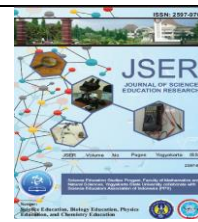




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Students' Perceptions of Green Chemistry through the Project-Based Learning (PjBL) Model Integrated with Local Culture

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Abstract

Green chemistry education is essential in fostering students' environmental awareness and sustainability-oriented thinking. However, chemistry learning is often perceived as abstract and difficult, which may reduce students' motivation and engagement. This study aims to analyze students' perceptions of green chemistry learning through the implementation of a culturally integrated Project-Based Learning (PjBL) model. A descriptive qualitative approach was employed involving 35 tenth-grade students at a senior high school in North Jakarta during the even semester of the 2024/2025 academic year. Learning activities were conducted through a compost-making project that integrated green chemistry principles with local cultural and environmental contexts. Data were collected using questionnaires and analyzed descriptively to capture students' cognitive, affective, and social responses to the learning experience. The findings indicate that culturally integrated PjBL provides meaningful, contextual, and relevant learning experiences. Students were able to connect green chemistry concepts with real-life environmental issues, particularly organic waste management, which strengthened both conceptual understanding and practical application. The learning process also positively influenced students' affective domain, as students reported increased interest, motivation, and engagement. Although students encountered challenges related to project execution and collaboration, these difficulties were successfully addressed through group discussion, cooperation, and problem-solving. Furthermore, the results reveal a positive shift in students' perceptions of chemistry, from an abstract and intimidating subject to a useful and applicable science closely related to everyday life. Overall, culturally integrated PjBL supports the development of environmental awareness and 21st-century skills, including critical thinking, creativity, collaboration, and communication.

Keywords:

Project Based Learning, cultural integration, students' perceptions, environmental awareness

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1. INTRODUCTION

Education plays an important role in national development, particularly in the era of globalization where the quality of education determines the competitiveness of human resources (Suryanto et al., 2025). Education is a planned and conscious process aimed at developing students' knowledge, attitudes, and behavior through systematic learning activities (Marbun & Saragih, 2022; Rahmat, 2024). In addition to transferring knowledge, education is also expected to develop students' awareness and responsibility toward environmental sustainability by strengthening their cognitive abilities, creativity, and innovation in managing natural resources wisely (Simanjuntak, 2017; Nurhayati et al., 2024).

Education is closely related to the social and cultural values that exist within society. Cultural diversity may influence the learning process because differences in language, values, communication patterns, and learning habits can affect how students understand learning materials and interact in the classroom (Dasmo et al., 2022). Therefore, integrating cultural values into the learning process is considered important in order to create meaningful learning experiences and strengthen students' understanding of local wisdom (Saihu, 2019). The integration of culture in education also contributes to strengthening character development and social awareness among students. In Indonesia, the implementation of the Merdeka Belajar policy provides greater flexibility for educational institutions to design contextual learning that aligns with local culture, social conditions, and available resources (Rahmat, 2024). This policy encourages teachers to develop innovative learning strategies that not only focus on academic achievement but also support the preservation of cultural values and the development of students' character (Dasmo et al., 2022).

To support innovative learning within the Merdeka Belajar framework, various student-centered learning models can be implemented, one of which is Project-Based Learning (PjBL). PjBL is a learning approach that actively involves students in solving real-world problems through project activities and collaborative work (Abdurahman et al., 2024). Through such learning experiences, students can develop critical thinking, creativity, collaboration, and problem-solving skills in meaningful learning contexts (Lestari & Ilhami, 2022; Taliak et al., 2024). Several studies also show that PjBL can improve students' creativity and learning outcomes because students are actively involved in constructing their knowledge through project activities (Utomo, 2024; Rahmat, 2024).

However, in chemistry education, students often experience difficulties in understanding abstract chemical concepts. Previous studies have reported that many students perceive chemistry as a difficult subject due to the complexity of microscopic and symbolic representations of chemical phenomena (Muderawan et al., 2019). As a result, students tend to have lower motivation and interest in learning chemistry more deeply (Maulidiningsih & Kusumaningrum, 2023). Therefore, innovative learning strategies are needed to help students understand chemical concepts in a more contextual and meaningful way.

One of the chemistry topics that is considered challenging for students is green chemistry, as it is relatively new in the chemistry curriculum (Harefa, 2023). Green chemistry refers to the design, production, and application of chemical products and processes that aim to reduce or eliminate hazardous substances and minimize negative impacts on the environment and human health (Mustafa, 2016). The principles of green chemistry emphasize energy efficiency, waste reduction, the use of safer materials, and sustainable resource management (Widyawati et al., 2024). Therefore, integrating green chemistry into the learning process is important to support environmental education and promote sustainable development among students (Maharani, 2024; Ningsih, 2024).

Previous studies have shown that green chemistry learning can be effectively implemented through the Project-Based Learning (PjBL) model because this approach allows students to learn in a contextual manner and focus on solving real-world environmental problems (Janah & Hidayah, 2025; Ningsih, 2024). Through project activities, students can also develop creativity, collaboration, and environmental awareness while applying chemical concepts in real-life situations (Utomo, 2024). In addition, integrating cultural elements or local wisdom into learning can further strengthen students' understanding by connecting scientific concepts with their daily experiences and community practices (Saihu, 2019; Suryanto et al., 2025).

Students' perceptions also play an important role in the learning process because they influence students' responses, engagement, and learning motivation (Triyono & Febriani, 2018). Positive perceptions toward learning activities can increase students' interest and participation, while negative perceptions may reduce their motivation and understanding of the subject matter. Therefore, analyzing students' perceptions is important to evaluate the effectiveness of learning strategies and to understand how students interpret the learning experiences they encounter.

However, studies examining students' perceptions of green chemistry learning through a culture-integrated Project-Based Learning model are still limited. Therefore, this study aims to analyze students' perceptions of green chemistry learning through a culture-integrated Project-Based Learning (PjBL) model. The

findings of this research are expected to contribute to the development of more contextual and meaningful chemistry learning strategies while supporting the development of students' environmental awareness in accordance with the objectives of the Merdeka Curriculum.

2. LITERATURE REVIEW

2.1 Green Chemistry

The concept of green chemistry emerged in the 1980s and 1990s as awareness of the environmental impacts of industrial activities increased. Since chemical products remain essential for modern society, the main scientific challenge for the chemical industry is not whether such products are needed, but rather how they are designed, characterized, and produced in ways that support sustainable development. Although chemistry has long contributed to the creation of valuable products and highly efficient processes, technological developments have often focused only on functional performance without sufficiently considering potential environmental and health impacts (Zimmerman, 2020). Green chemistry is guided by twelve fundamental principles aimed at minimizing environmental harm and promoting sustainability in chemical processes. These principles include:

1. Preventing waste rather than treating it after it is formed;
2. Designing synthetic methods that maximize the incorporation of all materials into the final product;
3. Using and generating substances that are safe for human health and the environment whenever possible;
4. Designing chemical products that remain effective while reducing toxicity;
5. Minimizing the use of auxiliary substances such as solvents and separation agents, and ensuring they are harmless when used;
6. Minimizing energy requirements by considering environmental and economic impacts, preferably conducting reactions at ambient temperature and pressure;
7. Using renewable raw materials whenever technically and economically feasible to reduce resource depletion;
8. Avoiding unnecessary derivatization such as protection and deprotection steps or temporary modifications;
9. Using catalytic reagents that are more selective and efficient than stoichiometric reagents;
10. Designing chemical products that can degrade into harmless substances and do not persist in the environment;
11. Improving analytical methods to enable real-time monitoring and control of chemical processes before hazardous substances are formed; and
12. Selecting chemical substances and reaction conditions that minimize the risk of accidents such as chemical releases, explosions, and fires.

2.2 Project Based Learning (PjBL)

Project-Based Learning (PjBL) is an educational approach that integrates constructivism, problem-solving, integrated learning, and research. This approach emphasizes both theoretical understanding and practical investigation in the learning process. The learning process typically begins with the generation of ideas and questions from students related to a selected topic, which then develops into exploration and learning activities. Through this approach, students are encouraged to work both individually and collaboratively to develop projects and produce meaningful products. PjBL enables students to manage and actively construct their own learning experiences in the classroom. As a learner centered approach, teachers act as facilitators who guide, support, and motivate students in developing their abilities, helping them become more independent learners (Padwa, 2021). This method involves concrete project-based activities carried out independently or collaboratively, often based on real-world problems that encourage practical problem-solving skills (Murniati, 2016). Furthermore, project-based learning allows students to participate directly in selecting the topics or materials they wish to study, either individually or in groups. This active involvement makes the learning process more meaningful because students feel engaged in the learning experience, and such meaningful experiences are more likely to be retained in long-term memory.

Table 1. Stages of Project Based Learning

Work Stages	Teacher Activities	Student Activities
Introduction Activities		
Main Activities		
Fundamental Question	The teacher introduces the topic and provides fundamental questions to students related to the learning topic.	Students respond to the fundamental questions given by the teacher.

Work Stages		Teacher Activities	Student Activities
Designing Product Planning		The teacher ensures that each student in the group selects and understands the procedures for developing the project/product to be produced.	Students discuss and prepare a plan for problem-solving, including task distribution, preparation of tools, materials, media, and required resources.
Developing the Project Schedule		The teacher and students agree on the project timeline (stages until submission).	Students arrange the project completion schedule by considering the agreed deadlines.
Monitoring Project Activity and Progress		The teacher monitors students' participation during the project implementation.	Students carry out the project while paying attention to the agreed deadlines.
Testing the Results		The teacher asks students to present their project results.	Students present their work in front of the teacher and other student groups.
Evaluating Learning Experience		The teacher provides a general conclusion of the project results, including responses to questions during the presentation.	Students and the teacher jointly reflect on the overall project implementation process.
Closing Activities			

2.3 Cultural Integration and Contextual Learning in the Merdeka Curriculum

Each region of Indonesia has its own distinctive features, such as variations in language, ethnicity, religion, customs, and social values. The country is known for its vast cultural diversity. Because humans both create and preserve culture, there is a strong relationship between humans and culture. Even though people may die, the information and cultural values they produce are passed on to subsequent generations. The education system is also impacted by this process of cultural transmission since cultural values influence the techniques, approaches, and content of instruction. As a result, Indonesian culture is crucial to the growth of the country's educational system. Education, often referred to as pedagogy, focuses on the processes of cultural transmission, personal development, and human maturation, which contribute to improving the quality of human resources and shaping national character (Normina, 2017). Cultural integration is seen as a crucial strategy for developing meaningful and relevant learning experiences in the educational setting. Learning resources can be linked to students' actual experiences, local knowledge, and community customs through cultural integration. With this method, students can comprehend ideas both theoretically and through the social and cultural situations they come across in daily life.

The Merdeka Curriculum's implementation in Indonesia also reflects the value of contextual learning. Teachers are encouraged to provide more adaptable and creative learning activities that are pertinent to students' settings and real-life circumstances as a result of the switch from the 2013 Curriculum to the Merdeka Curriculum (Suprpto et al., 2021). This curriculum gives teachers more freedom to create innovative teaching methods that meet the interests, skills, and learning requirements of their students (Zakso, 2022). The creation of the Pancasila Student Profile, which highlights six essential competencies faith and noble character, independence, teamwork, global variety, critical thinking, and creativity is one of the primary objectives of the Merdeka Curriculum (Kemendikbud Ristek, 2022).

Creativity is an important dimension of the Pancasila Student Profile. Creative students are able to generate new ideas, produce meaningful works, and develop alternative solutions to problems encountered in their environment. This ability includes generating original ideas, creating unique works or actions, and demonstrating flexible thinking in solving problems (Kemendikbud Ristek, 2022). Integrating scientific ideas with students' sociocultural contexts helps enhance contextual learning in science education. Green chemistry and project-based learning (PjBL) are two significant strategies that promote contextual and relevant science learning, according to this study's literature evaluation.

Green chemistry promotes ecologically friendly chemical reactions and helps students become conscious of sustainable scientific methods. Through group projects and hands-on learning exercises, PjBL enables students to actively investigate real-world issues. The integration of PjBL with local cultural contexts provides opportunities for students to connect scientific concepts with environmental issues and community practices. Through project-based activities related to everyday life, students can better understand scientific concepts while developing creativity, collaboration skills, and environmental awareness. Therefore, integrating green chemistry concepts with the PjBL model and local culture can create meaningful learning experiences that support the goals of the Merdeka Curriculum and the development of the Pancasila Student Profile.

3. RESEARCH METHOD

This study employed a descriptive qualitative approach aimed at exploring students' perceptions of green chemistry learning integrated with cultural elements through the Project-Based Learning (PjBL) model. The research was conducted over approximately four months at a private senior high school in North Jakarta. The participants consisted of 35 tenth-grade students selected using a purposive sampling technique. The school was chosen because it has implemented the Merdeka Curriculum, which integrates green chemistry material into chemistry learning and supports innovative learning approaches such as Project-Based Learning (PjBL). Tenth-grade students were selected because they had just begun studying chemistry at the senior high school level, making it important to explore their initial perceptions of chemistry learning. The research procedure consisted of three main stages: preparation, implementation of learning activities, and data analysis. During the preparation stage, the researcher conducted a preliminary survey to identify students' initial psychological conditions toward chemistry learning. The learning implementation stage was conducted in five meetings, following the six stages of the PjBL model:

1. formulating essential questions,
2. designing project plans,
3. developing project schedules,
4. implementing the projects,
5. presenting project results, and
6. evaluating learning experiences.

The data collection technique used in this study was a student perception questionnaire distributed through Google Forms after the completion of the learning activities. The questionnaire consisted of open-ended questions designed to explore students' perceptions, experiences, and reflections regarding green chemistry learning integrated with cultural contexts. To ensure the validity of the instrument, the questionnaire was reviewed through an expert judgment process involving two experts in chemistry education and educational research. The collected data were analyzed using thematic analysis. The analysis process involved several stages, including data organization, qualitative coding, categorization, and interpretation. NVivo software was used to facilitate the coding process, organize the data, and identify emerging themes from students' responses. To enhance the credibility of the findings, the analysis process was conducted iteratively by reviewing the coding and data categorization to ensure consistency in the identified themes.

4. RESULT AND DISCUSSION

Project-Based Learning (PjBL) is a learning approach that aligns with the principles of the Merdeka Curriculum and supports learner-centered learning. In this study, data were collected through a Google Form containing five questions related to the green chemistry project. The results showed that most students responded positively to the implementation of the green chemistry project, as they were actively involved in designing and completing project activities. This finding indicates that PjBL provides meaningful learning experiences because students directly engage in solving real-world problems. According to [Syafila \(2024\)](#), PjBL encourages active learning by allowing students to explore problems, design solutions, and produce tangible outcomes, which can increase students' motivation and understanding of learning concepts.

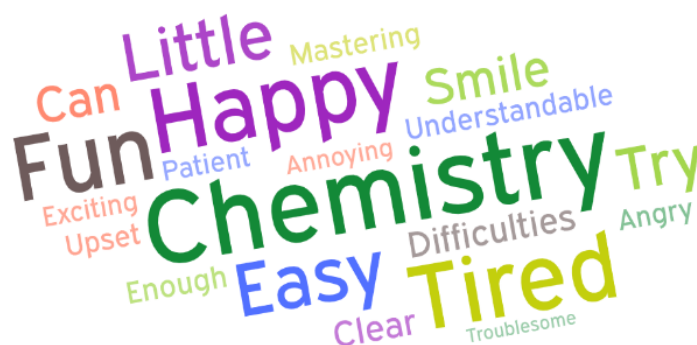
Diagram 1. Answers to the question, “What work did your team produce, and why did you produce it?”



Based on the data shown in Diagram 1, the majority of students chose to create composters as the final product of their project. This choice indicates that students were able to relate environmentally friendly chemistry concepts to real-life problems, particularly in managing food and organic waste. The processing of organic waste into natural fertilizer reflects the practical application of green chemistry principles, especially waste reduction and the use of safer materials (Kustiyah, 2024). Students understood that organic waste can be

transformed into environmentally friendly compost, which supports environmental sustainability. This finding is consistent with the idea that environmental awareness, including the ecological footprint of food and local food consumption, can be developed through contextual chemistry learning that involves scientific practical skills and critical thinking (Simanjuntak, 2019). In addition, this result supports Utomo (2024), who states that project-based learning helps students identify environmental problems and develop practical solutions through the products they create. The stages in project-based learning encourage students to design and produce contextual products, allowing them to connect chemical concepts with real-life situations. Furthermore, the selection of composters also reflects the integration of cultural and local environmental contexts in learning. Organic waste management is closely related to daily practices in Indonesian society, particularly in household food waste management and agricultural traditions that are still practiced in many areas. Therefore, the project not only demonstrates students' understanding of green chemistry concepts but also shows their awareness of sustainable practices aimed at maintaining environmental balance and reducing dependence on chemical fertilizers through contextual innovations.

Diagram 2. Answers to the question: How did you feel while learning green chemistry and creating this work?



Students' responses about their feelings while learning green chemistry and creating projects (Diagram 2) show that words such as "happy," "easy," "interesting," and "chemistry" appeared most frequently, while terms like "tired" and "difficult" were mentioned less often. This indicates that most students experienced an enjoyable learning process even though project-based activities required effort and collaboration. The positive emotional responses suggest that students were more actively engaged because they were not only listening to theoretical explanations but also directly involved in creating projects related to real-life applications of green chemistry. Such experiences help students understand the material more easily and meaningfully. These findings are consistent with Maulidiningsih (2023), who reported that the implementation of the Project-Based Learning (PjBL) model in green chemistry learning can increase students' interest and motivation to learn. Although chemistry is often perceived as a difficult subject, experience-based learning can reduce students' anxiety and encourage more active participation. This result also supports Simanjuntak (2023), who emphasizes the importance of giving students opportunities to express the difficulties they encounter in learning chemistry so that teachers can identify learning barriers. Therefore, the role of teachers in providing guidance and support remains essential, especially when students experience fatigue or difficulty during project completion (Hapsari, 2021), so that learning becomes more meaningful, contextual, and supportive of students' emotional development.

Diagram 3. Answers to the question: Are there any regional conditions that you imagined when creating this work?



Student responses regarding the conditions of the areas they imagined while completing the assignment (Diagram 3) show that words such as "waste," "garbage," "compost," and "environment" appeared most

frequently. These responses indicate that students imagined environments facing organic waste problems in both household and agricultural contexts. This demonstrates that students are able to think contextually and view the project as a potential solution to real environmental issues, particularly through composting as an environmentally friendly waste management strategy. The responses also reflect the integration of green chemistry concepts into social and cultural aspects of daily life, as students relate the project to farming practices, waste disposal habits, and environmental management in their communities. These findings align with [Lestari \(2022\)](#), who states that project-based learning can enhance students' creative thinking by encouraging them to generate ideas relevant to real-life situations while strengthening 21st-century skills, particularly the 4Cs (critical thinking, creative thinking, communication, and collaboration). Furthermore, students' focus on organic waste is closely related to daily food consumption, considering that food waste is a major component of household waste. In this context, the composter project not only offers a practical waste management solution but also promotes environmental awareness and responsible attitudes toward food consumption. This finding is consistent with [Simanjuntak \(2024\)](#), who explains that research since 2015 has explored the concept of food plates as a way to develop environmentally conscious mindsets and behaviors through everyday food consumption.

Diagram 4. Answers to the question: What difficulties did you encounter in creating this work and how did you overcome them?



In Diagram 4, students' responses show that the main challenges during the project were related to the process of creation, task distribution, and technical obstacles during implementation. Dominant words such as "creation," "contribution," and "difficulty" indicate that these challenges emerged during the project process. However, students were able to overcome them through group discussions, cooperation, role distribution, and simplifying work steps. This finding demonstrates that Project-Based Learning (PjBL) not only supports the understanding of chemistry concepts but also strengthens students' collaboration, communication, and problem-solving skills. Through participation in projects that require critical thinking, creativity, and teamwork, students develop skills that are useful beyond the classroom and help prepare them to face real-life challenges ([Sormin, 2024](#)). In the context of green chemistry learning, collaboration becomes particularly important because environmental problem-solving often requires collective efforts. Students' involvement in the composting project also reflects their awareness of cultural values and local traditions related to the reuse and management of organic waste. This finding supports [Saihu's \(2019\)](#) research, which states that education based on local wisdom can encourage students to become agents of change who contribute to environmental sustainability through responsible application of chemistry. Thus, through composting activities, students not only learn green chemistry principles but also develop responsibility, independence, and environmental awareness that reflect a more sustainable and responsible mindset.

Diagram 5. Answers to the question: Did your views on chemistry change during the creation of this work?



Diagram 5 shows that students experienced a change in their perspectives on chemistry after participating in the project-based learning process. Dominant words such as “learning,” “agriculture,” “consider,” “inspiring,” “transformation,” “perceive,” and “perspective” indicate that students began to view chemistry not merely as abstract and difficult material, but as knowledge that can be learned, reconsidered, and applied in real-life contexts. The appearance of the word “agriculture” further shows that students were able to relate chemical concepts to everyday activities, particularly in agricultural practices, making chemistry more relevant to societal needs. Words that previously carried negative connotations such as “scary” and “imagined” were balanced by more positive expressions like “inspiring,” “enjoyable,” “creative,” and “beneficial,” indicating a shift from perceiving chemistry as frightening and difficult to viewing it as meaningful and useful. This transformation suggests that green chemistry learning through the Project-Based Learning (PjBL) model successfully provides a more meaningful learning experience by connecting scientific concepts with real environmental issues and daily life. Such experience-based learning allows students not only to understand theoretical concepts but also to apply them in practical situations. These findings support [Nurhayati et al. \(2024\)](#), who state that learning strategies that develop 21st-century skills, particularly the 4Cs (critical thinking, creative thinking, communication, and collaboration), can enhance students’ readiness to face real-world challenges. Similarly, [Sari \(2025\)](#) explains that PjBL functions not only as a learning model but also as a medium for strengthening the 4C competencies, which are important components of the Pancasila Student Profile. In addition, the increasing complexity of global challenges such as technological development, globalization, environmental issues, and global competition requires students to possess adaptive knowledge and higher-order skills ([Zubaidah, 2016](#)). Therefore, the shift in students’ perceptions after participating in project-based green chemistry learning indicates that this approach not only improves conceptual understanding but also contributes to the development of students’ character, creativity, and readiness to face future challenges.

The culture-integrated Project-Based Learning (PjBL) model changes students’ perceptions of green chemistry by connecting theoretical concepts with their environmental and cultural realities. Through projects such as compost production to manage organic waste, students not only learn the principles of sustainability but also develop greater environmental awareness and stronger emotional and cognitive engagement in learning. During the process, students demonstrate critical thinking, problem-solving, and collaboration skills despite encountering challenges. This experience helps students realize that chemistry is not merely abstract theory but a meaningful and useful science in everyday life. Overall, the findings show that culturally integrated PjBL creates more contextual and relevant learning. The composting project enhances students’ understanding of green chemistry while fostering environmental responsibility and reinforcing cultural values related to environmental care. Cultural integration is reflected in how students relate green chemistry concepts to daily practices in Indonesian society, particularly in household waste management and agricultural contexts, making the learning experience more meaningful and applicable.

5. CONCLUSION

The findings of this study indicate that the implementation of culturally integrated Project-Based Learning (PjBL) in green chemistry learning provides meaningful, contextual, and relevant learning experiences for students. Through the compost-making project, students were able to connect green chemistry concepts with real environmental issues in their surroundings, particularly organic waste management, thereby strengthening both conceptual understanding and practical application. The learning process also positively influenced students’ affective domain, as they became more engaged, motivated, and interested in chemistry learning. The integration of local culture further strengthened students’ understanding of environmentally responsible practices rooted in daily life and contributed to the development of environmentally conscious and socially responsible character. Through active involvement in projects such as making composters, students not only understood green chemistry concepts more contextually but also developed critical thinking, creativity, collaboration, and communication skills as part of essential 21st-century competencies. Overall, culturally integrated PjBL proved effective in fostering positive perceptions of chemistry, making learning more enjoyable, meaningful, and relevant to everyday life, and transforming students’ views of chemistry from a difficult subject into a useful science closely connected to their cultural and environmental realities.

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