ORIGINAL ARTICLE

INTERNATIONAL JOURNAL OF ARTIFICIAL INTELLIGENCE

ISSN: 2692-515-x, Impact Factor: 9.23
American Academic publishers, volume 6, issue 02,2026

Journal: https://www.academicpublishers.org/journals/index.php/ijai

DEVELOPING SUSTAINABLE DEVELOPMENT COMPETENCIES THROUGH CHEMISTRY EDUCATION IN GENERAL AND HIGHER EDUCATION

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Abstract. This article analyzes the scientific and methodological foundations for developing sustainable development competencies through chemistry education in general and higher education institutions. The study focuses on the integration of sustainable development concepts into the content of chemistry education, the application of green chemistry principles, and the potential for fostering environmental, social, and economic competencies among learners. In addition, the effectiveness of modern pedagogical approaches, competency-based education, and practice-oriented learning activities is substantiated. The findings highlight the role of chemistry education in promoting responsible decision-making, ecological awareness, and sustainable thinking among students.

Keywords: chemistry education, sustainable development, competency-based approach, green chemistry, environmental education, modern pedagogical technologies.

Introduction. In recent years, global environmental challenges, rational use of natural resources, and environmental protection issues have necessitated the deep integration of the concept of sustainable development into the education system. Chemistry, as a science directly related to natural resources, chemical processes, and technological development, plays a significant role in fostering sustainable development competencies. Within both general and higher education, chemistry teaching should aim not only at transmitting subject knowledge but also at developing ecological responsibility, critical thinking, and the ability to make sustainable decisions. Therefore, revising and improving the content and methodology of chemistry education based on sustainable development principles has become an urgent educational task.

Materials and Methods / Results and Discussion

Modern education systems increasingly emphasize the formation of competencies that meet the needs of contemporary society rather than focusing solely on theoretical knowledge. From this perspective, integrating sustainable development ideas into the teaching and learning process represents a key priority. Sustainable development seeks to meet the needs of the present generation without compromising the ability of future generations to meet their own needs, emphasizing environmental balance, efficient resource use, and social responsibility. Chemistry, as a natural science, offers substantial methodological opportunities to embed these ideas into education.

Chemistry examines the structure, properties, transformations of substances, and their interactions with nature and human activities. This characteristic makes chemistry an effective tool for developing sustainable development competencies. Many industrial processes, energy production systems, agricultural technologies, medical applications, and environmental issues are rooted in chemical principles. Consequently, chemistry lessons can be used to cultivate students' awareness of environmental protection, efficient resource management, chemical safety, and ecological responsibility.

Sustainable development competencies reflect an individual's ability to understand, analyze, and address environmental, economic, and social challenges through informed decision-making. These competencies consist of cognitive knowledge, value-based attitudes,

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practical skills, and reflective abilities. Chemistry education provides opportunities to develop all of these components. For example, topics such as chemical pollution, waste management, and energy efficiency contribute to cognitive development, while discussions on environmental safety and nature conservation promote value formation. Laboratory and practical activities strengthen students' action-oriented competencies.

At the level of general secondary education, organizing chemistry lessons around sustainable development concepts helps form foundational ecological thinking. Topics such as air and water pollution, acid rain, the greenhouse effect, and ozone layer depletion can be scientifically explained within the chemistry curriculum. Furthermore, addressing household chemicals, their composition, and potential effects on human health enables students to develop responsible consumer behavior. In this context, problem-based learning, project-based instruction, and the analysis of real environmental situations prove to be particularly effective.

In higher education institutions, the development of sustainable development competencies through chemistry education becomes more systematic and in-depth. Students are encouraged to analyze chemical processes not only theoretically but also from professional and research perspectives. The incorporation of green chemistry principles, waste-free technologies, energy-efficient processes, and environmentally safe materials fosters innovative thinking and professional responsibility. Additionally, studying chemical risk assessment and management prepares future specialists to make decisions that support sustainable development.

To successfully implement a sustainability-oriented approach in chemistry education, alignment between educational objectives, content, teaching methods, and learning outcomes is essential. Educational content should be integrated with environmental, economic, and social issues, while instructional methods should promote independent thinking and research-oriented learning. As a result, education contributes to the formation of environmentally literate, socially responsible individuals who actively support sustainable development values.

The research employed methods such as analysis of scientific and pedagogical literature, observation of the educational process, and comparative analysis. The findings indicate that the development of sustainable development competencies through chemistry education can be effectively achieved in the following ways:

First, integrating green chemistry principles into the chemistry curriculum enhances understanding of environmental safety and efficient resource use. This includes practical demonstrations of low-waste reactions, energy-saving processes, and safe handling of chemical substances.

Second, competency-based instruction enables learners to analyze problem situations, assess environmental consequences, and propose sustainable solutions. Project-based and research activities play a crucial role in this process.

Third, applying an interdisciplinary approach by linking chemistry with ecology, biology, and economics supports the comprehensive development of sustainable development competencies in both general and higher education.

Overall, the analysis demonstrates that systematic incorporation of sustainable development concepts into chemistry lessons significantly enhances students' ecological culture and social responsibility.

Conclusion. Developing sustainable development competencies through chemistry education in general and higher education is one of the key objectives of modern education. Methodological approaches based on green chemistry principles promote ecological thinking, responsible decision-making, and sustainability-oriented attitudes among learners. The research

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findings confirm that enriching chemistry education with sustainable development concepts is pedagogically effective. Moreover, the study demonstrates that chemistry lessons can successfully foster environmentally responsible thinking and competencies aimed at sustainable development.

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