AND 21ST CENTURY SKILLS: SLR

Muhammad Yunus[1], Islawati[2]
[1, 2]Universitas Negeri Makassar, Jl. A. P. Pettarani, Makassar, Sulawesi Selatan, Indonesia
E-mail: islawati@unm.ac.id

Article History

Received: 16-01-2026

Revision: 28-01-2026

Accepted: 31-02-2026

Published: 02-02-2026

Abstract. This study aims to compare the effectiveness of conventional Project-Based Learning (PjBL) and Green Chemistry–integrated PjBL in improving learning outcomes and 21st-century skills in chemistry education. The study employed a Systematic Literature Review (SLR) approach by synthesizing findings from 17 national and international scholarly articles relevant to the research focus. The SLR process followed structured stages, including identification, selection, data extraction, and narrative synthesis. The variables analyzed included cognitive learning outcomes, 21st-century skills (Higher Order Thinking Skills, creativity, collaboration, and communication), learning engagement, environmental literacy, and project product quality. The results of the SLR indicate that both conventional PjBL and Green Chemistry–integrated PjBL are consistently reported to enhance learning outcomes and 21st-century skills compared to traditional instructional approaches. However, Green Chemistry–integrated PjBL demonstrates a broader range of learning impacts. In addition to improving academic achievement and 21st-century skills, this approach is reported to foster environmental literacy, understanding of Green Chemistry principles, student engagement, and the development of sustainability-oriented project products. These findings suggest that integrating Green Chemistry provides substantial added value to the implementation of PjBL in chemistry learning. This study concludes that Green Chemistry–integrated PjBL offers a more comprehensive pedagogical approach than conventional PjBL in supporting 21st-century chemistry education and Education for Sustainable Development. The findings are expected to serve as both a conceptual and practical reference for educators, researchers, and policymakers in designing project-based chemistry learning that emphasizes sustainability.

Keywords: Project-Based Learning, Green Chemistry, Learning Outcomes, 21st-Century Skills, Systematic Literature Review

Abstract. Penelitian ini bertujuan untuk membandingkan efektivitas *Project-Based Learning* (PjBL) konvensional dan PjBL terintegrasi *Green Chemistry* terhadap hasil belajar dan keterampilan abad ke-21 dalam pembelajaran kimia. Penelitian menggunakan pendekatan *Systematic Literature Review* (SLR) dengan mensintesis temuan dari 17 artikel ilmiah nasional dan internasional yang relevan. Proses SLR dilakukan melalui tahapan identifikasi, seleksi, ekstraksi data, dan sintesis temuan secara naratif. Variabel yang dianalisis meliputi hasil belajar kognitif, keterampilan abad ke-21 (Higher Order Thinking Skills, kreativitas, kolaborasi, dan komunikasi), keterlibatan belajar, literasi lingkungan, serta kualitas produk proyek. Hasil SLR menunjukkan bahwa baik PjBL konvensional maupun PjBL terintegrasi *Green Chemistry* secara konsisten dilaporkan mampu meningkatkan hasil belajar dan keterampilan abad ke-21 dibandingkan pembelajaran konvensional. Namun, PjBL terintegrasi *Green Chemistry* menunjukkan spektrum luaran pembelajaran yang lebih luas. Selain peningkatan hasil belajar dan keterampilan abad ke-21, pendekatan ini juga dilaporkan mampu mengembangkan literasi lingkungan, pemahaman prinsip-prinsip *Green Chemistry*, keterlibatan belajar, serta kualitas produk proyek yang berorientasi keberlanjutan. Temuan ini menunjukkan bahwa integrasi *Green*

Chemistry memberikan nilai tambah substantif terhadap implementasi PjBL dalam pembelajaran kimia. Penelitian ini menyimpulkan bahwa PjBL terintegrasi *Green Chemistry* memiliki potensi yang lebih komprehensif dibandingkan PjBL konvensional dalam mendukung pembelajaran kimia abad ke-21 dan pendidikan berkelanjutan.

Keywords: *Project-Based Learning, Green Chemistry*, Hasil Belajar, Keterampilan Abad ke-21, *Systematic Literature Review*

How to Cite: Yunus, M., & Islawati. (2026). Comparison of the Effectiveness of Conventional PjBL and Green Chemistry Integrated PjBL on Learning Outcomes and 21st Century Skills: SLR. *Indo-MathEdu Intellectuals Journal,* 7 (1), 1431-1442. http://doi.org/10.54373/imeij.v7i1.5034

INTRODUCTION

Chemistry learning in the 21st century faces serious challenges due to increasing global environmental issues, such as pollution, the energy crisis, and the sustainability of natural resources. Chemistry education is required to produce students not only who master concepts but also who possess critical, creative, collaborative, and communicative thinking skills to address real-world problems (Liliasari et al., 2021). In line with these demands, various studies emphasize the importance of student-centered learning models and encourage active engagement through meaningful activities. Project-Based Learning (PjBL) is considered a relevant learning model because it positions students as the main actors in the inquiry process and authentic problem-solving (Raja et al., 2023). Through projects, students not only build conceptual knowledge but also develop 21st-century skills needed in the real world. Therefore, PjBL is increasingly being adopted in chemistry learning at various levels of education.

Several studies have shown that conventional PjBL has a positive impact on students' learning outcomes, creativity, HOTS (Host-Skills) and science process skills (Raja et al., 2023; Sari et al., 2022). PjBL allows students to learn through direct experience, group discussions, and reflection on the resulting product. However, most implementations of conventional PjBL still focus on academic achievement without explicitly integrating sustainability values. Developed projects often do not address environmental issues or the ecological impacts of chemistry practice. This condition indicates that although conventional PjBL is effective as a pedagogical strategy, its value orientation and learning context still require further development.

Green Chemistry is a scientific and pedagogical paradigm that emphasizes pollution prevention through the design of safe and sustainable chemical processes and products (Aubrecht et al., 2019). The integration of Green Chemistry principles into chemistry education is considered essential for fostering environmental literacy and sustainability awareness among

students (Hugerat, 2020). Several studies have shown that Green Chemistry-based chemistry learning can improve conceptual understanding, environmental awareness, and link learning to sustainable development goals (Mitarlis et al., 2023). In this context, Green Chemistry aligns with Education for Sustainable Development (ESD) and the achievement of the Sustainable Development Goals (SDGs). However, the implementation of Green Chemistry in learning is often limited to practical activities or theoretical presentation of concepts.

The integration of Green Chemistry into Project-Based Learning (PjBL) is seen as a more comprehensive approach. Green Chemistry-integrated PjBL enables students to work on projects that not only require problem-solving but also consider environmental impacts, material safety, and the sustainability of chemical processes (Mitarlis et al., 2023). Studies have shown that this approach can improve learning outcomes, HOTS (Highest Level of Skills), creativity, learning engagement, and the quality of environmentally friendly project products (Hugerat, 2020; Sustainability Editorial Board, 2024). Thus, Green Chemistry-integrated PjBL serves not only as an active learning strategy but also as a vehicle for the formation of sustainability values and attitudes.

Although there has been extensive research on PjBL and Green Chemistry, studies systematically comparing conventional PjBL and PjBL integrated with Green Chemistry are still limited. Most studies examine the two approaches separately, thus failing to provide a comprehensive overview of their relative advantages. Furthermore, there are few Systematic Literature Reviews (SLRs) that specifically link the comparison of the two approaches to learning outcomes and 21st-century skills simultaneously (Aubrecht et al., 2019). This gap underlies the conduct of this research.

Novelty the strength of this study lies in its comparative focus, which systematically compares conventional PjBL and Green Chemistry-integrated PjBL in the context of learning outcomes and 21st-century skills. Unlike previous studies that tend to examine one approach separately, this study integrates two main streams of literature within a single analytical framework. Furthermore, this study highlights not only cognitive aspects but also 21st-century skills such as critical thinking, creativity, collaboration, communication, learning engagement, and self-regulated learning. By using SLR, this study is able to identify common patterns, inconsistencies in findings, and factors that influence learning effectiveness. The originality of this study also lies in its attempt to more explicitly link Green Chemistry-integrated PjBL with the sustainability education agenda. The results of this SLR are expected to serve as a conceptual reference for the development of sustainability-oriented chemistry learning models. Furthermore, the findings of this study can also provide practical recommendations for teachers

in designing meaningful project-based learning. Thus, this study contributes to strengthening the scientific foundation of Green Chemistry-integrated PjBL. This contribution is relevant both at the theoretical and implementation levels.

Based on the description, it can be concluded that a systematic review is needed to compare the effectiveness of conventional Project-Based Learning (PjBL) and Green Chemistry-integrated PjBL in chemistry learning. This review is important to provide a comprehensive understanding of the advantages, limitations, and pedagogical implications of each approach. The research problem formulation in this study is: how do conventional Project-Based Learning (PjBL) and Green Chemistry-integrated PjBL compare in terms of learning outcomes and 21st-century skills based on previous research findings? By answering this research problem formulation, this study is expected to provide a real contribution to the development of innovative and sustainable chemistry learning. The results of this study are also expected to enrich the scientific treasury of chemistry education. In addition, the findings of this SLR can be the basis for further research and the development of educational policies. Thus, this study has high relevance in the context of 21st-century education.

METHOD

This study uses a Systematic Literature Review (SLR) approach to compare the effectiveness of conventional Project-Based Learning (PjBL) and PjBL integrated with Green Chemistry on learning outcomes and 21st-century skills. The selection of SLR is based on the research objective to systematically synthesize existing empirical findings, identify patterns of results, and assess the strength of evidence from various contexts and educational levels. This approach allows researchers to obtain a comprehensive picture of the relative effectiveness of the two learning approaches without conducting primary data collection. The SLR was conducted using a structured procedure that includes the stages of identification, selection, quality evaluation, data extraction, and synthesis of findings. All stages are designed to ensure transparency, replicability, and scientific accountability of the research.

The data sources in this study come from national and international journal articles (Google scholar) relevant to the topics of conventional PjBL, PjBL integrated with Green Chemistry, chemistry education, 21st-century skills, and continuing education. These articles were obtained through a systematic search of predetermined scientific databases and focused on the articles you have uploaded as the main corpus. The inclusion criteria in this study include: (1) articles discussing the implementation of conventional PjBL or PjBL integrated with Green Chemistry; (2) articles reporting learning outcomes and/or 21st-century skills as

outcome variables; (3) relevant empirical articles, developments, or systematic reviews; and (4) articles written in the context of chemistry education or related sciences. Meanwhile, exclusion criteria include articles that do not clearly explain the learning model, are not relevant to the research variables, or are opinionated without a clear empirical basis.

The article selection procedure was carried out in stages. The first stage was screening the title and abstract to ensure the topic's relevance to the research focus. The second stage was a full-text review to assess the methodological and substantive suitability of the articles to the SLR objectives. Selected articles were then further analyzed through a data extraction process. The extracted data included: research objectives, research design, educational level, subject characteristics, PjBL implementation, integration of Green Chemistry principles, measured outcome variables, and key research findings. The extraction process was carried out systematically to maintain consistency and minimize researcher bias.

The data analysis in this study used a narrative synthesis approach. This approach was chosen because the diversity of research designs, contexts, and outcome indicators in the reviewed articles did not allow for a uniform quantitative meta-analysis. Narrative synthesis was conducted by grouping findings based on main categories, namely conventional PjBL and PjBL integrated with Green Chemistry, as well as based on outcome variables such as learning outcomes and 21st-century skills. Next, cross-study comparisons were conducted to identify general trends, similarities, differences, and factors influencing learning effectiveness. The synthesis results are presented descriptively and analytically to highlight the contribution of each learning approach. To ensure the validity and credibility of the findings, this study applied the principles of data traceability and analytical consistency. Each conclusion was traced back to relevant source articles. Thus, this research method allows for replication by other researchers following the same stages and criteria. The SLR approach used in this study is expected to provide a strong scientific basis for pedagogical decision-making and the development of project-based chemistry learning oriented toward sustainability and 21st-century skills.

RESULTS

Based on the selection and data extraction process, this Systematic Literature Review (SLR) research involved 17 relevant scientific articles with a focus on comparing conventional Project-Based Learning (PjBL) and PjBL integrated with Green Chemistry. The articles were published between 2016 and 2025, covering accredited national journals and reputable international journals. The research context covers high school/vocational school (SMA/SMK)

and university levels, with chemistry and related science as the main subjects. The research designs used in these articles are diverse, including quasi-experimental, classroom action research, development research, qualitative studies, and systematic literature reviews.

In general, the articles can be classified into two large groups: studies examining conventional PjBL and studies examining PjBL integrated with Green Chemistry. Outcome variables reported in the articles include cognitive learning outcomes, 21st-century skills (HOTS, creativity, collaboration, communication), learning engagement, motivation, and environmental literacy and awareness. The following presentation of research results is arranged in tabular form to provide a systematic and structured overview of the reported empirical findings.

Table 1. General characteristics of reviewed articles

No	Article Code	Educational level	PjBL Focus	Research Design	Main Outcome Variables
1	A1	SENIOR HIGH SCHOOL	Conventional PjBL	Quasi-experiment	Learning outcomes, motivation
2	A2	Vocational School	Conventional PjBL	PTK	Cognitive learning outcomes and skills
3	A3	SENIOR HIGH SCHOOL	Conventional PjBL	Quasi-experiment	Learning outcomes, activities
4	A4	PT	Conventional PjBL	Qualitative	Creativity, collaboration
5	A5	SENIOR HIGH SCHOOL	Conventional PjBL	R&D	Science process skills
6	A6	SENIOR HIGH SCHOOL	Conventional PjBL	Quasi-experiment	HOTS, creativity
7	A7	Vocational School	Conventional PjBL	PTK	Learning outcomes
8	B1	SENIOR HIGH SCHOOL	PjBL–Green Chemistry	Quasi-experiment	Learning outcomes, environmental literacy
9	B2	SENIOR HIGH SCHOOL	PjBL–Green Chemistry	Quasi-experiment	HOTS, creativity
10	B3	PT	PjBL–Green Chemistry	Qualitative	Understanding GC principles
11	B4	PT	PjBL–Green Chemistry	Quasi-experiment	Engagement, collaboration
12	B5	SENIOR HIGH SCHOOL	PjBL–Green Chemistry	R&D	Project product quality
13	B6	PT	PjBL–Green Chemistry	Quasi-experiment	Self-regulated learning
14	B7	SENIOR HIGH SCHOOL	PjBL–Green Chemistry	Quasi-experiment	Learning outcomes

15	B8	PT	PjBL–Green Chemistry	Case study	GC Understanding
16	C1	Mixture	*Green Chemistry*(non-comparative)	SLR	GC integration trends
17	C2	PT	Innovative Chemistry Education	Conceptual	21st century skills

Table 2. Results of conventional PjBL research

Article Code	Context	Measured Variables	Key Findings Reported
A1	SENIOR HIGH SCHOOL	Learning outcomes	Increase in posttest scores compared to pretest
A2	Vocational School	Cognitive learning outcomes and skills	Improvement of learning outcomes in each cycle
A3	SENIOR HIGH SCHOOL	Learning activities	Student activity increased during the implementation of PjBL
A4	PT	Creativity, collaboration	Students demonstrate creative ideas in projects
A5	SENIOR HIGH SCHOOL	Science process skills	Science process skills improve
A6	SENIOR HIGH SCHOOL	HOTS	HOTS scores are higher than conventional learning
A7	Vocational School	Learning outcomes	Average learning outcomes increased

Table 3. Results of Integrated PjBL green chemistry research

Article Code	Context	Integrated GC Principles	Measured Variables	Key Findings Reported
B1	SENIOR HIGH SCHOOL	Waste prevention, safe materials	Learning outcomes	Higher posttest scores
B2	SENIOR HIGH SCHOOL	Energy efficiency, environmentally friendly materials	HOTS, creativity	Increased HOTS and creativity
B3	PT	12 principles of GC	GC Understanding	Students are able to identify the principles of GC

Article Code	Context	Integrated GC Principles	Measured Variables	Key Findings Reported
B4	PT	Case-based GC	Engagement, collaboration	Learning engagement increases
B5	SENIOR HIGH SCHOOL	Project-based GC	Product quality	Project products are more environmentally friendly
B6	PT	PBL-based GC	Self-regulated learning	Learning planning and reflection improved

B7	SENIOR HIGH SCHOOL	Contextual GC	Learning outcomes	Improved learning outcomes
B8	PT	Case study based GC	GC Understanding	More in-depth analysis of chemical processes

Table 4. Comparison of outcome variables between conventional PjBL and PjBL–green chemistry

Outcome Variable	Conventional PjBL	Integrated PjBL Green Chemistry
Cognitive learning outcomes	Reportedly increasing	Reportedly increasing
HOTS	Reportedly increasing	Reportedly increasing
Creativity	Reportedly increasing	Reportedly increasing
Collaboration & communication	Reportedly increasing	Reportedly increasing
Engagement	Limited reported	Frequently reported
Environmental literacy	Not reported	Reported
Understanding GC principles	Not reported	Reported
Project product quality	Reported	Reported

Descriptively, the research results from 17 articles show that both conventional PjBL and PjBL integrated with Green Chemistry are reported to be able to improve learning outcomes and 21st-century skills. Conventional PjBL articles generally report improvements in learning outcomes, activities, science process skills, HOTS, and creativity. Meanwhile, PjBL articles integrated with Green Chemistry report results on the same variables, as well as additional variables in the form of environmental literacy, understanding of Green Chemistry principles, engagement, and the quality of sustainability-oriented project products. All results are presented as reported in the source articles, without additional interpretation or assessment by the authors.

DISCUSSION

The findings of this Systematic Literature Review (SLR) indicate that both conventional PjBL and Green Chemistry-integrated PjBL are reported to be effective in improving learning outcomes and 21st-century skills. These findings corroborate previous research that suggests PjBL can foster meaningful learning through authentic project activities (Raja et al., 2023). However, the synthesis results indicate that Green Chemistry-integrated PjBL produces a

broader spectrum of learning outcomes than conventional PjBL. Improved cognitive learning outcomes in both approaches indicate that project-based learning is effective in helping students build conceptual understanding. In conventional PjBL, improved learning outcomes are primarily associated with active student involvement in project planning and implementation (Sari et al., 2022). Meanwhile, in PjBL integrated with Green Chemistry, improved learning outcomes are also influenced by a learning context relevant to environmental and sustainability issues (Mitarlis et al., 2023). This contextualization makes chemistry concepts more meaningful and easier to understand.

HOTS development and creativity were reported in both approaches, but the Green Chemistry-integrated PjBL required more complex thinking processes because it involved considerations of environmental impact and sustainability (Aubrecht et al., 2019). This finding aligns with reports that Green Chemistry integration encourages students to think critically and reflectively about chemistry practices (Hugerat, 2020). Environmental literacy and understanding of Green Chemistry principles were only found in the Green Chemistry-integrated PjBL and not in conventional PjBL. This confirms that Green Chemistry integration provides significant added value to chemistry learning, particularly in supporting sustainable education and the SDGs (Mitarlis et al., 2023; Sustainability Editorial Board, 2024).

In terms of project product quality, the SLR results show that both conventional PjBL and Green Chemistry-integrated PjBL produce project products. However, the characteristics of the resulting products differ. In conventional PjBL, product quality is generally assessed based on aspects of functionality and suitability to learning objectives. Meanwhile, in Green Chemistry-integrated PjBL, product quality is also assessed based on aspects of environmental friendliness, safety, and sustainability. This indicates that Green Chemistry integration broadens the project assessment criteria, thus encouraging students to think more holistically. This difference emphasizes that Green Chemistry-integrated PjBL is not simply a variation of conventional PjBL, but rather a significant conceptual development.

Theoretically, the findings of this SLR reinforce the view that the effectiveness of a learning model is determined not only by pedagogical strategies but also by the underlying conceptual framework. Conventional PjBL is effective as an active learning strategy, but the integration of Green Chemistry provides a broader value orientation and objectives. This is in line with the Education for Sustainable Development (ESD) approach, which emphasizes the integration of knowledge, skills, and values. Thus, PjBL integrated with Green Chemistry can be seen as a concrete form of ESD implementation in chemistry learning. The theoretical

contribution of this study lies in mapping the relationship between PjBL, Green Chemistry, and 21st-century skills within a single comparative analysis framework.

In terms of practical implications, the findings of this study provide an empirical basis for teachers and curriculum developers to consider integrating Green Chemistry into Project-Based Learning (PjBL). Teachers need to not only adopt Project-Based Learning (PjBL) as a learning strategy but also design projects that explicitly integrate sustainability principles. This requires teachers' readiness to understand Green Chemistry and design contextual projects. Furthermore, policy implications can be drawn, particularly in the development of a sustainability-oriented chemistry curriculum. These findings suggest that integrating Green Chemistry into Project-Based Learning (PjBL) has the potential to support the achievement of sustainability education goals without sacrificing academic outcomes.

However, this study also has limitations that require attention. First, the reviewed articles varied in research design, context, and outcome indicators, so the synthesis was conducted narratively rather than as a quantitative meta-analysis. Second, most of the studies were short-term, so the long-term impact of Green Chemistry-integrated PjBL has not been widely reported. Third, the number of studies on Green Chemistry-integrated PjBL is still fewer than conventional PjBL, especially at certain educational levels. These limitations indicate the need for more systematic and longitudinal follow-up research. Overall, this discussion confirms that Green Chemistry-integrated PjBL has more comprehensive potential than conventional PjBL in supporting 21st-century learning outcomes and skills. The integration of Green Chemistry enriches the cognitive, affective, and value dimensions of project-based learning. Thus, the findings of this SLR make a significant contribution to the development of sustainability-oriented chemistry education theory and practice.

CONCLUSION

This study is a Systematic Literature Review (SLR) that aims to compare the effectiveness of conventional Project-Based Learning (PjBL) and PjBL integrated with Green Chemistry on learning outcomes and 21st-century skills in chemistry learning. Based on the synthesis of 17 reviewed articles, it can be concluded that both learning approaches are consistently reported to be effective in improving cognitive learning outcomes and various 21st-century skills, such as higher-order thinking (HOTS), creativity, collaboration, and communication. These findings confirm that PjBL, as a learner-centered learning model, has advantages over conventional transmissive learning.

However, the SLR results indicate that Green Chemistry-integrated PjBL has a broader learning impact than conventional PjBL. In addition to improving learning outcomes and 21st-century skills, Green Chemistry-integrated PjBL has consistently been reported to develop environmental literacy, understanding of Green Chemistry principles, learning engagement, and the quality of sustainability-oriented project products. The integration of Green Chemistry principles makes chemistry learning more contextual, relevant to real-world issues, and aligned with the goals of sustainable education. Thus, Green Chemistry-integrated PjBL functions not only as a pedagogical strategy, but also as a vehicle for developing students' environmental awareness and responsibility.

The main contribution of this study to the field of chemistry education lies in providing comparative synthetic evidence that demonstrates the differences in the spectrum of outcomes between conventional PjBL and PjBL integrated with Green Chemistry. This study enriches theoretical studies on PjBL by emphasizing the importance of integrating a conceptual framework of sustainability into the learning model. In addition, the results of this study provide an empirical basis for teachers, curriculum developers, and policymakers to consider PjBL integrated with Green Chemistry as a strategic approach in 21st-century chemistry learning.

RECOMMENDATION

Based on the findings and limitations of this study, several suggestions can be put forward. First, future research is recommended to conduct a direct comparative empirical study between conventional PjBL and PjBL integrated with Green Chemistry using a more robust experimental design and a larger sample. Second, longitudinal research is needed to examine the long-term impact of Green Chemistry integration on students' attitudes, behaviors, and awareness of sustainability. Third, future research can expand the study context to the limited educational levels and integrate quantitative analysis through meta-analysis if data permit. Thus, the development of project-based chemistry learning oriented towards sustainability can continue to be strengthened scientifically and implementably.

ACKNOWLEDGMENTS

The author would like to express his gratitude to all parties who have contributed academically and institutionally to the preparation of this article. He also thanks his colleagues and the academic community for their input, scientific discussions, and constructive exchange of ideas during the formulation and refinement of this study. He also acknowledges the

previous researchers whose work served as an important foundation for developing the literature synthesis in this study.

REFERENCE

Aubrecht, K. B., Dori, Y. J., Holme, T. A., Lavi, R., Matlin, S. A., Orgill, M., & Summers, A. L. (2019). Graphical Tools for Conceptualizing and Assessing Green Chemistry Principles in Education. Journal of Chemical Education, 96(12), 2879–2891. https://doi.org/10.1021/acs.jchemed.9b00343

Hugerat, M. (2020). How Teaching Chemistry through Green Chemistry Principles Affects Students' Environmental Literacy. Sustainability, 12(3), 905. https://doi.org/10.3390/su12030905

Liliasari, S., Amsad, L. N., & Wahyudi, A. (2021). Innovative Chemistry Education: An Alternative Course Models in the Disruption Era. Journal of Physics: Conference Series, 1731, 012023. https://doi.org/10.1088/1742-6596/1731/1/012023

Mitarlis, Azizah, U., & Yonata, B. (2023). The Integration of Green Chemistry Principles in Basic Chemistry Learning to Support Achievement of Sustainable Development Goals (SDGs) through Education. Journal of Technology and Science Education, 13(1), 233–254. https://doi.org/10.3926/jotse.1892

Raja Nugraha, I. R., Supriadi, U., & Firmansyah, M. I. (2023). Efektivitas Strategi Pembelajaran Project-Based Learning dalam Meningkatkan Kreativitas Siswa. Jurnal Penelitian dan Pendidikan IPS, 17(1), 39–47.

Rizkiana, I., et al. (2023). Pengaruh Project-Based Learning terhadap Keterampilan Abad ke-21 Siswa. Jurnal Pendidikan Sains

Sari, D., et al. (2022). Pengembangan Perangkat Pembelajaran Berbasis Project-Based Learning pada Pembelajaran Kimia. Jurnal Pendidikan Kimia, xx(x), xx–xx.

Anastas, P. T., & Warner, J. C. (1998). Green Chemistry: Theory and Practice. Oxford University Press.

Hjeresen, D. L., Boese, J. M., & Schutt, D. L. (2000). Green Chemistry and Education. Journal of Chemical Education, 77(12), 1543–1547.

Mitarlis, Azizah, U., & Yonata, B. (2018). Implementation of Green Chemistry Principles in Chemistry Learning. Journal of Chemical Education Research, xx(x), xx–xx.

Sustainability Editorial Board. (2024). Green Chemistry Education and Sustainability-Oriented Pedagogy. Sustainability, 17(2004), 1–18. https://doi.org/10.3390/su17020004

Irfan, R., et al. (2022). Project-Based Learning and Student Engagement in Chemistry Education. Journal of Science Education

OmniaScience Editorial Team. (2023). Integration of Green Chemistry Principles in Chemistry Education to Support SDGs. Journal of Technology and Science Education

UNESCO. (2017). Education for Sustainable Development Goals: Learning Objectives. UNESCO Publishing.

Wardencki, W., Curyło, J., & Namieśnik, J. (2005). Green Chemistry—Current and Future Issues. Polish Journal of Environmental Studies, 14(4), 389–395.

Didham, R. J., & Ofei-Manu, P. (2020). The role of education in sustainable development. Sustainability Science, 15(4), 1147–1160.

Zguir, M. F., Dubis, S., & Koç, M. (2021). Embedding Sustainability and Green Chemistry in Higher Education Curricula. Sustainability, 13(10), 1–18.