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Article

Methodological Foundations for Organizing Organic Chemistry Laboratory Classesi Schools Based on Virtual Technologies

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Abstract: This article examines the didactic and methodological foundations of organizing organic chemistry laboratory classes in general education schools using virtual technologies. The main objective of the study is to improve the effectiveness of developing students' practical knowledge and laboratory skills through the integration of virtual laboratory platforms into the educational process. Analytical, comparative, and modeling methods were employed in the research. As a result, the educational capabilities of modern platforms such as ChemCollective, Labster, MolView, PhET Interactive Simulations, and Virtual Chemistry Laboratory were substantiated, and methodological recommendations for their effective integration into chemistry education were developed.

Keywords: Organic chemistry, virtual experimental environment, teaching chemistry, school education, general education institutions

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1. Introduction

Currently, the use of digital educational technologies in teaching chemistry in general education schools has become one of the key factors in improving the quality of education. In particular, organic chemistry laboratory classes are often not fully implemented due to the hazardous nature of many chemical reagents, insufficient laboratory equipment, and time constraints.

Therefore, organizing laboratory activities in a virtual environment enables students to perform experiments safely, economically, and in a visually understandable manner. Virtual laboratories contribute to the development of students' independent thinking and facilitate the formation of STEM competencies.

The purpose of this study is to develop methodological foundations for organizing organic chemistry laboratory classes in general education schools based on virtual technologies.

Didactic potential of virtual laboratory platforms

The following virtual laboratory platforms provide extensive opportunities for teaching organic chemistry:

PhET Interactive Simulations – Explains the properties of organic and inorganic substances through interactive simulations. It is particularly suitable for primary and secondary school students.

Labster – Provides highly realistic 3D virtual laboratory environments that closely simulate real experimental conditions.

ChemCollective – Enables calculation, modeling, and analysis of chemical reactions, enhancing students' analytical and experimental skills.

MolView – Visualizes molecular structures in 3D, helping students understand isomerism, molecular geometry, and reaction mechanisms.

Virtual Chemistry Laboratory – Allows step-by-step simulation of organic chemistry experiments, facilitating the development of essential laboratory skills.

Table 1. Virtual platforms and their educational capabilities

Platform	Description	Advantage
PhET	Provides visual representations of chemical processes	Suitable for primary and secondary school students
Labster	Offers immersive 3D virtual laboratory experiments	High accuracy and realistic simulation
ChemCollective	Enables modeling of chemical reactions and calculations	Appropriate for intermediate and advanced-level students
MolView	Displays molecular structures in interactive 3D format	Effective for studying molecular chemistry
Virtual Chemistry Laboratory	Provides a virtual experimental environment	Helps develop practical laboratory skills

1. Materials and Methods

Virtual laboratory classes are organized in the following stages:

Selection of a virtual platform appropriate to the lesson topic.

Development of an experimental scenario.

Step-by-step implementation of the experiment in a virtual environment.

Analysis of experimental results and preparation of an electronic laboratory report (e-laboratory journal).

Integration of virtual laboratory activities with traditional laboratory instruction.

For example, the addition reactions of alkenes can be modeled using the Labster platform, the esterification process can be analyzed using ChemCollective, and isomers can be compared in a 3D format using MolView.

2. Result and Discussion

The use of virtual laboratories enables students to perform experiments accurately, understand reaction mechanisms more deeply, and draw independent conclusions. Furthermore, the educational process becomes more efficient due to the conservation of time and material resources, improved laboratory safety, and increased student interest in chemistry. Virtual laboratory technologies also contribute to the development of analytical thinking, experimental competence, and independent learning skill.

Figure 1. Modeling the properties of organic substances using the PhET platform.

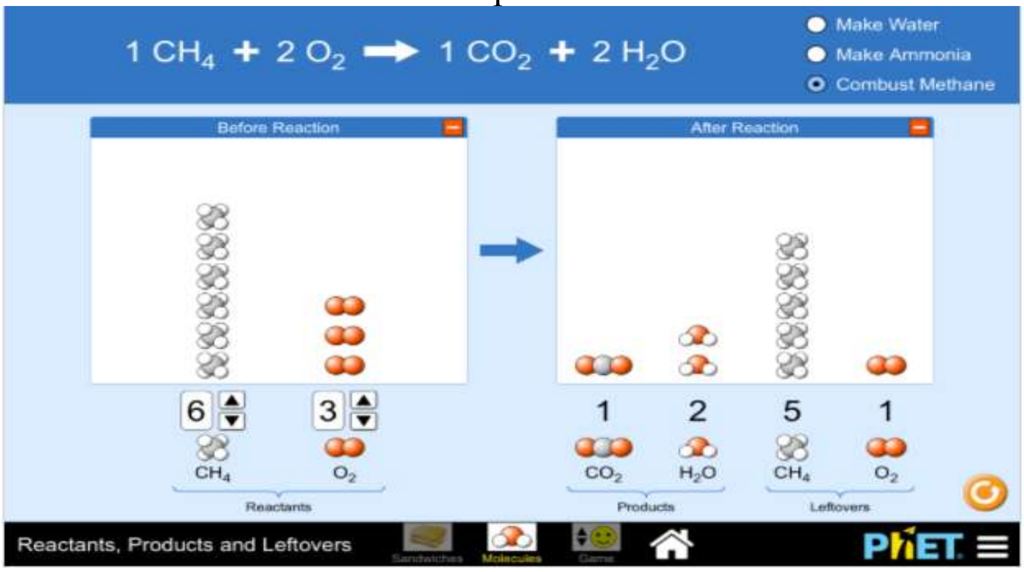

Figure 2. Modeling the properties of organic substances using the PhET platform.

Concept for Developing a New Virtual Laboratory Application

In the future, based on the findings of this research, it is advisable to develop a unified virtual application designed for organic chemistry laboratory classes in general education schools. This application should be aligned with national educational curricula and include an Uzbek-language interface.

The proposed application should incorporate the following features: a virtual laboratory environment, 3D molecular modeling of organic compounds, step-by-step visualization of reaction mechanisms, interactive training on laboratory safety rules, identification and analysis of experimental errors, and automatic recording of experimental results through an electronic laboratory journal.

The proposed application will contribute to the development of students' practical laboratory skills, support independent learning activities, and further enhance the effectiveness of teaching organic chemistry.

3. Conclusion

The results of the study indicate that organizing organic chemistry laboratory classes based on virtual technologies improves students' understanding of experimental processes and makes learning more systematic. Laboratory activities conducted in a virtual environment help students understand the logical sequence of chemical processes and develop their ability to analyze experimental results and draw scientific conclusions.

This approach strengthens students’ psychological readiness for laboratory work and prepares them to perform experiments confidently in real laboratory conditions. Furthermore, virtual laboratories allow experiments to be repeated multiple times, which ensures the stability of acquired knowledge and provides opportunities for error analysis and correction.

The conducted analysis also demonstrates that integrating virtual laboratories with traditional laboratory instruction leads to higher educational outcomes. Such integration increases students’ interest in organic chemistry, facilitates the development of practical competencies, and significantly improves the overall effectiveness of the educational process. Therefore, the gradual implementation of virtual laboratory technologies into educational practice is highly recommended.

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