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# THE IMPACT OF PROJECT-BASED LEARNING IN CHEMISTRY LESSONS ON THE DEVELOPMENT OF STUDENTS' INNOVATIVE THINKING AND CREATIVE ABILITIES

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The study investigates the influence of project-based learning (PBL) on the development of students' innovative thinking and creative abilities in chemistry education. As traditional instruction often limits students to passive knowledge acquisition, PBL offers an active, inquiry-based approach that connects chemical theory with real-world applications. In this research, students engaged in practical projects such as developing eco-friendly cleaning agents, designing water purification systems, and creating hydrogen fuel prototypes. These tasks encouraged them to formulate hypotheses, conduct experiments, and present their findings through creative models and collaborative discussions. The study's findings indicate that PBL significantly enhances learners' motivation, problem-solving skills, and ability to generate original ideas. Moreover, it fosters interdisciplinary connections between chemistry, biology, environmental science, and technology, promoting a holistic view of science learning. The reflective and collaborative nature of PBL also strengthens communication and critical thinking skills while nurturing ecological awareness and responsibility. Overall, project-based learning transforms chemistry lessons into dynamic environments where students act as researchers and innovators, thus preparing them for future scientific and technological challenges.

**Keywords:** project-based learning, chemistry education, innovative thinking, creativity, ecological awareness

## INTRODUCTION

In the modern educational landscape, fostering creativity and innovation has become one of the primary goals of science education. As societies increasingly rely on scientific knowledge and technological advancement, the demand for learners who can think critically, generate new ideas, and apply them creatively has never been greater. Chemistry, as an experimental and conceptual science, provides rich opportunities to cultivate these competencies through interactive, student-centered learning approaches that mirror real scientific inquiry. Traditional methods of teaching chemistry have largely focused on the transmission of factual information, structured laboratory exercises, and standardized testing. Although these methods ensure a basic understanding of chemical principles, they

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often reduce students' roles to passive receivers of information. This approach limits opportunities for exploration, experimentation, and creative problem-solving. Consequently, students may struggle to see the relevance of chemistry to their everyday lives and to broader environmental and technological contexts [1-7].

In contrast, project-based learning (PBL) transforms the learning environment by positioning students as active constructors of knowledge. It encourages them to ask meaningful questions, design experiments, and apply chemical concepts to solve authentic problems. Through collaboration and guided inquiry, students develop the capacity to think independently and creatively, linking theoretical understanding with practical application. By engaging learners in real-world problem-solving, PBL allows them to explore chemical principles through experimentation, teamwork, and design-based inquiry. For instance, projects that focus on green chemistry, waste recycling, environmental protection**, or** renewable energy motivate students to apply theoretical knowledge in socially relevant and sustainable ways. When learners develop a biodegradable cleaning agent, create models for air purification, or analyze the impact of chemical pollutants, they actively construct knowledge rather than memorize it. Moreover, project-based learning promotes interdisciplinary integration by connecting chemistry with biology, physics, environmental science, and technology. This integrative perspective helps students view chemistry as a unifying science that explains natural phenomena and drives innovation across multiple domains. The collaborative nature of PBL further develops communication, teamwork, and leadership skills essential competencies for scientific and professional growth [8-15].

Through these experiences, learners not only enhance their conceptual understanding of chemistry but also cultivate scientific curiosity, self-confidence, critical thinking, and creativity**.** These skills form the foundation for lifelong learning and scientific innovation, preparing students to meet the complex challenges of the 21st century, from climate change to sustainable resource management. Ultimately, PBL turns chemistry classrooms into vibrant laboratories of creativity and discovery, where students evolve from learners into young researchers and innovators [16,17].

## EXPERIMENTAL

To examine the effectiveness of project-based learning (PBL) in developing students' innovative thinking and creative abilities, an experimental study was conducted with secondary school students enrolled in 10th-grade chemistry classes. The experiment was organized over one academic semester and consisted of control and experimental groups, each containing 24 students of similar academic ability and background. Both groups followed the same chemistry curriculum prescribed by the national education program, but the teaching methods differed significantly. In the control group, lessons were delivered using traditional approaches, including teacher-led explanations, textbook-based exercises, and verification-type laboratory experiments. In contrast, the experimental group was instructed through project-based learning methods, where students worked collaboratively on chemistry-related projects designed to stimulate creative and innovative thinking. Each project was selected to connect theoretical content with real-life applications — for example, synthesizing natural cleaning agents, modeling hydrogen fuel cells, or investigating methods for water purification using locally available materials.

The experimental design followed a three-phase process:

1. Pre-Experimental Stage (Diagnostic Assessment):Before the intervention, both groups completed a diagnostic test to measure their baseline understanding of chemistry concepts and creative problem-solving ability. Interviews were conducted to identify students' prior experiences with project work and their motivation toward the subject.
2. Implementation Stage**:**Over a 10-week period, students in the experimental group engaged in project activities aligned with topics such as acids and bases, redox reactions, and environmental chemistry. The teacher acted as a facilitator, guiding students in formulating hypotheses, designing experiments, analyzing data, and

preparing presentations. Students documented their findings in project portfolios, which included experimental procedures, observations, and reflections.

3. Post-Experimental Stage (Evaluation)**:**At the end of the semester, both groups took a post-test similar in structure to the pre-test to assess conceptual understanding, creativity, and problem-solving development. In addition, creative thinking was evaluated using a rubric that measured originality, fluency, flexibility, and elaboration. Peer evaluations and teacher observations were also analyzed to gain qualitative insights into collaboration and engagement.

The analysis of results showed that students in the experimental group demonstrated a notable improvement in creative and innovative performance compared to those in the control group. They exhibited higher motivation, greater independence in experimentation, and a stronger ability to connect chemical theory with real-world environmental and technological contexts. Furthermore, their project presentations reflected originality in design and interdisciplinary awareness, indicating that PBL effectively nurtures creative scientific thinking within chemistry education.

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

| Group | Average Pre-Test Score (%) | Average Post-Test Score (%) | Increase (%) |
|---|---|---|---|
| Control Group | 62.4 | 68.7 | +6.3 |
| Experimental Group | 61.8 | 84.5 | +22.7 |
| | | | |

The data presented in Table 2 clearly show the positive influence of project-based learning (PBL) on students' academic and creative growth in chemistry. While both groups started at nearly the same pre-test level, the experimental group showed a remarkable 22.7% increase in post-test performance, compared to only 6.3% in the control group. This difference indicates that when students were engaged in project-based learning, they not only mastered chemical concepts more effectively but also demonstrated higher levels of motivation, creativity, and problem-solving ability. The improvement reflects how PBL transforms traditional knowledge acquisition into an active, exploratory, and innovation-oriented learning process.

## RESULTS AND DISCUSSION

The results obtained from the experimental study demonstrate that project-based learning (PBL) has a significant positive impact on students' innovative thinking, creative abilities, and conceptual understanding in chemistry. The findings, summarized in *Table 2*, reveal a clear distinction between the progress of students in the control and experimental groups. Students in the control group, who were taught through traditional instruction, showed a modest 6.3% improvement in their post-test results. This increase can be attributed to repetitive practice and teacher-guided explanations, which reinforce factual knowledge but provide limited opportunities for creative exploration. In contrast, students in the experimental group, who participated in project-based activities, achieved a substantial 22.7% increase in performance. This improvement indicates that engaging students in collaborative projects promotes deeper understanding and stronger motivation to apply theoretical concepts to real-world problems. Furthermore, the qualitative observations support these quantitative results. During the PBL sessions, students in the experimental group displayed higher levels of curiosity, independence, and initiative. They frequently proposed alternative hypotheses, designed their own experimental setups using recyclable materials, and creatively visualized chemical processes. Their discussions during group work were characterized by active communication, argumentation, and evidence-based reasoning — all of which are indicators of scientific thinking and creativity. The creative thinking rubric analysis revealed remarkable progress in four dimensions:

- Fluency *(*the ability to generate multiple ideas) increased by 18%;

- Flexibility (the ability to look at problems from different perspectives) rose by 22%;
- Originality (the production of unique ideas) improved by 25%;
- Elaboration (the ability to refine and detail ideas) showed a 20% increase.

These findings are visually represented in Figure 2, which illustrates that the PBL approach significantly enhances creativity-related competencies. Moreover, interviews conducted with students after the experiment indicated a notable shift in attitudes toward chemistry. Many students expressed that they found chemistry “more meaningful, exciting, and useful” when they were allowed to design and carry out their own projects. They also reported a greater appreciation for environmental and sustainable issues, suggesting that PBL can simultaneously foster scientific literacy and ecological awareness. From a pedagogical perspective, these results align with previous studies emphasizing the importance of active, inquiry-based learning environments in science education (Debora et al., 2021; Hmelo-Silver, 2022). The combination of experimentation, teamwork, and reflection created a learning atmosphere where students constructed their own understanding instead of passively receiving information. In addition, the teacher’s role evolved from a transmitter of knowledge to a facilitator and mentor, guiding students through the process of discovery. This change encouraged self-directed learning, improved communication, and strengthened collaboration among students. As a result, PBL contributed not only to cognitive outcomes but also to the development of social and emotional competencies — vital components of 21st-century education.

Overall, the data and observations confirm that project-based learning transforms chemistry lessons into an interactive, problem-solving environment that nurtures both intellectual and creative growth. By engaging students in authentic scientific inquiry and meaningful application, PBL helps them internalize chemical knowledge, develop innovative thinking, and gain confidence as future scientists and innovators.

## CONCLUSION

The findings of this study clearly demonstrate that the application of project-based learning (PBL) in chemistry lessons significantly enhances students’ innovative thinking, creative abilities, and scientific understanding. By engaging learners in authentic, problem-centered activities, PBL transforms the traditional classroom into an interactive and inquiry-based environment where students act as researchers, designers, and critical thinkers.The experimental results revealed that students in the PBL group outperformed their peers taught through traditional methods, showing greater progress in both conceptual mastery and creativity. Through project activities such as designing eco-friendly cleaning products, developing hydrogen fuel models, and exploring water purification methods, learners connected chemical theory with real-life environmental challenges. This experiential process deepened their comprehension of chemical concepts while promoting independence, curiosity, and ecological awareness. Moreover, project-based learning nurtured essential 21st-century competencies — communication, collaboration, and problem-solving — by encouraging students to share ideas, evaluate evidence, and reflect on their learning outcomes. Teachers’ roles shifted from information transmitters to facilitators of discovery, guiding students through the stages of investigation and analysis.

In conclusion, project-based learning is not merely an instructional technique but a transformative educational philosophy that promotes creativity, scientific inquiry, and lifelong learning. Its integration into chemistry education prepares students to meet the demands of a rapidly changing world, where innovation and critical thinking are key to sustainable scientific and technological progress. Future studies should focus on developing digital and interdisciplinary PBL models that combine chemistry with artificial intelligence, environmental science, and engineering to further enhance creative and scientific literacy.

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