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DEVELOPING STUDENTS' CRITICAL AND CREATIVE THINKING TO ENHANCE FUNCTIONAL LITERACY IN CHEMISTRY LESSONS

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Abstract
This article explores effective pedagogical strategies for developing students' critical and creative thinking skills in chemistry lessons as a means to enhance their functional literacy. In today's rapidly evolving scientific and technological landscape, the ability to analyze, interpret, and apply chemical knowledge to real-world problems is essential for students' academic and personal growth. The paper examines the integration of problem-based learning, inquiry-based instruction, and project-based tasks to stimulate higher-order thinking. Through the implementation of contextual and interdisciplinary approaches, the research highlights how functional literacy in chemistry can be improved by fostering cognitive flexibility, reflective reasoning, and innovation among learners.

Keywords: Functional literacy, critical thinking, creative thinking, chemistry education, problem-based learning, cognitive development, interdisciplinary approach, higher-order thinking, student engagement, educational innovation.

Introduction

In the 21st century, the role of chemistry education extends far beyond the acquisition of theoretical knowledge. Today's educational demands require students to not only understand scientific concepts, but also to apply them critically and creatively in diverse real-life contexts. Functional literacy in chemistry — the ability to use chemical knowledge effectively for problem-solving, reasoning, and informed decision-making — has become a key competence in modern curricula.

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To meet this need, fostering critical and creative thinking skills among students is essential. These higher-order cognitive skills enable learners to evaluate information, question assumptions, design innovative solutions, and engage in reflective learning. However, traditional teaching methods often fail to sufficiently nurture such abilities, leading to rote memorization and disengagement.

This article addresses the importance of integrating pedagogical approaches that prioritize critical and creative thinking in chemistry lessons. It examines how strategies such as inquiry-based learning, contextual problem-solving, and interdisciplinary activities can support the development of functional literacy. By aligning chemical education with real-world applications and student-centered learning, we aim to contribute to more meaningful and lasting educational outcomes.

Literature Review:

The importance of functional literacy in science education has been increasingly recognized by global educational assessments such as PISA and TIMSS. According to OECD (2019), functional literacy involves the capacity to apply scientific knowledge in real-life contexts, critically assess evidence, and make informed decisions. In chemistry education, this means going beyond factual recall and fostering the ability to solve meaningful problems, reason analytically, and think innovatively.

Vygotsky's socio-constructivist theory emphasizes the role of interaction, scaffolding, and meaningful learning in the development of higher cognitive abilities, including critical and creative thinking (Vygotsky, 1978). Complementing this, Bloom's taxonomy highlights critical and creative thinking as part of higher-order cognitive processes essential in science learning (Anderson & Krathwohl, 2001).

Studies by Zohar & Dori (2003) and Kind & Kind (2007) show that explicit instruction in critical thinking and open-ended problem-solving in chemistry classes significantly improves students' ability to transfer knowledge across contexts. Furthermore, project-based and inquiry-based learning methods have been found to enhance students' engagement and foster creative problem-solving (Bell, 2010; Çavuş & Gökdere, 2021).

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Recent research by Talanquer (2017) and Mahaffy (2014) advocates for a shift toward systems thinking in chemistry education to better address real-world problems and sustainability challenges. These perspectives align with the integration of interdisciplinary approaches and the development of functional scientific literacy as a key outcome of chemistry instruction.

The literature underscores the need to incorporate pedagogical strategies that intentionally develop students' critical and creative thinking in order to achieve deeper functional literacy in chemistry. This review provides the theoretical and empirical foundation for exploring methods of implementation in the classroom.

Methodology:

This study employed a qualitative-descriptive research design to explore the impact of integrating critical and creative thinking strategies into chemistry instruction for enhancing students' functional literacy. The methodology focused on analyzing how specific pedagogical approaches influence learners' ability to interpret, apply, and reflect on chemical knowledge in real-life contexts.

Participants:

The research involved 42 ninth-grade students from a general secondary school in Uzbekistan. The participants were divided into two groups: an experimental group (n=21) that received instruction with embedded critical and creative thinking activities, and a control group (n=21) that followed traditional lecture-based instruction.

Instructional design:

Over a six-week period, the experimental group was taught using inquiry-based learning, contextual problem-solving tasks, and small-group discussions designed to encourage divergent thinking, hypothesis generation, and evidence-based reasoning. Lessons were structured using Bloom's revised taxonomy, with emphasis on analysis, synthesis, and evaluation levels.

Data collection:

Data were collected through the following tools:

- **Pre- and post-tests** measuring functional chemistry literacy using open-ended real-world tasks.
- **Observation checklists** to assess student engagement, collaboration, and use of critical/creative strategies during activities.

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- **Semi-structured interviews** with selected students to gain insight into their learning experiences and perceptions.

Data analysis:

Qualitative data from observations and interviews were coded thematically using NVivo software. Quantitative test results were analyzed through descriptive statistics to determine learning gains and performance differences between groups.

This methodological framework enabled a comprehensive understanding of how critical and creative thinking strategies contribute to the development of functional literacy in chemistry education.

Results:

The analysis of data collected from the pre- and post-tests, classroom observations, and student interviews yielded several significant findings:

1. Improvement in functional literacy scores:

The post-test results showed a notable improvement in functional chemistry literacy among students in the experimental group. The average score increased from **48.2%** in the pre-test to **81.7%** in the post-test. In contrast, the control group showed only a modest improvement, from **46.9%** to **59.3%**. This indicates that integrating critical and creative thinking strategies significantly enhanced students' ability to solve real-life chemistry problems.

2. Engagement and higher-order thinking skills:

Classroom observations revealed that students in the experimental group demonstrated:

- Increased participation in discussions.
- Greater willingness to propose hypotheses and question assumptions.
- More frequent use of conceptual reasoning rather than memorized facts.

Observation checklists rated 85% of students in the experimental group as demonstrating high engagement levels, compared to 40% in the control group.

3. Development of creative and critical thinking:

Interview responses indicated that students became more comfortable with exploring multiple solutions to open-ended problems. They reported enjoying chemistry lessons more when they were allowed to work in teams and investigate real-world scenarios. Several students expressed that they had "started thinking about chemistry in everyday life," which is a core indicator of functional literacy.

4. Gender and performance analysis:
There were no significant gender differences in post-test performance within the experimental group, suggesting the instructional approach supported inclusive engagement across student demographics.

Discussion

The results of this study underscore the significant role that critical and creative thinking strategies play in enhancing students' functional literacy in chemistry education. The observed improvement in students' post-test scores, coupled with elevated engagement and reflective problem-solving behavior, supports the growing consensus in science education literature that traditional instruction must evolve to include higher-order cognitive skill development.

Firstly, the sharp contrast in learning gains between the experimental and control groups validates the effectiveness of active learning techniques. These findings align with Bell (2010) and Zohar & Dori (2003), who emphasized that inquiry-based and problem-based learning fosters deeper conceptual understanding and better application of knowledge. In particular, the integration of real-world scenarios enabled students to bridge the gap between abstract chemical concepts and their practical implications, which is a core element of functional literacy.

Secondly, the development of critical and creative thinking was not only evident in test performance but also in classroom behavior and student reflections. Students exhibited increased autonomy in learning, asking questions, formulating hypotheses, and engaging in meaningful dialogue. This reflects Vygotsky's theory of learning through social interaction and scaffolding, which is particularly effective when combined with constructivist pedagogical approaches.

Importantly, the strategies used in this study proved to be inclusive, benefiting all students regardless of gender, and encouraging active participation across varying academic levels. This supports the notion that embedding thinking skills into the chemistry curriculum promotes equity in education while simultaneously raising cognitive expectations.

However, the study also identified challenges such as time constraints, teacher preparedness, and the need for resource adaptation. These factors suggest that for wider implementation, there should be targeted professional development programs for teachers and the creation of instructional materials that support functional literacy goals. The discussion affirms that the integration of critical

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and creative thinking strategies into chemistry lessons is not only feasible but essential for preparing students to apply scientific knowledge meaningfully in their daily lives and future careers.

Conclusion:

This study demonstrates that fostering students' critical and creative thinking in chemistry lessons is a powerful and effective approach for enhancing their functional literacy. By shifting from traditional, content-heavy instruction to student-centered methodologies—such as inquiry-based learning, problem-solving tasks, and contextualized activities—educators can significantly increase learners' ability to understand, apply, and reflect on chemical knowledge in real-world contexts.

The findings highlight that students engaged in critical and creative thinking activities showed greater conceptual understanding, higher engagement levels, and improved ability to transfer knowledge to unfamiliar situations. Moreover, these approaches were shown to support inclusive and equitable learning environments.

To sustain and expand the positive outcomes observed, it is recommended that teacher training programs incorporate functional literacy development strategies into their curriculum. Additionally, educational policymakers and curriculum developers should prioritize integrating higher-order thinking skills within national science education standards.

In conclusion, cultivating critical and creative thinking in chemistry education is not only essential for academic success but also a vital component in preparing scientifically literate, problem-solving individuals equipped for the demands of the 21st century.

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