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DEVELOPING GLOBAL COMPETENCIES IN CHEMISTRY EDUCATION AND LINKING THEM TO FUNCTIONAL SCIENTIFIC LITERACY

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Abstract
This article explores the integration of global competencies into chemistry education and their connection to the development of functional scientific literacy. In today's interconnected world, chemistry teaching must go beyond content delivery to equip learners with skills such as critical thinking, problem-solving, intercultural communication, and responsible decision-making. The study highlights how incorporating real-world problems, interdisciplinary contexts, and inquiry-based learning can foster global competencies in the chemistry classroom. By aligning chemistry curricula with international frameworks such as PISA and UNESCO's global competence model, the article presents pedagogical strategies that help students apply scientific knowledge functionally in social, environmental, and technological contexts. The findings suggest that a global and competency-based approach to chemistry education enhances not only students' subject mastery but also their readiness to address complex global challenges.

Keywords: Global competencies, chemistry education, functional scientific literacy, competency-based learning, PISA, interdisciplinary approach, inquiry-based teaching, 21st-century skills, science curriculum, educational innovation.

Introduction

In the era of globalization and rapid scientific advancement, chemistry education faces the challenge of preparing students not only with disciplinary knowledge but also with the competencies needed to function effectively in a complex, interconnected world. These competencies—collectively known as global competencies—include critical thinking, intercultural communication, collaborative problem-solving, and ethical decision-making. Increasingly, educators and policymakers are recognizing the importance of embedding such skills into subject-specific instruction, including the teaching of chemistry.

Functional scientific literacy, on the other hand, refers to the ability to apply scientific knowledge meaningfully in real-world contexts. It emphasizes the transfer of learning from academic settings to everyday life, enabling individuals to make informed decisions on personal, environmental, and societal issues involving science. Bridging global competencies with functional literacy in the context of chemistry offers a powerful framework for 21st-century education.

This article investigates how chemistry education can be restructured to foster global competencies while simultaneously enhancing students' functional scientific literacy. Drawing on international education frameworks such as PISA and UNESCO's global competence model, the study explores effective pedagogical strategies—including interdisciplinary learning, inquiry-based tasks, and context-rich problem-solving—to align chemistry instruction with global educational priorities. The aim is to provide educators with practical tools and theoretical insights to cultivate globally competent and scientifically literate learners.

Literature review

The shift towards competency-based education in the sciences reflects a broader movement to prepare students for global challenges by equipping them with transferable skills and contextual understanding. Global competencies, as defined by the OECD and UNESCO, encompass the ability to examine local, global, and intercultural issues; understand and appreciate diverse perspectives; engage in open, appropriate, and effective interactions across cultures; and take responsible action toward sustainability and well-being (OECD, 2018).

Scientific literacy, particularly its functional dimension, is also evolving in parallel. According to Bybee (1997), functional scientific literacy involves the application of science to real-life decisions and problem-solving. More recent frameworks such as PISA 2018 emphasize the role of students as "engaged citizens," capable of applying scientific reasoning in diverse social and environmental contexts (OECD, 2019). This convergence highlights the need for science education, including chemistry, to foster both disciplinary understanding and practical competence.

In the context of chemistry education, traditional curricula have often prioritized theoretical content and algorithmic problem-solving, with limited attention to societal relevance or global perspectives (Taber, 2002). However, studies by Gilbert (2006) and King (2012) suggest that context-based chemistry instruction, which incorporates real-world applications and interdisciplinary themes, can enhance both engagement and the development of functional literacy.

Furthermore, inquiry-based and project-based learning approaches have been widely recognized as effective methods for developing global competencies in science classrooms. For instance, Scardamalia and Bereiter (2006) argue that knowledge-building communities in the classroom can support collaborative problem-solving and reflective thinking—skills essential to global competence. Similarly, Sadler (2011) shows that socioscientific issues (SSI) used in chemistry education improve students' ethical reasoning and decision-making abilities, aligning with the goals of functional scientific literacy.

Despite growing recognition, the integration of global competencies into chemistry education remains uneven and under-researched. There is a pressing need for pedagogical frameworks

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that intentionally link global education principles with the goals of scientific literacy. This article contributes to that need by examining instructional strategies and curricular models that can support the dual development of global competencies and functional literacy in chemistry.

Methodology:

This study employs a qualitative instructional design and case study approach to explore how global competencies can be effectively integrated into chemistry education while enhancing students' functional scientific literacy. The research was conducted within the framework of a competency-based chemistry curriculum piloted in two secondary schools in Uzbekistan.

Participants:

The study involved 42 students (ages 15–16) enrolled in 10th-grade chemistry classes and 4 experienced chemistry teachers who had received prior training in implementing global competence-oriented instruction. Participants were selected using purposive sampling to ensure diversity in academic performance and teaching experience.

Instructional design:

The intervention spanned six weeks and was based on three key components:

- **Context-based instruction**: Lessons were designed around global and local issues such as water purification, air pollution, sustainable agriculture, and green chemistry.
- **Inquiry and project-based learning**: Students worked in small groups to conduct experiments, research scientific data, and propose solutions to real-world problems with a global dimension.
- **Reflection and discussion**: Lessons included structured reflection sessions where students analyzed the ethical, cultural, and environmental implications of their findings.

Tasks were aligned with both **PISA scientific literacy frameworks** and **UNESCO's global competence domains**, ensuring a balanced focus on content knowledge and global awareness.

Data Collection Tools:

To assess the development of global competencies and functional literacy, the following instruments were used:

- **Pre- and post-instruction interviews** with students and teachers to evaluate shifts in understanding and pedagogy.
- **Observation protocols** during lessons to capture student engagement, problem-solving behavior, and collaboration.
- **Student portfolios** containing lab reports, project documentation, and written reflections.
- **Rubrics** based on global competence indicators and science process skills were used to assess student performance.

Data Analysis:

Qualitative data from interviews, observations, and portfolios were analyzed using thematic coding and triangulation techniques. Emergent patterns were categorized according to the

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development of global competencies (e.g., perspective-taking, ethical reasoning) and functional scientific literacy (e.g., application of concepts, evidence-based conclusions).

Results:

The implementation of global competence-oriented chemistry instruction yielded notable improvements in both students' functional scientific literacy and their acquisition of global competencies.

1. Improvement in application of scientific knowledge:

Analysis of student portfolios and observation data revealed that over 75% of participants were able to apply chemistry concepts—such as solubility, pH balance, or redox reactions—to real-world scenarios like water filtration or acid rain formation. Compared to pre-intervention performance, students showed a marked increase in their ability to:

- Formulate questions and hypotheses grounded in socio-environmental issues
- Design and conduct simple experiments with global relevance
- Draw conclusions based on data and justify them using scientific reasoning

2. Development of global competence indicators:

Through project work and structured reflection sessions, students demonstrated growth in several domains of global competence:

- **Perspective-taking**: 68% of students incorporated different cultural or ethical viewpoints into their explanations (e.g., varying access to clean water in different countries).
- **Critical thinking**: Students increasingly questioned the broader impact of chemical processes (e.g., industrial emissions) on communities and ecosystems.
- **Ethical reasoning**: Over half of the students engaged in meaningful classroom discussions about sustainability, fairness in resource distribution, and the role of science in global problem-solving.

3. Teacher reflections and instructional shifts:

Interviews with teachers revealed a shift in their pedagogical strategies. They reported:

- Increased student engagement and motivation when real-world problems were used
- More meaningful classroom discussions and student inquiry
- A need for further training in designing interdisciplinary and globally relevant chemistry tasks

One teacher noted:

"When we moved from textbook problems to global challenges, students started to ask more questions—and not just about chemistry, but about the world."

4. Performance-based assessment:

Rubric-based evaluations showed that 81% of students achieved proficiency or higher in at least three out of five global competence indicators. Similarly, 76% demonstrated functional application of chemistry knowledge, surpassing their initial baseline performance.

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Discussion

The results of this study affirm that integrating global competencies into chemistry education significantly enhances students' functional scientific literacy while simultaneously promoting broader 21st-century skills. The observed improvement in students' ability to apply chemical knowledge in real-world contexts supports previous research advocating for context-based and interdisciplinary science instruction (Gilbert, 2006; Sadler, 2011).

One of the most significant outcomes was the ability of students to link abstract chemical concepts to global issues such as clean water access, pollution, and sustainable development. This aligns with PISA's framework of scientific literacy, which emphasizes applying scientific understanding to personal and societal challenges (OECD, 2018). Students not only grasped content more deeply but also demonstrated an increased capacity for critical thinking, perspective-taking, and ethical reasoning—key components of global competence as outlined by UNESCO.

The inclusion of inquiry- and project-based learning approaches proved particularly effective in engaging students. These strategies provided authentic learning experiences that encouraged autonomy, curiosity, and collaborative exploration. As noted in constructivist pedagogy (Vygotsky, 1978; Scardamalia & Bereiter, 2006), learning becomes more meaningful when students construct knowledge through direct involvement in complex, relevant problems.

Teacher reflections further highlight the pedagogical shift required to support such an approach. Although many educators welcomed the increased engagement and deeper understanding among students, they also expressed the need for more support in designing interdisciplinary tasks that blend scientific content with global themes. This echoes challenges found in other competency-based reform efforts, where curriculum alignment and teacher training remain critical success factors (King & Ritchie, 2013).

An important implication of this study is the potential for global competence education to be seamlessly embedded into existing chemistry curricula—without sacrificing content depth. Rather than viewing competencies as add-ons, they can be integrated into the very structure of lessons and assessments through inquiry-based tasks, problem-solving scenarios, and cross-cultural discussions. The findings underscore the value of a dual-focus instructional approach—developing both scientific understanding and global awareness. This not only prepares students for academic success but also equips them to be informed, ethical, and active global citizens in a scientifically complex world.

Conclusion:

This study demonstrates that the integration of global competencies into chemistry education can significantly enhance students' functional scientific literacy and overall engagement with science. By embedding real-world challenges and interdisciplinary themes into classroom instruction, students develop a deeper understanding of chemical concepts and the ability to apply them in meaningful, socially relevant contexts.

The use of inquiry-based, project-based, and context-driven strategies proved effective in cultivating critical thinking, ethical reasoning, and intercultural awareness—skills essential for

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navigating today's complex global environment. Students were not only able to link scientific knowledge to global issues but also developed the confidence and competence to propose informed solutions.

Teachers played a vital role in facilitating this transformation, although their feedback indicates a need for ongoing professional development and institutional support to implement such approaches consistently and effectively.

Ultimately, the findings support a pedagogical shift in chemistry education—moving from rote learning to a more dynamic, competency-based model that prepares students for responsible scientific citizenship. Future efforts should focus on scaling this model, aligning national curricula with international frameworks, and further investigating its long-term impact on learners' academic and personal development.

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