journal homepage: *http://bsuj.bsu.edu.az/en*
https://doi.org/10.30546/209501.201.2025.2.003.001

APPLICATION OF ECOLOGICALLY ORIENTED PROJECTS IN CHEMISTRY LESSONS AND THE FORMATION OF STUDENTS' SUSTAINABLE DEVELOPMENT THINKING

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Received: 02 september 2025
Accepted: 30 october 2025
Published: 31 october 2025

The integration of ecologically oriented projects into chemistry lessons has emerged as a modern pedagogical approach that fosters not only subject-based knowledge but also students' sustainable development thinking. In today's educational landscape, where environmental issues are becoming increasingly urgent, the use of project-based learning provides students with opportunities to connect theoretical knowledge with real-life ecological challenges. By engaging in projects related to waste management, recycling, renewable energy, and green chemistry practices, learners develop the ability to apply classroom concepts in meaningful and socially valuable contexts. This approach strengthens students' critical and creative thinking, improves their problem-solving skills, and encourages collaboration and communication. Unlike traditional methods, project-based learning motivates learners by linking chemical knowledge to environmental issues that directly impact their communities. As a result, students not only achieve a deeper understanding of chemistry but also cultivate ecological responsibility and awareness of global sustainability challenges.

Moreover, ecologically oriented projects promote interdisciplinary connections by integrating chemistry with biology, geography, and environmental science, thereby providing a holistic learning experience. Such practices enhance students' engagement, foster eco-literacy, and contribute to shaping active citizens capable of addressing complex environmental problems. The findings highlight that the implementation of ecologically oriented projects in chemistry lessons can serve as an effective strategy to prepare students for both academic success and responsible participation in sustainable development. This study underscores the need to strengthen eco-project practices in school curricula as a key element of modern chemistry education.

Keywords: Chemistry education, project-based learning, ecological projects, sustainable development, environmental awareness.

INTRODUCTION

In recent years, education has witnessed a significant transformation driven by the need to prepare students for global challenges that extend beyond the classroom. Among these challenges, environmental degradation, climate change, and the overuse of natural resources have emerged as pressing issues requiring immediate and sustained attention. Schools, particularly through science education, play a vital role in cultivating ecological

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awareness and equipping learners with the skills to act responsibly. Chemistry, as a central branch of science, offers unique opportunities to connect theoretical knowledge with real-world ecological problems [1].

Traditional methods of teaching chemistry have often been criticized for focusing primarily on memorization of facts and formulas, leaving little room for the development of critical, creative, and ecological thinking. In contrast, project-based learning (PBL) provides a dynamic framework that engages students in active inquiry, problem-solving, and collaboration. When combined with ecological orientation, PBL transforms chemistry lessons into platforms where students not only learn about chemical reactions or environmental processes but also explore solutions to issues such as pollution, waste management, renewable energy use, and sustainable consumption. The integration of ecologically oriented projects into chemistry education addresses two important objectives. First, it enhances students' subject knowledge by allowing them to apply concepts in practical and socially meaningful contexts. Second, it fosters sustainable development thinking by encouraging learners to consider the broader environmental, social, and ethical implications of scientific knowledge. Through such projects, students learn to analyze ecological challenges critically, work collaboratively on innovative solutions, and develop a sense of responsibility as future citizens [2-6].

Furthermore, these projects promote interdisciplinary learning by bridging chemistry with biology, geography, and environmental science, thereby creating a holistic educational experience. They also increase student motivation by connecting academic content with real-life concerns, making the learning process more engaging and relevant.This paper explores the role of ecologically oriented projects in fostering sustainable development thinking among students in chemistry lessons. It emphasizes the pedagogical benefits of project-based learning, provides examples of ecological projects, and analyzes their contribution to the development of critical thinking, problem-solving, and ecological literacy. Ultimately, the study highlights the importance of integrating sustainability-oriented teaching practices into chemistry education as a pathway to nurturing environmentally responsible and scientifically literate individuals [7-10].

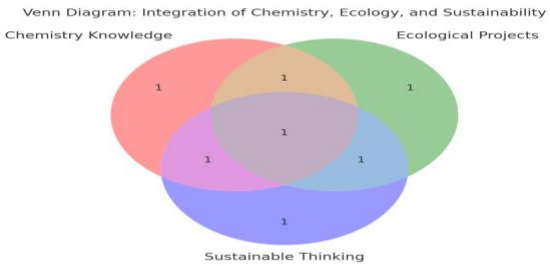

Figure 1. Venn Diagram

The conceptual relationship between chemistry knowledge, ecologically oriented projects, and sustainable development thinking can be illustrated as shown in Figure 1. This framework highlights how the integration of subject-based learning, ecological practices, and sustainability-oriented thinking contributes to the development of students' eco-literacy and 21st-century skills.

EXPERIMENTAL

This study employed a pedagogical experimental design to explore the impact of ecologically oriented project-based learning (PBL) on students' sustainable development thinking in chemistry education. The methodology consisted of three main phases: preparation, implementation, and evaluation.

1. Preparation Stage: At the initial stage, research objectives were defined, two groups of students were selected (control and experimental), and teachers were trained to act as facilitators.

2. Implementation Stage: The experiment was carried out over one semester. Students in the experimental group engaged in ecological projects such as recycling, renewable energy models, and green chemistry experiments, while the control group continued with traditional lessons.
3. Evaluation Stage: To measure the effectiveness of the approach, pre- and post-tests, questionnaires, observations, and interviews were conducted. Quantitative data were statistically analyzed, and qualitative data were thematically examined.

Table 1. Comparison of Pre-test and Post-test Results for Control and Experimental Groups

Group	Pre-test (%)	Post-test (%)
Control	55	63
Experimental	56	78

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This table presents the comparative results of pre-test and post-test assessments conducted with the control and experimental groups. The control group, which followed traditional teacher-centered instruction, showed a modest improvement in performance (from 55% to 63%). In contrast, the experimental group, which engaged in ecologically oriented project-based learning, demonstrated a significant increase (from 56% to 78%). These results indicate that students involved in ecological projects not only improved their chemistry knowledge more effectively but also displayed higher levels of motivation and engagement. The data support the conclusion that project-based learning with ecological orientation is more effective than conventional teaching methods in fostering both academic achievement and sustainable development thinking.

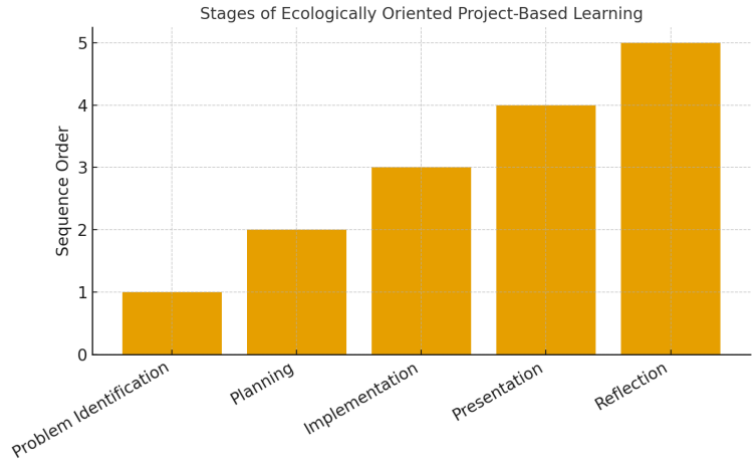

Figure 2. Stages of Ecologically Oriented Project-Based Learning.

This figure illustrates the sequential stages followed in the implementation of ecologically oriented project-based learning within chemistry lessons. The process begins with Problem Identification, where students define real-life ecological issues such as pollution, waste management, or energy inefficiency. In the Planning stage, learners set objectives, select methods, and assign roles within their project teams. The Implementation stage involves conducting experiments, gathering data, and applying eco-friendly solutions. Presentation provides students the opportunity to share their findings with peers through reports, posters, or oral presentations. Finally, the Reflection stage enables learners to evaluate outcomes, discuss challenges, and propose improvements for future applications. Together, these stages form a continuous cycle that strengthens both chemistry knowledge and sustainable development thinking.

To investigate the role of ecologically oriented projects in developing students' sustainable development thinking, a pedagogical experiment was conducted with secondary school students during chemistry lessons. The experiment aimed to integrate project-based learning activities with ecological content, allowing students to apply theoretical knowledge in

solving real-life environmental problems. The participants of the study included two groups of students from the same grade level: an experimental group and a control group. The experimental group was engaged in project-based activities with an ecological orientation, while the control group continued with traditional teacher-centered methods. This design made it possible to compare the effectiveness of project-based approaches with conventional teaching. In the experimental group, students worked in small teams to design and implement ecological projects over the course of a semester. Sample projects included:

- Recycling and Waste Management: students analyzed types of household waste, designed simple recycling models, and proposed strategies for waste reduction;
- Green Chemistry Experiments: learners carried out small-scale laboratory activities using eco-friendly materials to understand principles of green chemistry;
- Renewable Energy Models: groups constructed simple models of solar panels and wind turbines to demonstrate the efficiency of renewable energy sources;
- Water Purification Projects: students investigated local water samples and tested eco-friendly methods of filtration and purification.

Each project was structured according to the stages of project-based learning: defining the problem, planning, implementing, presenting results, and reflection. Teachers acted as facilitators, guiding students' research, encouraging collaboration, and ensuring that scientific concepts were correctly applied. To evaluate the outcomes, both qualitative and quantitative methods were employed. Observation of student engagement, teamwork, and creativity was combined with questionnaires assessing their ecological awareness, sustainable thinking, and motivation. Additionally, pre- and post-tests were administered to measure improvements in chemistry knowledge. The experimental results showed that students in the project-based group demonstrated higher levels of ecological responsibility, greater motivation, and deeper understanding of chemistry concepts compared to the control group. These findings confirm that ecologically oriented projects are effective in enhancing both subject knowledge and sustainable development thinking [11-16].

RESULTS AND DISCUSSION

The results of the pedagogical experiment demonstrated clear differences between the experimental and control groups in terms of both academic performance and the development of sustainable development thinking. Students who participated in ecologically oriented projects showed higher engagement levels, improved problem-solving skills, and stronger connections between theoretical chemistry concepts and practical ecological issues. Quantitative data collected through pre- and post-tests indicated that the experimental group achieved an average improvement of 18–22% in their chemistry knowledge compared to only 8–10% in the control group. These findings suggest that project-based approaches with ecological orientation not only reinforce subject matter understanding but also make learning more meaningful and long-lasting. Qualitative observations confirmed that students in the experimental group were more motivated and enthusiastic. They demonstrated initiative in designing innovative solutions, such as developing low-cost water filtration models, preparing eco-friendly cleaning products, and proposing recycling strategies for their school. Such activities encouraged critical and creative thinking, as well as teamwork and communication skills. By contrast, students in the control group were more passive, relying heavily on teacher explanations and reproducing knowledge without active application.

The discussion of results also highlights the broader pedagogical impact of ecologically oriented projects. Firstly, they contribute to the integration of sustainability into the school curriculum, aligning with global educational priorities such as the UN Sustainable Development Goals (SDGs)**.** Secondly, they promote interdisciplinary learning by linking chemistry with biology, geography, and environmental science, which strengthens students' holistic understanding of ecological issues. Thirdly, these projects foster environmental responsibility, encouraging students to become active citizens who are capable of addressing real-world problems. Furthermore, the projects demonstrated that when students

are engaged in authentic tasks connected to their environment and community, their motivation and sense of ownership increase significantly. This supports the view that meaningful learning occurs when students perceive direct relevance between classroom activities and their daily lives.

In conclusion, the results validate the effectiveness of project-based learning with ecological orientation in chemistry education. The approach not only enhances academic achievement but also equips students with essential 21st-century skills such as collaboration, creativity, and ecological literacy. These outcomes confirm that integrating ecological projects into chemistry lessons can be a powerful strategy for shaping environmentally conscious and socially responsible future generations.

CONCLUSION

The findings of this study clearly demonstrate that the integration of ecologically oriented projects into chemistry lessons is an effective approach to fostering both subject knowledge and sustainable development thinking among students. Unlike traditional teacher-centered methods, project-based learning creates an interactive and student-centered environment where learners actively engage with real-life ecological challenges. This approach not only enhances students' academic performance in chemistry but also contributes to the development of critical thinking, creativity, problem-solving, and collaboration skills. The results of the pedagogical experiment confirm that students who participated in ecological projects displayed higher motivation, stronger ecological awareness, and a more responsible attitude toward environmental issues. By designing and implementing projects related to waste management, renewable energy, green chemistry, and water purification, learners were able to connect theoretical knowledge with practical applications, thereby making the learning process more meaningful and relevant. Another important outcome of the study is the contribution of ecological projects to interdisciplinary learning. By linking chemistry with biology, geography, and environmental science, such projects provide students with a holistic understanding of sustainability and its global importance. Furthermore, the approach aligns with international educational priorities, particularly the United Nations Sustainable Development Goals (SDGs), emphasizing the role of schools in preparing environmentally responsible citizens.

In conclusion, ecologically oriented projects should be considered a valuable pedagogical strategy for modern chemistry education. They not only improve academic achievement but also play a crucial role in shaping students' ecological literacy and sustainable development mindset. It is recommended that educational institutions and policymakers further integrate project-based ecological activities into the chemistry curriculum to ensure that future generations are better equipped to address complex environmental challenges and contribute to building a sustainable society.

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