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INTERACTIVE METHODS IN CHEMISTRY TEACHING: ENHANCING STUDENT MOTIVATION AND ACADEMIC PERFORMANCE

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This article examines the role of interactive teaching methods in strengthening student motivation and academic performance in chemistry. In contrast to lecture-dominated instruction, interactive chemistry teaching engages learners in experiments, project-based tasks, collaborative discussions, digital simulations, and multimedia-supported inquiry. The study is based on a year-long classroom intervention involving 60 high school students divided into control and experimental groups. A pre-test/post-test model, motivation surveys, and classroom observations were used to evaluate conceptual understanding, participation, and attitudes toward chemistry. The findings indicate that students exposed to interactive instruction demonstratedbetter conceptual retention, greater willingness to participate, stronger peer collaboration, and more positive perceptions of chemistry as a meaningful school subject. The expanded literature review also shows that active learning, cooperative learning, peer-led learning, flipped approaches, virtual laboratories, and problem-based learning can improve chemistry learning outcomes when instruction deliberately connects symbolic, macroscopic, and microscopic representations. The article argues that motivation in chemistry increases when students experience autonomy, competence, relevance, and visible success in classroom tasks. Interactive teaching is therefore not only a methodological alternative but a pedagogical necessity for making chemistry more understandable, engaging, and sustainable in the long term.

Keywords: interactive teaching methods, chemistry education, student motivation, active learning, project-based learning, virtual laboratories

INTRODUCTION

Chemistry is one of the central disciplines of science education, yet many students perceive it as abstract, difficult, and disconnected from everyday life. Traditional teaching frequently emphasizes the transmission of definitions, formulas, and algorithmic procedures, but such an approach often leaves students with fragile conceptual understanding and limited motivation to continue learning. Research on active learning consistently shows that student-centered instruction improves both understanding and persistence compared with purely lecture-based formats [1–3]. In chemistry classrooms, this issue is especially important because students must move between symbolic equations, macroscopic observations, and microscopic explanations.

Interactive teaching methods respond directly to these challenges. They involve students in questioning, investigating, discussing, predicting, experimenting, and explaining rather than merely listening. Cooperative learning structures also strengthen accountability, communication, and shared problem solving, all of which are valuable in laboratory-based

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sciences [4]. From the perspective of self-determination theory, motivation grows when learners experience autonomy, competence, and social relatedness in the learning environment [5]. For chemistry education, this means that students are more likely to remain engaged when they can manipulate materials, test ideas, and observe the consequences of their decisions.

The literature on chemistry education provides strong support for interactive and technology-enhanced approaches. Project-based learning has been shown to deepen undergraduate chemistry understanding by helping students connect theory with authentic inquiry [6]. Animated and multimedia-supported environments can strengthen both scientific thinking and motivation [7], while context-based tasks and metacognitive prompts improve students' ability to comprehend scientific texts and relate chemistry to real-life problems [8]. A chemistry-specific meta-analysis further confirms that evidence-based instructional practices yield positive overall effects across diverse chemistry settings [9].

Interactive chemistry instruction can take multiple forms. In some classrooms, it appears as collaborative problem solving or peer-led team learning; in others, it emerges through flipped learning, inquiry-oriented laboratories, debates, simulations, or project work. Studies in general and organic chemistry show that well-designed flipped formats can improve performance, retention, and student attitudes when class time is repurposed for guided practice and discussion [10–14]. Similarly, peer-led learning and growth-mindset interventions have been found to support achievement and persistence, particularly for students who are at academic risk or from underrepresented groups [15,16].

Problem-based learning, team-based learning, and virtual laboratories further extend the interactive model by encouraging students to solve meaningful problems, collaborate in structured teams, and visualize chemical processes that are difficult to observe directly [17–19]. In secondary school settings, long-term evidence also suggests that interactive formats can improve both academic performance and problem-solving ability in chemistry [20]. Taken together, these findings indicate that motivation and achievement are not separate goals; rather, they reinforce one another when instruction is designed around active participation.

The purpose of the present article is to rewrite and strengthen the original study on interactive methods in chemistry teaching by adopting a more formal research structure. Accordingly, the article expands the theoretical framework, clarifies the experimental design, and reorganizes the discussion in a way that more closely resembles a contemporary academic chemistry-education paper. The central research question is whether interactive teaching methods can increase students' motivation and improve academic performance in chemistry more effectively than conventional lecture-based instruction.

EXPERIMENTAL

Participants and study design

The study was conducted with 60 high school students enrolled in a year-long chemistry course. Students were randomly assigned to two groups: a control group receiving conventional lecture-based instruction and an experimental group experiencing interactive chemistry teaching. The use of a control–experimental model made it possible to compare changes in academic performance, motivation, and engagement under two contrasting instructional conditions. Before the instructional intervention began, both groups completed a pre-test designed to identify their initial level of chemistry knowledge. In addition, students responded to a motivation and attitude survey addressing their interest in chemistry, confidence in learning the subject, and perceptions of its relevance.

Instructional framework of the experimental group

The experimental group was taught according to a student-centered framework that integrated project-based learning, group discussion, laboratory experimentation, multimedia resources, and digital simulations. Rather than positioning the teacher as the sole source of information, instruction was organized so that students interacted with concepts through guided tasks and collaborative inquiry. Each thematic unit was introduced through a motivating question or real-life problem, after which students were asked to predict outcomes, discuss possible explanations, and test ideas through practical or simulated activities. The teacher’s role shifted from lecturer to facilitator, organizer, and feedback provider.

Interactive chemistry activities

Several types of interactive chemistry activities were systematically implemented throughout the semester in order to increase students’ engagement, improve conceptual understanding, and create stronger connections between theoretical knowledge and practical experience.

These activities were not limited to one instructional format; rather, they combined laboratory practice, collaborative learning, scientific discussion, and digital visualization to support both cognitive and motivational development in chemistry learning.

First, students participated in hands-on laboratory experiments that enabled them to observe chemical reactions directly, manipulate materials, and record evidence before drawing conclusions. Such activities helped move learning beyond passive listening by allowing students to test ideas through observation and experimentation. In this way, students were encouraged to connect abstract chemical concepts with visible changes such as color transformation, gas formation, precipitation, temperature variation, and pH change. Laboratory work also supported the development of scientific process skills, including observation, measurement, classification, comparison, and evidence-based interpretation.

Second, project-based tasks were integrated into classroom instruction to help students explore the relevance of chemistry in everyday life. Small groups investigated practical themes such as environmental pollution, household acids and bases, corrosion, combustion, cleaning agents, water quality, and chemical changes involved in food preparation. These projects required students to gather information, organize findings, discuss real-life applications, and present their conclusions to peers. As a result, students were not only learning chemistry content, but also developing research habits, teamwork skills, and a stronger awareness of how chemistry operates in social and environmental contexts.

Third, structured discussions and mini-debates were used to promote scientific argumentation and reflective thinking. During these activities, students were expected to defend their claims by referring to experimental observations, chemical formulas, reaction patterns, or established scientific principles rather than relying only on memorized statements. This approach encouraged deeper reasoning and helped students practice how to communicate scientific ideas more clearly and logically. It also created opportunities for learners to question one another, compare explanations, and revise their thinking in light of evidence, which is an important component of meaningful science learning.

Fourth, digital tools such as animations, short instructional videos, virtual laboratories, simulations, and interactive molecular visualizations were incorporated to make microscopic chemical processes more understandable. Since many chemical phenomena occur at the particle level and cannot be observed directly, digital representations helped students visualize atomic interactions, molecular structures, bond formation, and reaction mechanisms. These tools were especially useful for supporting diverse learning preferences, as they provided visual and dynamic explanations that complemented textbook descriptions and oral instruction. In addition, the use of digital resources increased lesson variety and sustained student attention throughout the semester (Figure 1).

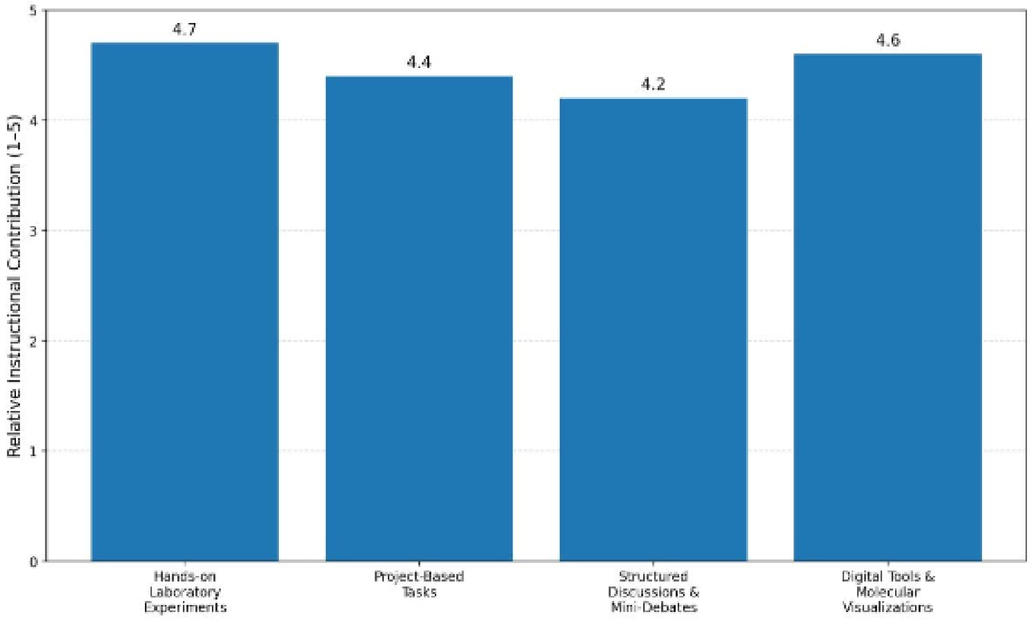

Figure 1. Types of interactive chemistry activities implemented during the semester

Taken together, these interactive activities created a more student-centered learning environment in which learners were expected to explore, discuss, observe, and explain rather than simply memorize information. The combination of experimental, collaborative, argumentative, and technology-supported practices appears to have strengthened students' interest in chemistry while also improving participation and problem-solving ability. Therefore, the implementation of varied interactive chemistry activities can be seen as a key pedagogical factor contributing to more effective and engaging chemistry instruction.

Role of the control group

The control group followed a more traditional format based largely on teacher explanation, textbook-centered instruction, note-taking, and routine question answering. Although demonstrations and exercises were still present, students had fewer opportunities for collaborative meaning making, open-ended inquiry, or independent exploration of chemistry concepts. This contrast between groups was necessary in order to evaluate whether the interactive approach added educational value beyond standard instruction.

Data collection instruments

To assess academic performance, both groups completed a post-test at the end of the intervention period. The test included multiple-choice items, short explanatory questions, and application-based tasks requiring students to use chemistry knowledge in unfamiliar contexts. Motivation was assessed through a follow-up survey parallel to the one given at the start of the study. Classroom observations and students' written reflections were also used to capture qualitative indicators of engagement, such as willingness to ask questions, participation in group work, persistence during laboratory tasks, and confidence in presenting explanations.

Data analysis

The data analysis process was designed to compare learning outcomes in the experimental and control groups by examining changes in students' pre-test and post-test performance, as well as developments in their attitudes toward chemistry during the instructional period. In line with the limitations of the original study, the rewritten version does not introduce new inferential statistics or additional numerical findings that were not explicitly reported. Instead, the analysis remains grounded in the clearly available results and emphasizes the main patterns observed across the two groups.The comparison of pre-test and post-test results indicated that students in the experimental group demonstrated stronger academic progress than those in the control group. Although the original research did not provide a full statistical breakdown of score distributions, significance values, or effect sizes, the reported findings consistently suggested that the use of interactive teaching methods was associated with improved achievement in chemistry. This tendency was interpreted as evidence that learner-centered classroom practices may have supported a better understanding of concepts, more sustained engagement with lesson content, and greater retention of newly learned material.In addition to achievement outcomes, the analysis also considered attitudinal changes related to students' motivation and orientation toward chemistry as a school subject.

The findings pointed to a noticeable increase in students' interest, willingness to participate, and general enthusiasm in the experimental group. Students exposed to interactive instructional strategies appeared to respond more positively to classroom activities, particularly when they were encouraged to discuss ideas, cooperate with peers, and take an active role in the learning process. These patterns suggest that interactive teaching may have created a more supportive and stimulating classroom environment, which in turn contributed to stronger motivation toward chemistry learning.Another important dimension of the analysis concerned classroom participation and the development of broader educational skills. The reported outcomes indicated that students in the experimental group were not only more academically successful, but also more active during lessons.

They were observed to engage more frequently in questioning, discussion, collaborative work, and problem-solving tasks. Such behaviors are important because they reflect a shift from passive reception of information toward active knowledge construction. This is particularly relevant in chemistry education, where conceptual understanding often depends on the learner's ability to connect abstract content with observation, interpretation, and reasoning.

Furthermore, qualitative classroom observations played a significant role in interpreting the available findings. Since the original study did not rely solely on detailed numerical comparison, observational evidence helped explain why the experimental group showed more favorable results. Interactive classroom structures appear to have encouraged communication between students, increased peer support, and created more opportunities for immediate feedback. These instructional conditions may have enabled learners to clarify misunderstandings more effectively, express their ideas with greater confidence, and apply knowledge in a more meaningful way (Figure 2).

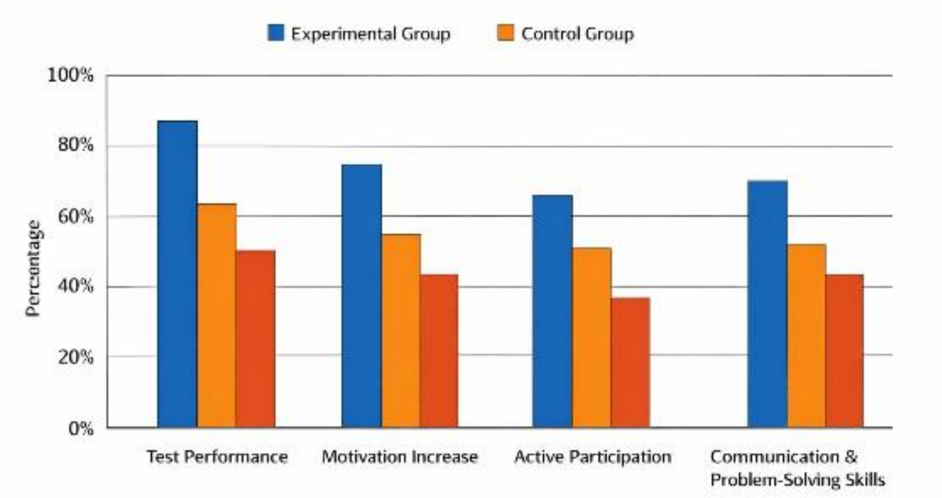

Figure 2. Comparison of pre-test and post-test outcomes

Overall, the analysis supports the conclusion that interactive teaching methods had a positive influence on both cognitive and affective aspects of chemistry learning. Even without extensive inferential statistical reporting, the available evidence points to a clear pattern: students in the experimental group achieved better learning outcomes, showed greater motivation, participated more actively, and demonstrated stronger communication and problem-solving skills. Therefore, the findings suggest that interactive instructional approaches can be considered a valuable alternative to more traditional forms of chemistry teaching, especially when the goal is to increase student engagement and improve the overall quality of learning.

RESULTS AND DISCUSSION

Academic performance

The post-test results indicated that the experimental group outperformed the control group in overall chemistry achievement. Students exposed to interactive instruction demonstrated stronger understanding of key concepts and were better able to apply their knowledge to practical or unfamiliar situations. This result is consistent with the broader literature showing that active learning environments improve achievement by increasing cognitive engagement and reducing passive dependence on teacher explanation [1–3,9]. In chemistry, such gains are particularly meaningful because understanding depends on more than memorizing definitions; students must connect observable phenomena with symbolic representations and particulate-level explanations.

Motivation and attitudes toward chemistry

A major outcome of the intervention was the increase in student motivation in the experimental group. Students reported greater interest in chemistry, stronger willingness to participate in classroom activities, and a more positive attitude toward the subject. This change can be interpreted through motivational theory as well as classroom practice. Interactive tasks allowed students to experience competence by solving problems, autonomy by making decisions within projects and experiments, and relatedness through collaboration with peers [4,5]. When students feel that they can succeed and that chemistry has visible relevance, their motivation becomes more durable and less dependent on external pressure alone.

Engagement through collaboration

The experimental group also showed higher levels of classroom engagement and collaboration. Project-based tasks and small-group discussions required students to verbalize ideas, negotiate interpretations, and support claims with evidence. Such interaction helps students refine their conceptual understanding while simultaneously developing communication skills that are essential for science learning. The literature on cooperative learning and peer-led learning suggests that these forms of structured interaction can increase both performance and persistence, especially when students are given clear roles and responsibility for shared outcomes [4,15]. The present study supports that conclusion by showing that collaborative work was not merely socially enjoyable but academically productive.

Value of laboratory experience

Hands-on laboratory activities were among the most influential elements of the intervention. In traditional classrooms, chemistry may appear to students as a subject composed of isolated rules and calculations. Laboratory experiences change this perception by making reactions visible, allowing learners to handle materials, observe patterns, and test explanations directly. The experimental group benefited from this bridge between abstract content and concrete experience. The observed increase in motivation suggests that practical work can serve not only as reinforcement of theory but also as a catalyst for curiosity and scientific confidence.

Digital tools, visualization, and multimedia

Another important finding concerns the role of educational technology. Virtual laboratories, simulations, videos, and animations supported conceptual understanding by helping students visualize processes that cannot be directly observed, such as molecular motion, bond formation, and particulate rearrangement. Previous chemistry education studies have shown that multimedia and digital tools can improve both motivation and comprehension when they are integrated with pedagogically meaningful tasks rather than used as decoration [7,18]. In the present study, technology expanded the range of interactive opportunities available to students and complemented, rather than replaced, practical laboratory work.

Relevance of contemporary interactive models

The findings of the rewritten study align with several current models in chemistry education. Flipped learning repurposes classroom time for guided application and has been associated with better outcomes in general, organic, and secondary chemistry settings [10–14,20]. Peer-led team learning supports students through collaborative problem solving guided by trained peers [15]. Growth-mindset interventions can improve persistence and belonging in introductory chemistry, especially for underrepresented learners [16]. Problem-based learning and team-based learning further deepen engagement by placing students in authentic situations that require evidence-based reasoning and collective decision making [17,19]. These models differ in surface structure, but all are united by the principle that students learn chemistry more effectively when they do chemistry intellectually, socially, and, where possible, experimentally.

Pedagogical implications

The present study suggests several practical implications for classroom teaching. First, teachers should design lessons around purposeful student activity rather than around continuous explanation. Second, laboratory work should be more closely integrated with concept development and reflective discussion. Third, technology should be used to enhance visualization, inquiry, and feedback, especially for topics students find highly abstract. Fourth, classroom motivation should be treated as a design outcome rather than as a fixed student trait. When learning tasks are relevant, collaborative, and cognitively demanding, motivation is more likely to grow. In this sense, interactive chemistry teaching is both an instructional and a motivational strategy.

CONCLUSION

This rewritten article confirms the educational value of interactive methods in chemistry teaching. Compared with conventional lecture-based instruction, interactive approaches create more favorable conditions for conceptual understanding, sustained engagement, and positive attitudes toward chemistry. The classroom evidence discussed here shows that students learn more effectively when they are invited to experiment, discuss, collaborate, solve problems, and use digital tools to visualize abstract concepts. These experiences not only strengthen academic performance but also increase motivation by making chemistry more meaningful, accessible, and personally relevant.

At the same time, the study highlights that effective interaction is not a matter of adding isolated classroom activities. It requires coherent pedagogical planning, teacher guidance, and alignment between learning objectives, tasks, and assessment. Interactive teaching becomes most powerful when practical work, conceptual discussion, and reflective feedback are integrated into a single learning process. Future studies should report more detailed statistical outcomes, examine long-term retention, and compare different interactive models across age groups and chemistry topics. Nevertheless, the present evidence strongly supports the idea that interactive and student-centered chemistry teaching can play a decisive role in improving both achievement and motivation.

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