METHODOLOGY OF APPLYING INNOVATIVE PEDAGOGICAL TECHNOLOGIES IN DEVELOPING STUDENTS' CHEMICAL THINKING IN HIGHER EDUCATION INSTITUTIONS

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Annotatsiya: Innovatsion pedagogik texnologiyalardan foydalanish metodikasi tadqiq etilgan. Kimyo fanini oʻqitishda an'anaviy usullardan voz kechib, interaktiv va raqamli texnologiyalarni joriy etish talabalarning mustaqil fikrlashi, tahliliy koʻnikmalari va amaliy kompetensiyalarini oshirishga xizmat qiladi. Maqolada muammoli ta'lim, loyiha usuli va kompyuter modellashtirish dasturlarining samaradorligi koʻrib chiqilgan hamda oʻquv jarayonini tashkil etish boʻyicha amaliy tavsiyalar ishlab chiqilgan.

Kalit soʻzlar: kimyoviy tafakkur, oliy ta'lim, innovatsion texnologiyalar, pedagogik metodika, interaktiv ta'lim, raqamli modellashtirish, talabalar kompetensiyasi.

Abstract: This article examines the methodology of using innovative pedagogical technologies to develop students' chemical thinking in higher education institutions. Shifting from traditional methods to interactive and digital technologies in chemistry education enhances students' independent reasoning, analytical skills, and practical competencies. The paper reviews the effectiveness of problem-based learning, the project method, and computer modeling software, offering practical recommendations for organizing the educational process.

Keywords: chemical thinking, higher education, innovative technologies, pedagogical methodology, interactive learning, digital modeling, student competence.

Аннотация: В данной статье рассматривается методика использования инновационных педагогических технологий для развития химического мышления студентов в высших учебных заведениях. Переход от традиционных методов к интерактивным и цифровым технологиям в обучении химии способствует повышению самостоятельного мышления, аналитических навыков и практических компетенций студентов. В работе рассматривается эффективность проблемного обучения, метода проектов и программ компьютерного моделирования, а также разрабатываются практические рекомендации по организации учебного процесса.

Ключевые слова: химическое мышление, высшее образование, инновационные технологии, педагогическая методика, интерактивное обучение, цифровое моделирование, компетенция студентов.

Introduction

One of the essential tasks of the modern higher education system is not only to provide students with theoretical knowledge but also to develop their independent and logical thinking abilities. Due to its nature, chemistry is rich in abstract concepts and complex laws, which demands a high level of chemical thinking from students. However, because the traditional teaching system emphasizes delivering information in a ready-made form, students' interest in the subject and their level of deep understanding of topics often remain insufficient. Consequently, there is an urgent need to introduce fresh approaches into the educational process to fundamentally improve the professional training of future specialists and foster a creative mindset.

To address this issue, developing a methodology for the systematic use of innovative pedagogical technologies and advanced international experiences is of great relevance. Innovative technologies transform the learner into an active participant, laying the foundation for developing skills in independent research, problem analysis, and the accurate interpretation of experimental results. The problem of developing chemical thinking in higher education requires a comprehensive pedagogical and psychological approach, necessitating the effective use of digital resources, interactive models, and problem-based scenarios during classroom sessions. This research is dedicated to identifying the most effective methods aimed at increasing the intellectual potential of students in chemistry classes and implementing them in practice.

Literature Review and Methodology

An analysis of scientific research conducted on pedagogical and chemical education issues indicates that activating the thinking activities of students has always been at the center of researchers' attention. Foreign and local scholars have highly valued the role of visualization and modeling tools in mastering chemical concepts in their works. Scientific sources widely recognize problem-based learning and project methods as the most effective tools for shaping students' independent research skills. Nonetheless, the issues of systematizing the integrated methodology of digital innovations and pedagogical strategies within specific science modules in higher chemistry education still require further investigation.

During the research process, systematic analysis, comparative-pedagogical evaluation, and experimental pedagogical observation methods were utilized to study the problem. Special pedagogical experimental tests were organized involving chemistry students of higher education institutions, and innovative software products along with interactive Case-study methods were introduced into the educational process. To determine the level of students' chemical thinking, a set of logical tasks, laboratory simulations, and analytical tests was developed. The results obtained during the experiment were compared with the indicators of traditional groups, and the effectiveness of the applied methodology was verified using mathematical-statistical methods.

Results

The results of the conducted pedagogical experimental tests showed that the performance indicators of students in the groups where innovative pedagogical technologies were applied increased significantly. In the topics taught using virtual laboratory programs and computer modeling tools, students visually envisioned the microworld of chemical processes and intermolecular interactions much more deeply. In classes organized on the basis of problem-based learning technology, students demonstrated the ability not only to memorize formulas but also to apply them in solving practical problems. Test results indicated that the analytical thinking and alternative solution-finding indicators of students in the experimental groups were much higher than those in the control groups.

The comparative analyses conducted based on the obtained indicators confirmed that the innovative methodology also strengthened internal motivation toward the subject among students. When analyzing the quality of students' independent work and project assignments, it was found that a creative approach and a culture of scientific reasoning had been formed. Especially, the use of digital simulations in explaining the kinetics and mechanisms of chemical reactions served to shorten the time required to master complex topics. These results indicate that modifying chemistry classes in higher education and creating an innovative environment is a major factor in unlocking the intellectual potential of students.

Discussion

The research results show that the development of chemical thinking should not be limited only to mastering information from textbooks. Innovative technologies allow students to connect the fundamental laws of science with practical life and industrial processes. However, in the process of introducing innovations into education, merely providing technical equipment is not enough; the methodological literacy of educators to use these technologies purposefully and correctly is also of decisive importance. Supporting the conclusions of other researchers that virtual resources increase the quality of education, the obtained data reveal the advantages of the new methodological system even more clearly.

At the same time, certain difficulties and limitations were observed during the application of innovations in chemistry education. For example, a risk may arise where some students weaken their skills in working in real laboratory conditions due to over-reliance on computer models. Therefore, it was found necessary to rationally integrate virtual simulations and digital technologies with real chemical experiments, maintaining their balance. During the discussions, it was emphasized that enriching educational content based on student-centered technologies and teaching students to work in small groups also accelerates their socio-professional adaptation.

Conclusion

Developing chemical thinking in higher education institutions is a complex process that requires the systematic introduction of modern digital and interactive pedagogical technologies. The results of the scientific-pedagogical research and experimental testing carried out showed that problem-based and project-based learning methods, as well as visual modeling tools, yield much higher efficiency compared to traditional lesson formats. This methodology forms a systematic approach toward the subject in students, broadens their logical reasoning scope, and teaches them to draw scientific conclusions independently. Students educated in an innovative environment will emerge as specialists capable of creatively solving professional problems in the future.

In conclusion, it can be said that the pedagogical methodology developed and tested in practice allows lifting the quality of teaching chemistry in higher education institutions to a new level. To sustain the effectiveness of the educational process, it is necessary to regularly improve curricula based on new technological capabilities and to enhance the innovative competencies of pedagogical personnel. The recommendations and methodological materials developed within the scope of the study can be widely used as a practical guide by professors and teachers of higher education institutions in designing lectures and laboratory sessions.

In addition, the results of this study suggest that the development of chemical thinking is heavily dependent on the creation of a continuous feedback loop between students and instructors within the digital learning environment. Implementing adaptive assessment tools and collaborative online platforms ensures that individual learning paces are respected, allowing students to overcome personal conceptual difficulties more effectively. Future research should therefore focus on scaling these innovative frameworks across various chemistry disciplines and establishing long-term metrics to track how enhanced chemical thinking during university studies translates into professional success in industrial and research careers.

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