Improving the process of concept acquisition through the use of the project method in chemistry education

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Abstract: *The effective acquisition of scientific concepts is a fundamental objective of chemistry education, as it enables students to understand, interpret, and apply chemical knowledge in both academic and real-life contexts. However, traditional teacher-centered instructional approaches often limit students' active participation in the learning process and may hinder the development of deep conceptual understanding. In this regard, the project method has emerged as an effective pedagogical approach that promotes student-centered learning, problem-solving, collaboration, and practical application of knowledge. This study investigates the role of the project method in improving the process of concept acquisition in chemistry education. The research focuses on the implementation of project-based learning activities designed to engage students in exploring chemical phenomena, conducting investigations, and developing solutions to real-world problems related to chemistry. Through active participation in project work, students are encouraged to connect theoretical concepts with practical experiences, thereby enhancing their conceptual understanding and cognitive engagement. The effectiveness of the project method was evaluated by analyzing students' learning outcomes, conceptual understanding, and participation in project-based activities. Particular attention was given to the development of higher-order thinking skills, independent learning abilities, and the capacity to apply chemical concepts in authentic situations. The findings indicate that the project method contributes significantly to the acquisition of chemical concepts by promoting meaningful learning experiences and increasing students' motivation toward chemistry. The results further demonstrate that project-based learning facilitates the integration of theoretical knowledge with practical applications, enhances collaborative learning, and supports the development of scientific reasoning skills. Students involved in project activities showed improved understanding of key chemical concepts and greater ability to transfer acquired knowledge to new situations. The study confirms that the project method represents an effective instructional strategy for improving concept acquisition in chemistry education. Its implementation contributes to the development of active, motivated, and conceptually competent learners capable of applying chemical knowledge in academic, professional, and everyday contexts.*

Keywords: *chemistry education, project method, project-based learning, concept acquisition, conceptual understanding, active learning, scientific literacy, student-centered learning, chemistry teaching, educational innovation*

INTRODUCTION

The acquisition of scientific concepts constitutes one of the primary objectives of chemistry education. Chemical concepts serve as the foundation for understanding chemical phenomena, interpreting experimental observations, and applying scientific knowledge to solve real-world problems. Effective concept acquisition enables students to develop meaningful learning

experiences, establish connections between theoretical and practical knowledge, and build a coherent understanding of the fundamental principles of chemistry. Consequently, improving the process of concept acquisition remains an important challenge in contemporary chemistry education. Traditional instructional approaches in chemistry have often emphasized the transmission of factual knowledge through lectures and teacher-centered activities. While such methods may facilitate the acquisition of basic information, they frequently fail to promote deep conceptual understanding and active student engagement. Students often memorize chemical facts, formulas, and definitions without fully comprehending the underlying concepts or their practical significance. As a result, many learners experience difficulties in applying acquired knowledge to unfamiliar situations and solving authentic scientific problems.

Recent educational reforms have highlighted the importance of learner-centered instructional strategies that actively involve students in the learning process. Among these approaches, the project method has gained considerable attention due to its potential to promote meaningful learning, critical thinking, collaboration, and independent inquiry. The project method is based on the principle that students learn more effectively when they actively participate in investigating real-world problems, designing solutions, and creating meaningful products related to the subject matter. Project-based learning provides opportunities for students to engage in authentic tasks that require the application of scientific concepts, experimental skills, and analytical reasoning. In chemistry education, project activities may involve the investigation of environmental issues, chemical technologies, sustainable materials, water quality assessment, food chemistry, or laboratory-based research projects. Through such activities, students are encouraged to integrate theoretical knowledge with practical experience, thereby facilitating deeper conceptual understanding and long-term retention of learning outcomes. The theoretical foundations of the project method are closely associated with constructivist learning theory, which views knowledge as actively constructed by learners through interaction with their environment. According to this perspective, students develop conceptual understanding by exploring problems, testing hypotheses, analyzing evidence, and reflecting on their experiences. The project method creates a learning environment that supports these processes and encourages learners to assume an active role in knowledge construction.

Numerous studies have reported positive effects of project-based learning on academic achievement, motivation, problem-solving skills, and scientific literacy. Research findings indicate that students participating in project activities demonstrate higher levels of engagement, improved conceptual understanding, and greater ability to transfer knowledge to practical situations compared with students taught through traditional methods. Furthermore, project-based learning supports the development of twenty-first-century competencies, including communication, collaboration, creativity, and critical thinking. Despite the recognized advantages of the project method, its application in chemistry education remains insufficiently explored in relation to the process of concept acquisition. Many educational studies focus primarily on academic performance, while limited attention has been devoted to understanding how project activities contribute to the formation and development of chemical concepts. Therefore, further investigation is needed to identify effective strategies for integrating project-based learning into chemistry instruction and to evaluate its impact on students' conceptual development. The present study aims to investigate the effectiveness of the project method in improving the process of concept acquisition in chemistry education. Particular attention is given to the role of project-based activities in promoting conceptual understanding, enhancing student engagement, and facilitating the practical application of chemical knowledge. The findings of this research are expected to contribute to the development

of innovative instructional methodologies that support meaningful learning and improve the quality of chemistry education.

MATERIAL AND METHODS

This study employed a quasi-experimental research design to investigate the effectiveness of the project method in improving the acquisition of chemical concepts among students. The research was conducted during the teaching of selected chemistry topics and involved the implementation of project-based learning activities designed to promote active participation, inquiry, collaboration, and practical application of chemical knowledge. The study compared students' conceptual understanding before and after participation in project-based learning activities. The effectiveness of the instructional intervention was evaluated through analysis of students' academic performance, project outcomes, and conceptual development. The participants of the study consisted of undergraduate students enrolled in a chemistry education program at a higher educational institution. A total of 40 students participated in the research and were divided into two groups: an experimental group (n = 20) and a control group (n = 20). Students in the experimental group were taught using the project method, while those in the control group received instruction through conventional teaching approaches. Both groups studied the same chemistry content during the research period.

The project method was implemented through a series of chemistry-related projects focusing on real-life applications of chemical concepts. Students worked individually and in small groups to investigate practical problems, collect information, conduct experiments, analyze results, and present their findings.

Examples of project topics included:

- Investigation of water quality using chemical analysis;
- Development of environmentally friendly household products;
- Study of food additives and their chemical properties;
- Production and characterization of biodegradable materials;
- Investigation of corrosion prevention methods;
- Analysis of environmental pollution caused by chemical substances.

Each project required students to identify a problem, formulate research questions, design an investigation plan, collect and analyze data, and present conclusions supported by scientific evidence. A researcher-developed chemistry concept test consisting of multiple-choice and open-ended questions was administered before and after the instructional intervention. The test was designed to assess students' understanding of fundamental chemical concepts, their ability to explain chemical phenomena, and their capacity to apply knowledge in unfamiliar situations. Students' project performance was evaluated using a structured assessment rubric. The rubric included criteria related to scientific accuracy, problem-solving ability, creativity, data analysis, teamwork, and presentation quality. Classroom observations were conducted throughout the implementation process. An observation checklist was used to evaluate student engagement, participation, collaboration, and application of scientific reasoning during project activities. At the end of the study, students completed a questionnaire designed to collect information regarding their perceptions of project-based learning, learning motivation, and conceptual development. The study was conducted over a period of eight weeks. During the first week, both groups completed a pre-test to determine their initial level of conceptual understanding. The experimental group subsequently participated in project-based learning activities integrated into chemistry instruction. Students worked through the stages of project planning, investigation, experimentation, analysis, and

presentation. The instructor acted as a facilitator, providing guidance and support throughout the learning process.

The control group received instruction using traditional methods, including lectures, textbook-based exercises, and teacher-led discussions. At the conclusion of the intervention, all participants completed a post-test designed to measure changes in conceptual understanding. Quantitative data obtained from the pre-tests, post-tests, project assessments, and questionnaires were analyzed using descriptive statistical methods. Mean scores, percentages, and standard deviations were calculated to evaluate learning outcomes. The effectiveness of the project method was assessed by comparing pre-test and post-test results. Improvements in conceptual understanding were determined by analyzing differences in achievement levels before and after the intervention. Qualitative data obtained from classroom observations and student feedback were analyzed thematically to identify patterns related to student engagement, learning experiences, and conceptual development. Participation in the study was voluntary, and all participants were informed about the purpose and procedures of the research. Confidentiality of student information was maintained throughout the study, and the collected data were used exclusively for academic and research purposes.

RESULTS AND DISCUSSION

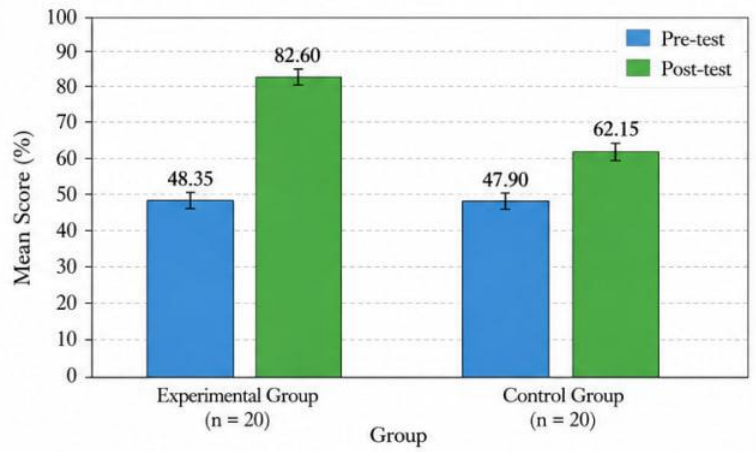

Figure 1. Comparison of pre-test and post-test mean scores between experimental and control groups.

The implementation of the project method had a positive impact on students' acquisition of chemical concepts. Analysis of the pre-test and post-test results revealed a noticeable improvement in students' conceptual understanding after participation in project-based learning activities. Prior to the intervention, many students demonstrated only a superficial understanding of key chemistry concepts and experienced difficulties when applying theoretical knowledge to practical situations. Following the implementation of project activities, students showed significant progress in their ability to explain chemical phenomena, interpret experimental observations, and solve chemistry-related problems. The improvement observed in the post-test results indicates that project-based learning facilitated deeper cognitive processing and more meaningful learning experiences. The increase in academic performance can be attributed to the active involvement of students in project planning, experimentation, data analysis, and presentation of results. Through these activities, learners were required to continuously apply and reinforce chemical concepts in authentic contexts, thereby strengthening conceptual understanding. One of the most important outcomes of the study was the enhancement of students' conceptual understanding of chemistry. During project implementation, students were encouraged to investigate real-life chemical problems, formulate hypotheses, collect evidence, and draw scientifically justified conclusions. Such activities promoted the construction of conceptual knowledge rather than simple memorization of facts.

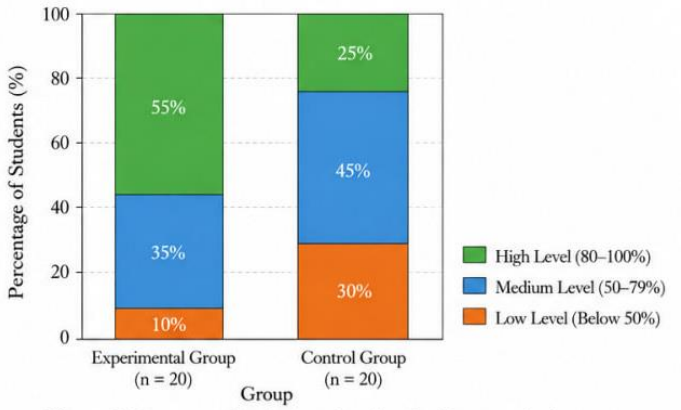

Figure 2. Percentage distribution of students' achievement levels in concept acquisition (post-test results).

Students demonstrated improved understanding of fundamental concepts such as chemical reactions, solution chemistry, environmental chemistry, and material properties. Classroom observations indicated that learners became more capable of identifying relationships between different chemical concepts and explaining scientific phenomena using appropriate chemical terminology. The project method also supported the development of higher-order cognitive skills. Students were required to analyze information, evaluate experimental results, and propose solutions to practical problems, which contributed to deeper conceptual learning. Project-based learning significantly increased student engagement throughout the instructional process. Observation data revealed that students actively participated in discussions, collaborative activities, laboratory investigations, and project presentations. Compared with traditional lessons, project activities generated greater interest and enthusiasm toward chemistry learning. Student feedback indicated that project-based tasks provided opportunities for independent exploration and creative problem-solving. Many participants reported that working on real-world chemistry projects made the subject more meaningful and relevant to everyday life. Increased motivation was reflected in higher levels of classroom participation, greater responsibility for learning, and improved persistence when encountering challenging tasks. The collaborative nature of project work also enhanced communication and teamwork skills. Students learned to share responsibilities, exchange ideas, and collectively solve problems, creating a more interactive and supportive learning environment. A major advantage of the project method was its ability to connect theoretical knowledge with practical applications. Through project activities, students applied chemical concepts to investigate authentic issues such as water quality assessment, environmental pollution, food chemistry, corrosion prevention, and sustainable materials.

The practical orientation of project tasks encouraged students to view chemistry as a useful tool for understanding and solving real-world problems. As a result, learners demonstrated improved ability to transfer acquired knowledge to new situations and to evaluate scientific information critically. The findings suggest that project-based learning contributes not only to conceptual acquisition but also to the development of scientific literacy and functional understanding of chemistry. Comparison of learning outcomes between the experimental and control groups demonstrated the educational effectiveness of the project method. Students who participated in project-based learning activities achieved higher post-test scores and exhibited stronger conceptual understanding than those taught through conventional instructional approaches. The experimental group showed greater improvement in problem-solving tasks, analytical reasoning, and application-oriented questions. These results indicate that project-based learning provides a more effective framework for developing conceptual understanding than traditional teacher-centered methods.b Project activities

encouraged active knowledge construction and facilitated the integration of theoretical concepts with practical experiences. This combination appears to be a key factor contributing to improved learning outcomes.

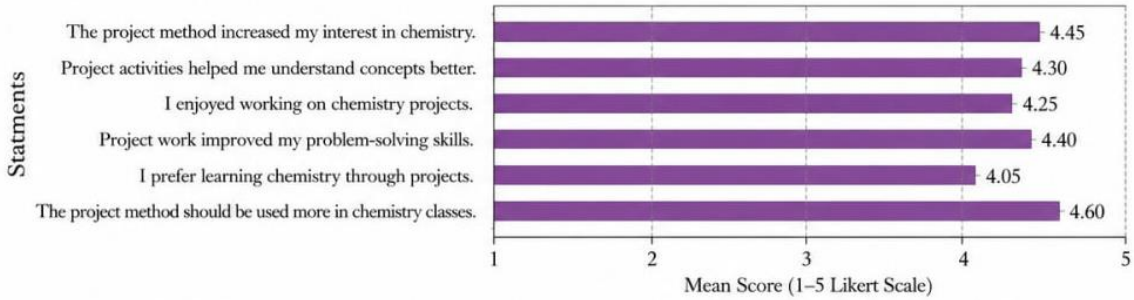

Figure 3. Students' perceptions and motivation toward the project method in chemistry education.

The results of the present study are consistent with contemporary educational theories emphasizing active and student-centered learning. Constructivist perspectives suggest that conceptual understanding develops most effectively when learners actively engage in meaningful tasks and construct knowledge through experience. The project method provides such opportunities by involving students in authentic investigations and collaborative problem-solving activities. The findings also support previous research demonstrating the positive influence of project-based learning on academic achievement, motivation, and conceptual development. By integrating inquiry, experimentation, and practical application, project activities create favorable conditions for meaningful learning and long-term retention of knowledge. The results indicate that the project method is an effective instructional approach for improving the process of concept acquisition in chemistry education. The observed improvements in conceptual understanding, student engagement, motivation, and practical application of knowledge highlight the pedagogical value of project-based learning and its potential contribution to modern chemistry education.

CONCLUSION

The present study demonstrated the effectiveness of the project method as an instructional approach for improving the process of concept acquisition in chemistry education. The findings revealed that the integration of project-based learning activities into chemistry instruction contributes significantly to the development of students' conceptual understanding, active participation, and ability to apply chemical knowledge in practical situations. The implementation of project activities enabled students to engage actively in the learning process through problem identification, investigation, experimentation, data analysis, and presentation of results. Such involvement facilitated meaningful learning experiences and promoted the construction of chemical knowledge rather than simple memorization of facts and definitions. As a result, students developed a deeper understanding of fundamental chemical concepts and demonstrated improved ability to explain chemical phenomena and solve chemistry-related problems.

The study also showed that project-based learning positively influences students' motivation and interest in chemistry. The opportunity to investigate real-world problems and participate in collaborative activities increased learners' engagement and encouraged independent learning. Students became more confident in applying theoretical concepts to practical contexts and exhibited greater responsibility for their own learning outcomes. Furthermore, the project method supported the development of higher-order thinking skills, including critical thinking, analytical reasoning, creativity, communication, and teamwork. These competencies are essential for scientific inquiry and align with the educational requirements of modern competency-based learning systems. The practical orientation of project activities also contributed to the development of scientific literacy

and strengthened the connection between classroom learning and everyday life. Comparative analysis of learning outcomes indicated that students who participated in project-based learning achieved higher levels of conceptual understanding than those taught through conventional instructional methods. The observed improvements confirm that the project method provides favorable conditions for meaningful concept acquisition and long-term retention of chemical knowledge. The results of this research confirm that the project method represents an effective pedagogical strategy for enhancing the acquisition of chemical concepts in chemistry education. Its application promotes student-centered learning, strengthens conceptual understanding, increases learning motivation, and facilitates the practical application of scientific knowledge. Therefore, the integration of project-based learning into chemistry curricula is recommended as an innovative approach for improving the quality and effectiveness of chemistry education.

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