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The Effect of Learning Methods on Student Participation and Achievement in Chemistry Education

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Abstract This study analyzes the role of various instructional methods in enhancing student engagement and academic achievement in chemistry learning. The research employed a qualitative descriptive approach using a literature review design that examined findings from peer-reviewed journal articles, classroom action research, and educational reports. The synthesis of the reviewed studies indicates that student-centered instructional methods, particularly Project-Based Learning (PBL) and collaborative learning, consistently lead to higher levels of participation, conceptual comprehension, and overall learning outcomes. Meanwhile, teacher-centered lecture methods tend to result in lower engagement and weaker retention. The review also shows that combining multiple instructional strategies allows teachers to respond more effectively to differences in learners' needs, characteristics, and learning objectives. The research concludes that blended instructional approaches that integrate project-based, collaborative, and reflective learning activities create more interactive and meaningful chemistry learning environments, while also supporting the development of essential twenty-first-century competencies.

Keywords: Chemistry, Learning activities, Learning methods, Learning outcomes, Student centered learning

INTRODUCTION

Education functions as the primary foundation for developing quality human resources and shaping national progress (Cong, 2025; Sihombing et al., 2024; Wati et al., 2024). Contemporary educational paradigms emphasize that students must be positioned as active participants in the learning process, constructing understanding through inquiry, collaboration, and reflection rather than receiving information passively (Bhardwaj et al., 2025; Aparicio et al., 2024). Achievement in learning is therefore not only determined by the content delivered, but also by the degree to which students are engaged intellectually and socially throughout instruction. However, classroom observations in many schools indicate that instructional practices often remain dominated by traditional teacher-centered methods (Dewi et al., 2025; Rohmah et al., 2025; Sya'adah & Nurlim, 2025; Tambak et al., 2024; Ghafar, 2023). Such practices frequently result in limited student interaction, low motivation, and minimal involvement in knowledge construction.

Chemistry, as a discipline within the natural sciences, requires students to understand abstract concepts related to the properties, structure, and transformation of matter (Byusa et al., 2022; Karch & Sevian, 2022). Many students find chemistry challenging because they struggle to connect theoretical content with real-world experiences (Salame & Makki, 2021; Chans & Portuguez, 2021). When instructional approaches rely primarily on lectures, students may have difficulties developing the conceptual reasoning and problem-solving skills required to master chemical principles. This situation underscores the importance of employing instructional methods that actively involve students in learning processes and foster meaningful engagement.

Student-centered learning approaches encourage learners to explore problems, collaborate with peers, and apply concepts in authentic contexts (Azizah et al., 2024; Kerimbayev et al., 2023; Tang, 2023). Models such as Problem-Based Learning and Project-Based Learning begin with real or simulated situations that require scientific reasoning and inquiry. These approaches allow students to develop independence, communication skills, and creative thinking while deepening their conceptual understanding. Collaborative learning likewise provides opportunities for students to exchange ideas, negotiate meaning, and build shared understanding within group settings, which contributes to stronger motivation and improved learning performance (Qureshi et al., 2023; Troussas et al., 2023).

Choosing the appropriate learning method is therefore a critical component of effective chemistry instruction (Dayal & Ali-Chand, 2022; Musengimana et al., 2021). Teachers must be capable of evaluating student needs, selecting suitable strategies, and applying methods that encourage interaction, experimentation, and reflection. Refining instructional practices contributes directly to improvements in learning outcomes, as teaching effectiveness is closely linked to the quality of student participation (Jowett et al., 2023; Li et al., 2022). Teaching requires thoughtful selection and application of methods that support meaningful learning. This study seeks to examine how different instructional approaches can be optimized to enhance student engagement and achievement in chemistry, while offering practical recommendations for classroom implementation.

METHOD

This study used a qualitative descriptive approach with a literature review (library research) design (Adlini, 2022). The research did not involve direct classroom experimentation; instead, it examined and synthesized findings from previously published studies related to instructional methods in chemistry learning, with particular attention to Project-Based Learning (PBL), collaborative learning, online learning, independent learning, and traditional lectures. The selected sources included peer-reviewed journal articles, conference papers, classroom action research reports, and educational research documents that focused on improving learning outcomes and student engagement in chemistry. The inclusion criteria required that the studies explore the influence of instructional methods on students at the secondary level (SMA/MA/SMK) and report measurable indicators such as average test scores, student participation rates, and mastery of learning objectives. This ensured that the data synthesized reflected practical, evidence-based classroom conditions.

The research procedure began with the identification of the study focus, namely analyzing the role of various instructional methods in enhancing chemistry learning outcomes. Relevant literature was collected systematically through academic databases using keywords including “Project-Based Learning in chemistry,” “collaborative learning in science education”, and “student engagement in chemistry learning”. Each source was then reviewed to evaluate its relevance, clarity of methodology, and completeness of reported data. The selected literature was analyzed to determine how instructional approaches influenced student performance and participation. Particular attention was given to similarities and differences across studies, allowing the researcher to identify consistent patterns, such as the tendency for student-centered learning models to produce higher engagement and achievement.

Data analysis was conducted using descriptive and comparative techniques. Reported learning outcomes, including average test scores, participation levels, and mastery percentages, were compiled to enable comparison across instructional methods.

Quantitative summaries from previous studies were interpreted narratively to illustrate trends. For instance, studies consistently showed that Project-Based Learning and collaborative approaches increased student participation and resulted in higher achievement scores compared to traditional lecture-based instruction. This aligns with the findings of the present review, which showed PBL scoring highest in effectiveness (average score = 90), followed by Group Discussion (85), Online Learning (83), Independent Learning (78), and Lecture Method (70). Inferential statistical testing was not conducted, as the study relied on secondary data that had already been analyzed in the original research contexts. The descriptive approach allowed a clear synthesis of how and why student-centered learning strategies are more effective for chemistry education.

FINDINGS AND DISCUSSION

The results of the analysis indicate that different instructional methods contribute varying effects on students' participation, understanding, and learning achievement. Table 1 illustrates the comparative effectiveness of five learning methods commonly applied in chemistry instruction.

Table 1. Effectiveness of learning methods.

Learning Method	Average score	Participation level (%)	Material Reference
Traditional Lecture Method	70	55	50
Group Discussion (Collaborative)	85	90	80
Independent Learning (Individual)	78	65	70
Project-Based Learning (PBL)	90	95	88
Interactive Online Learning	83	80	75

The data show that Project-Based Learning (PBL) achieved the highest average score (90), followed by Collaborative Group Discussion (85), Interactive Online Learning (83), Independent Learning (78), and the Traditional Lecture Method (70). These results suggest that student-centered instructional approaches generally produce higher levels of engagement and learning outcomes compared to teacher-centered approaches.

This finding aligns with constructivist learning theory, which maintains that learners construct knowledge actively through experience, exploration, and interaction (Wibowo et al., 2025; Al Abri et al., 2024). In PBL and collaborative learning environments, students are encouraged to investigate real-world problems, apply theoretical knowledge, and develop solutions collaboratively. Such processes foster deeper conceptual understanding and develop essential 21st-century skills, including critical thinking, communication, collaboration, and creativity.

Project-Based Learning is particularly advantageous because it integrates inquiry, teamwork, and real-world application (Kovalova, 2025; Omelianenko & Artyukhova, 2024). Students are required to design experiments, analyze findings, and present results, which strengthens both cognitive and procedural competencies. Collaborative learning, which includes group discussions, jigsaw activities, and peer-assisted learning, also supports knowledge construction through social interaction. According to Bandura's social learning theory, students learn effectively by observing and communicating with others, which increases motivation and shared responsibility for learning.

Independent learning provides benefits in terms of self-regulation and autonomy (Pulatovna, 2024; Paethrangsi et al., 2024). However, without adequate guidance, some students may find it difficult to understand complex concepts in chemistry. This suggests that independent learning is most effective when combined with reflective activities or instructional scaffolding.

The Traditional Lecture Method remains less effective in promoting long-term retention because student involvement is limited. Students typically act as passive recipients of information, which can reduce engagement. However, this method can still play a strategic role when introducing new concepts or clarifying key principles that require direct explanation.

Interactive Online Learning shows moderate to high effectiveness, particularly when supported by strong digital literacy and high-quality instructional design. It allows students to learn flexibly through synchronous and asynchronous interaction, though its success depends on the availability of technological resources and the ability of learners to manage online activities effectively (Mansour, 2024; Zeng & Luo, 2024).

Overall, no single method is universally applicable across all learning contexts. Each instructional approach has its strengths and limitations depending on learning objectives, student characteristics, and classroom conditions. A blended learning approach that integrates multiple methods tends to be the most effective. A teacher who can adjust strategies based on student needs, lesson goals, and subject complexity demonstrates pedagogical competence and instructional adaptability.

Therefore, it can be concluded that Project-Based Learning (PBL) and Collaborative Learning are the most effective approaches for enhancing student engagement, knowledge retention, and overall academic performance. Instructional effectiveness is maximized when teachers flexibly combine multiple methods to promote meaningful learning, develop soft skills, and prepare students for success in 21st-century education.

Table 2. Average comparison of the effectiveness of various learning methods.

Learning Method	**Average Effectiveness Score**
Lecture Method	70
Independent Learning	78
Online Learning	83
Group Discussion	85
Project-Based Learning (PBL)	90

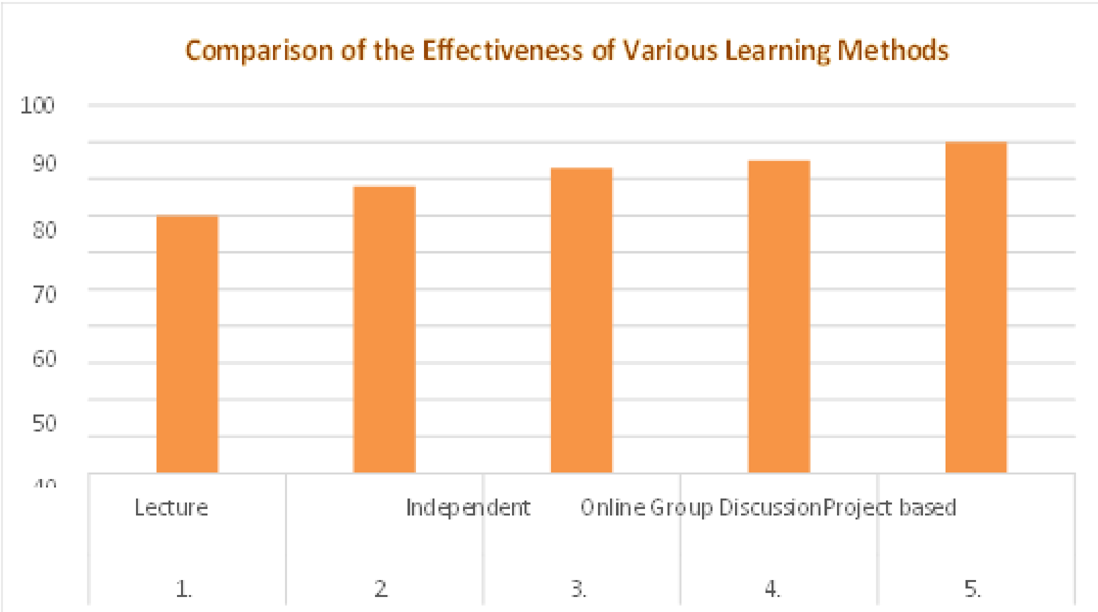

Figure 1. Comparison of the effectiveness of learning methods.

The comparison reinforces that student-centered instructional methods, particularly Project-Based Learning and Group Discussion, yield higher effectiveness scores than traditional lecture-based approaches. These results highlight the importance of active engagement, collaborative problem-solving, and contextual learning experiences in improving student outcomes.

Key indicators of effective learning methods include active student engagement, where in collaborative and project-based learning students are directly involved in experimentation, problem-solving, and discussion rather than passively receiving information. Such approaches lead to improved retention and understanding, as students demonstrate stronger conceptual mastery when they construct knowledge through hands-on activities or peer interaction instead of relying solely on teacher explanations. In addition, the development of soft skills is strongly supported, since strategies such as Project-Based Learning and group discussions foster essential 21st-century competencies, including communication, teamwork, critical thinking, and creativity. Another important indicator is flexibility of implementation, as modern instructional strategies can be adapted to diverse learning needs and integrate digital tools to enhance accessibility and interaction. By integrating these indicators into instructional planning, teachers can create more meaningful and impactful learning environments, further supporting the conclusion that flexible, student-centered learning approaches are most effective for improving engagement and learning outcomes in chemistry education.

CONCLUSION

The findings of this study indicate that no single instructional method is universally effective for all learning situations. Each method carries strengths and limitations that must be considered in relation to classroom context, student characteristics, and learning objectives. Student-centered learning approaches, particularly Project-Based Learning and collaborative learning, demonstrate clear advantages in promoting active participation, improving conceptual understanding, and increasing academic achievement. However, the effectiveness of instruction increases when teachers are able to integrate multiple strategies flexibly.

Effective teaching requires aligning instructional approaches with students' needs. Lectures remain useful for introducing foundational concepts, while group discussions deepen reasoning, and project-based activities enable practical application. Therefore, blended instructional models that combine complementary methods provide a more balanced and responsive framework for chemistry learning. Such integrated approaches move learning beyond the acquisition of knowledge and encourage the development of essential competencies, including critical thinking, communication, and collaboration. These competencies represent core requirements for student success within the demands of modern education.

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