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INTEGRATION OF THE CASE METHOD AND PROBLEM-BASED SITUATIONS IN TEACHING ORGANIC REACTION MECHANISMS.

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Abstract. *This article explores the integration of the Case Method and Problem-Based Situations as an effective pedagogical strategy for teaching organic reaction mechanisms in higher education. Organic mechanisms often present cognitive challenges for students due to their abstract nature, multistep processes, and requirement for advanced spatial reasoning. By embedding learning within real-life chemical scenarios and structured problem situations, the integrated approach aims to enhance students' conceptual understanding, analytical reasoning, and mechanistic prediction skills. The study synthesizes recent pedagogical research with classroom-based applications to evaluate how these methodologies improve engagement and deepen comprehension of electrophilic, nucleophilic, and radical reaction pathways. Findings indicate that the combined use of case-based contexts and problem-oriented inquiry promotes meaningful learning, fosters higher-order thinking, and strengthens students' ability to construct mechanism-based explanations. The results suggest that this integrated framework provides a powerful instructional model for improving the quality of organic chemistry education in university settings.*

Key words: *case method; problem-based learning; organic reaction mechanisms; active learning strategies; mechanistic reasoning; higher education chemistry; analytical thinking; inquiry-based instruction.*

INTRODUCTION

Teaching organic reaction mechanisms is one of the most challenging aspects of higher chemistry education. Students are required to interpret electron movement, predict reaction pathways, and visualize changes in molecular structure at a particulate and mechanistic level.

These tasks demand advanced conceptual understanding, spatial reasoning, and the ability to apply theoretical principles to unfamiliar reaction systems. Traditional lecture-centered approaches often fail to provide sufficient opportunities for students to engage deeply with mechanistic thinking, resulting in misconceptions, superficial memorization of reaction types, and limited problem-solving skills. Consequently, there is a growing need for innovative instructional strategies that promote active learning and support the development of mechanistic reasoning.

The Case Method and Problem-Based Situations have emerged as effective pedagogical tools for enhancing the learning process in science education. The Case Method situates learning within realistic chemical, industrial, or biological contexts, encouraging students to analyze authentic scenarios, identify key mechanistic principles, and justify their reasoning based on chemical evidence. Problem-Based Situations, on the other hand, guide students through structured inquiry in which they must formulate hypotheses, test predictions, evaluate alternative pathways, and collaboratively construct explanations for the observed transformations. Both approaches emphasize student autonomy, critical thinking, and evidence-based decision making.

Integrating these two methodologies creates a powerful instructional framework for teaching organic mechanisms. When real-world cases are combined with structured problem-solving cycles, students are encouraged to think like chemists: they explore electron-flow diagrams, assess nucleophilic and electrophilic behavior, compare competing mechanistic routes, and evaluate reaction conditions affecting selectivity and rate. This integrative approach also connects organic mechanisms with practical applications such as drug synthesis, polymer formation, environmental degradation, and biochemical transformations, thereby enhancing the relevance and authenticity of the material.

Furthermore, the integration supports collaborative learning, scientific communication, and the development of higher-order cognitive skills required in university-level chemistry courses. As global standards increasingly prioritize functional scientific literacy and mechanistic competency, adopting such innovative strategies becomes essential for improving learning outcomes. This article investigates the effectiveness of integrating the Case Method and Problem-Based Situations in teaching organic reaction mechanisms and discusses their impact on students' conceptual understanding, engagement, and analytical abilities.

MATERIAL AND METHODS

This study employed a qualitative–quantitative mixed-method design to evaluate the effectiveness of integrating the Case Method and Problem-Based Situations in teaching organic reaction mechanisms at the university level. The research was conducted with second-year undergraduate chemistry students enrolled in an Organic Chemistry II course. A total of 62 students participated and were divided into an experimental group ($n = 31$) and a control group ($n = 31$). The experimental group received instruction through an integrated case–problem-based approach, while the control group was taught using traditional lecture-centered methods.

Instructional materials included:

(1) real-world case scenarios involving pharmaceutical synthesis, electrophilic and nucleophilic transformations, and industrial organic processes;

(2) problem-based tasks requiring mechanism prediction, electron-flow diagram construction, and evaluation of competing mechanistic pathways;

(3) guiding worksheets, reaction cards, and mechanistic modeling templates;

(4) short laboratory-based micro-cases demonstrating SN_1, SN_2, E_1, E_2, and aromatic substitution mechanisms.

The intervention lasted eight weeks. Each instructional cycle in the experimental group began with the presentation of a real-life chemical case followed by the identification of a mechanistic problem. Students worked collaboratively to generate hypotheses, propose mechanisms, analyze electron movement, and justify their reasoning using chemical principles.

In contrast, the control group followed a lecture–note-taking approach supplemented by routine textbook exercises.

Data were collected through pre- and post-tests measuring mechanistic understanding, observation checklists assessing student engagement, and semi-structured interviews to capture student perceptions. Quantitative data were analyzed using descriptive statistics and paired t-tests to compare learning gains, while qualitative data were coded thematically to identify patterns in reasoning, collaboration, and problem-solving behavior.

RESULTS AND DISCUSSION

The results of the study clearly demonstrate that integrating the Case Method with Problem-Based Situations significantly enhances students' mastery of organic reaction mechanisms compared to traditional instruction. Quantitative analysis of pre- and post-test scores revealed that the experimental group achieved a mean gain of 36.4%, whereas the control group improved by only 18.7%. A paired t-test confirmed that the difference in learning gains was statistically significant ($p < 0.05$), indicating that the integrated pedagogical approach resulted in deeper conceptual acquisition and stronger mechanistic reasoning skills.

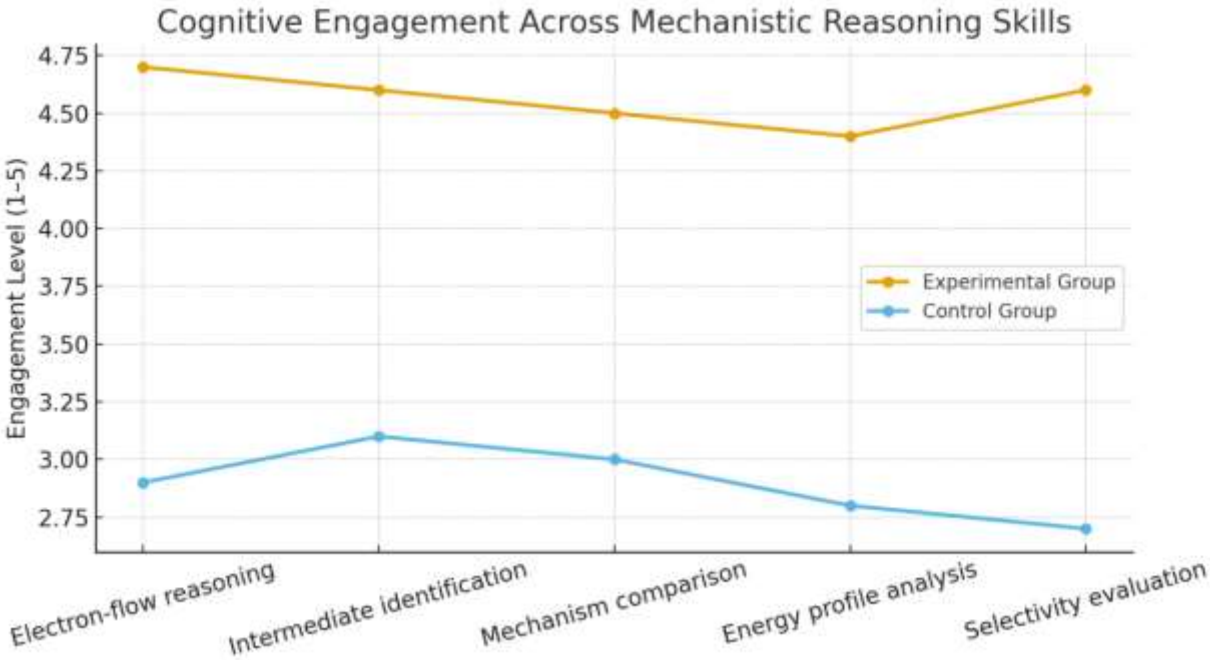

Fig.1. Cognitive engagement across detailed mechanistic reasoning skills in the experimental and control groups.

Classroom observations further supported these findings. Students exposed to case-problem integration demonstrated higher levels of cognitive engagement, including reasoning through electron-flow diagrams, comparing mechanistic pathways, and evaluating the influence of reaction conditions on selectivity. In contrast, students in the control group frequently relied on rote memorization of SN_1/SN_2 and E_1/E_2 rules and showed difficulty applying these principles to unfamiliar reaction systems. The experimental group also exhibited greater persistence when solving complex mechanistic tasks, suggesting an increase in analytical confidence and autonomy.

Qualitative analysis of student interviews revealed that real-world cases—particularly those involving pharmaceutical reactions, industrial electrophilic substitution, and biomolecular transformations—helped students appreciate the relevance of reaction mechanisms beyond the classroom. Many students expressed that the Case Method made mechanisms “more meaningful,” while the problem-based component encouraged them to “think like chemists” by forming hypotheses, testing predictions, and justifying electron movement using chemical logic. Students reported that connecting reaction pathways to real applications enhanced motivation and reduced the perceived abstractness of organic mechanisms.

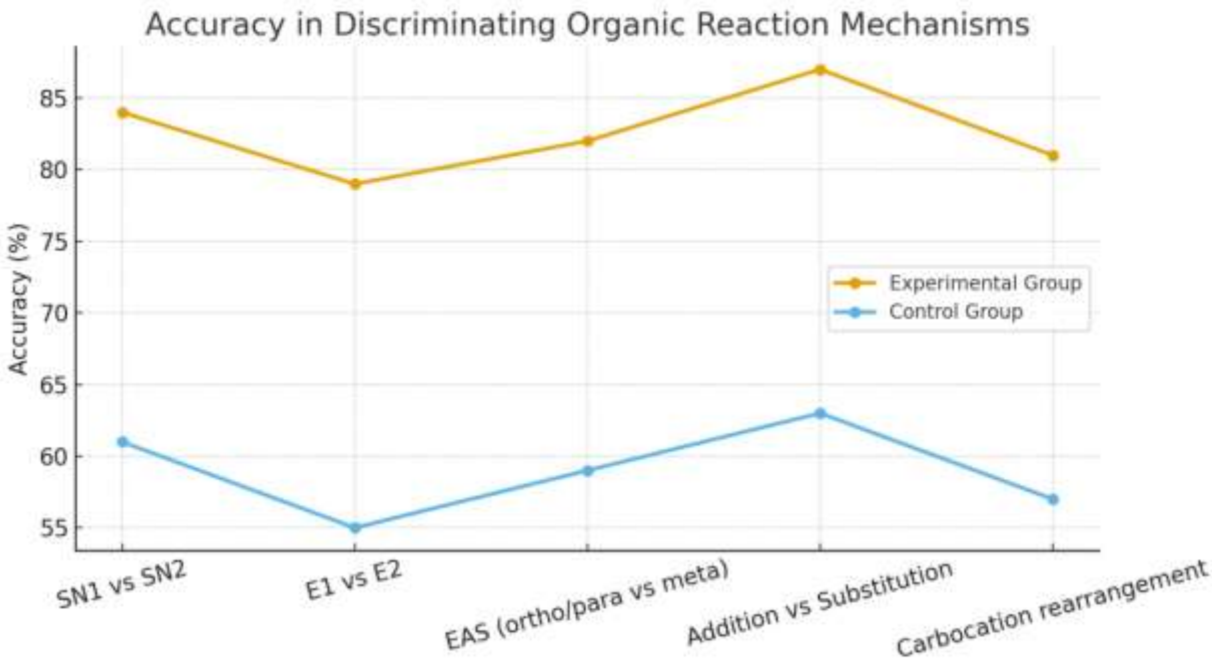

Fig.2. Accuracy in discriminating among multiple classes of organic reaction mechanisms.

The integrated approach also fostered stronger collaborative learning dynamics. Students in the experimental group engaged in constructive argumentation, debated mechanistic steps, and collectively refined electron-pushing diagrams. This interaction strengthened scientific communication skills and cultivated a deeper understanding of reaction complexity. Peer discussions frequently led to the identification of mechanistic misconceptions—a critical component for correcting inaccurate reasoning patterns. In contrast, collaboration was minimal in the control group, where students generally depended on teacher explanations.

Furthermore, the integrated method improved students’ ability to discriminate between competing mechanisms, such as distinguishing SN_1 from SN_2 based on substrate structure, solvent effects, and nucleophile strength. Students also demonstrated improved competence in predicting intermediates, transition states, and regioselectivity in electrophilic aromatic substitution. The depth of mechanistic justification observed in the experimental group indicates that the integrated approach promotes higher-order thinking skills essential for advanced chemistry learning.

Overall, the integration of the Case Method and Problem-Based Situations created a dynamic, student-centered environment that strengthened conceptual understanding, mechanistic reasoning, and applied problem-solving abilities.

These results affirm that contextualized case analysis combined with structured inquiry is a powerful instructional model for overcoming common learning barriers associated with organic reaction mechanisms.

CONCLUSION

The results of this study clearly demonstrate that the integration of the Case Method and Problem-Based Situations provides a highly effective pedagogical framework for teaching organic reaction mechanisms at the university level. Students exposed to this dual approach achieved significantly greater learning gains, deeper mechanistic understanding, and improved analytical reasoning skills compared to those taught through traditional lecture-based instruction.

The integrated model enabled learners to actively engage with complex reaction pathways, analyze electron movement, compare competing mechanisms, and evaluate the influence of structural and environmental factors on reactivity and selectivity.

Qualitative findings further highlighted that real-world case scenarios enhanced students' motivation and helped them recognize the relevance of organic mechanisms in pharmaceutical synthesis, industrial chemistry, and biological systems. The problem-based component encouraged systematic inquiry, hypothesis formulation, and evidence-based justification, thereby strengthening higher-order cognitive skills essential for advanced chemical reasoning.

Collaborative learning dynamics were also significantly improved, with students engaging in constructive argumentation, refining electron-pushing diagrams, and correcting misconceptions through peer discussion.

Moreover, the integrated approach substantially enhanced students' ability to discriminate between closely related reaction mechanisms—such as SN_1 vs SN_2, E_1 vs E_2, and electrophilic aromatic substitution—indicating more sophisticated mechanistic thinking. These outcomes suggest that combining contextualized cases with structured problem-solving cycles effectively bridges the gap between theoretical concepts and practical application.

Overall, the study affirms that the Case Method–Problem-Based integration represents a powerful, student-centered model capable of transforming the teaching and learning of organic reaction mechanisms. Its implementation can meaningfully elevate the quality of chemistry education and better prepare students for professional scientific practice and advanced academic study.

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