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**Rusyn I.**, CSc., assoc. prof.; **Slivka M.**, DrSc., prof.; **Korol N.**, CSc., assoc. prof.;  
**Lendel V.**, DrSc., prof.

## CHALLENGES AND BENEFITS OF USING INFORMATION TECHNOLOGIES IN TEACHING CHEMISTRY IN UKRAINE DURING WARTIME

*Uzhhorod National University, Fedyntsa St., 53, 88000 Uzhhorod, Ukraine*

*e-mail: [ivan.rusyn@uzhnu.edu.ua](mailto:ivan.rusyn@uzhnu.edu.ua)*

The education sector, which is one of the most important aspects of public life, has undergone critical changes due to the full-scale invasion of Russia in Ukraine. Educators and students have been forced to a rapid shift from traditional to digital learning methods. Chemical education has adapted to the new reality by using a number of digital platforms, virtual laboratories, and other IT tools for distant learning. These innovative educational technologies have become particularly useful in chemistry teaching, where interactive tools help replace hands-on experiments in wartime circumstances, where access to traditional laboratories is unsafe or impossible.

However, the transition to digital learning in Ukraine during the current period not only has complexities on its own, but is also accompanied by significant challenges caused by war conditions, including power shortages, limited Internet access, and digital inequality, especially in war-torn and rural areas. The issues of digital literacy, content localization, cybersecurity, and students' and educators' psychological well-being present further complications.

Developing and expanding access to relevant, localized chemistry educational content will be essential to closing the education gap and maintaining long-term sustainability. In the post-war period, it is appropriate to implement a blended learning model that combines digital tools with offline laboratories, which is critical for sustainable recovery, promoting community rebuilding, developing practical student skills, and the sustainability of the Ukrainian education system in general.

**Keywords:** Educational technology; online chemistry education; digital learning; virtual laboratories; blended learning.

The full-scale invasion of Russia on the territory of Ukraine radically affected all aspects of the state and society. In particular, severe challenges faced the educational process, the participants of which were forced to switch from traditional forms and tools to digital learning environments. The war has caused a whole series of new challenges related to security, availability of electricity, access to quality Internet and digital devices, as well as social aspects such as the impact on the psychological state of students and teachers, increasing digital inequality, etc.

According to a study conducted by the State Education Quality Service of Ukraine, a third of students did not have permanent access to education in wartime conditions [1].

According to the Ministry of Education and Science, with the beginning of the full-scale war, the number of distance-learning students

increased to more than 35%. More than 30% study in a mixed format [2]. Therefore, digital platforms for learning, such as Google Classroom or Moodle, have become important tools for ensuring the continuity of chemical education during wartime. These platforms allow teachers to deliver lectures, provide access to learning materials, and engage students in remote discussion and collaboration [3]. However, the effectiveness of the use of these platforms by educators, their adaptation to educational standards, as well as the real level of student involvement in the educational process during the war remain complex issues [4,5]. In addition, the dependence of the educational process on technology also increases the digital divide in Ukraine, where students in war zones or in rural areas may struggle with limited Internet access and outdated equipment. Also, given the general

and significant deterioration of material conditions caused by the war, students from disadvantaged families may lack the resources to fully participate in online learning, further increasing the educational gap [6].

Limited or no physical access to classrooms and laboratories forces educators to turn to electronic learning tools and resources specifically designed for teaching chemistry. These include digital textbooks and online quizzes, video demonstrations, and interactive simulations that help students visualize complex chemical reactions and concepts. Platforms such as PhET Interactive Simulation [7] or ChemCollective [8] provide accessible resources that can be integrated into the educational process. Virtual laboratories, such as Labster [9] and BeyondLabz [10], are an important alternative to traditional hands-on experiments in chemistry education. They allow students to conduct simulation experiments and observe chemical reactions in a controlled, safe environment. Although virtual labs cannot completely replace the tactile experience of physical labs, they are a valuable tool for supporting hands-on chemistry education under the challenging circumstances of war. However, despite the innovative approach to teaching that these digital tools offer, the challenge is to ensure that all students and teachers have the necessary digital literacy and access to take full advantage of such resources. The issue of localization of the proposed educational materials should be mentioned as well, since the vast majority of them are in English, which complicates their integration into the educational process.

That is why it is so important to stimulate the creation of Ukrainian educational content in chemistry. Various educational media resources are provided on the e-learning platform created with the support of the Ministry of Digital Transformation of Ukraine and the Ministry of Education and Science of Ukraine [11], as well as a number of other platforms [12-14]. During the war period they provide free access to a comprehensive educational product that includes theoretical and methodological educational material on chemistry, thematic video materials, and materials for project activities.

Also, a great example of the use of information technologies in teaching chemistry is the online Chemistry Olympiad [15], when holding it in the traditional way is impossible due

to Russian missile attacks on the entire territory of Ukraine.

Although the mentioned web resources provide the participants of the educational process with the necessary tools for studying chemistry, the ongoing war increased existing inequalities in access to technology, significantly affecting students' ability to participate in distance learning. In war-affected regions, many students have lost access to reliable electricity, the Internet and digital devices, creating significant barriers to their education. This technological gap is particularly impactful in the study of subjects such as chemistry, which often require specialized software and a stable Internet to conduct interactive lessons and work with virtual laboratories.

The wartime shift to online education has also raised significant concerns about cybersecurity, privacy, and personal data protection. Educational institutions are becoming increasingly vulnerable to cyber-attacks, which can not only disrupt education, but also compromise confidential data. Ensuring the security of online platforms used for chemistry education is essential to protect both students and educational institutions. This calls for the implementation of robust cyber security measures, such as secure authentication on educational platforms, encryption of communication channels, regular software updates, and learning and following digital security practices on the Internet [16].

Also, an extremely important issue is the psychological impact of war on students and teachers, which affects such aspects as emotional state, motivation, ability to participate in educational activities and benefit from them fully. When properly approached, information technology can offer important means of solving these complex issues. In response to the challenges caused by the war, online platforms and collective online projects in chemistry will facilitate group discussions, provide an opportunity to improve social interaction and cooperation between students and teachers. Group projects, virtual experiments, and collaborative research initiatives can be conducted entirely online, allowing students to collaborate as a team, share ideas, and support each other. Such activities help restore a sense of belonging, which is important for both social and educational development. In addition, joint

projects can focus on real-world problems of the present, such as solving environmental problems caused by war, making chemistry education even more relevant and interesting for students [17].

Significant advantages in the study of chemistry can be provided by generative artificial intelligence technologies [18,19]. They make it possible to improve such aspects of chemistry education as explaining complex chemical concepts to students, testing knowledge, virtual tutoring, etc.

Although a full-scale war is currently ongoing, it is important to think about the stage of post-war recovery of chemical education in Ukraine. It is obvious that despite all the advantages of digital technologies and learning tools, it is impossible to fully replace the traditional learning environment with laboratories and equipment to ensure the formation of practical skills in students. Therefore, it seems appropriate to move to a blended learning model that combines the advantages of innovative technologies with the capabilities and experience of traditional approaches. The blended learning can provide the necessary flexibility to adapt to changing conditions, ensuring a smooth transition from a remote to a traditional learning environment when it is allowed by security requirements. In chemistry education, this model involves continuing to work with virtual labs and online resources while gradually reintroducing hands-on experiments and collaboration in the classroom. This approach not only supports academic continuity, but will also help address the social need to rebuild the community and re-engage students after long periods of isolation and harsh wartime conditions.

### Conclusions

The war highlighted existing educational inequality, widening the digital divide and limiting access to quality education for students in Ukraine. Despite the advantages of virtual tools in chemistry education, there is an urgent need for expanded access, localized Ukrainian-language content, increased digital literacy, and cybersecurity measures to ensure the safety and effectiveness of education. Online learning platforms can promote student engagement and retention by promoting collaboration and real-world problem solving, which is especially valuable in challenging times. The post-war model of blended learning, which combines digital resources with hands-on experience, is

essential to the recovery of traditional chemistry education and practical skills. Ultimately, such an approach will contribute to the restoration of education in Ukraine, help to restore connections between communities and advance chemical education in a resilient and sustainable way.

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**Русин І.Ф., Сливка М.В., Король Н.І., Лендел В.Г.**

## **ВИКЛИКИ ТА ПЕРЕВАГИ ВИКОРИСТАННЯ ІНФОРМАЦІЙНИХ ТЕХНОЛОГІЙ ПРИ ВИКЛАДАННІ ХІМІЇ В УКРАЇНІ У ВОЄННИЙ ЧАС**

*ДВНЗ «Ужгородський національний університет», 88000,  
м. Ужгород, вул. Фединця, 53  
e-mail: [ivan.rusyn@uzhnu.edu.ua](mailto:ivan.rusyn@uzhnu.edu.ua)*

Сектор освіти, який є одним із найважливіших аспектів суспільного життя, зазнав серйозних змін через повномасштабне вторгнення Росії в Україну. Викладачі та студенти були змушені швидко переходити від традиційних до цифрових методів навчання. Хімічна освіта адаптувалася до нової реальності, використовуючи низку цифрових платформ, віртуальних лабораторій та інших ІТ-інструментів для дистанційної освіти. Ці інноваційні освітні технології стали особливо корисними у викладанні хімії, де інтерактивні інструменти допомагають замінити практичні експерименти в обставинах війни, коли доступ до традиційних лабораторій є небезпечним чи неможливим.

Однак перехід до цифрового навчання в Україні протягом поточного періоду не тільки має складності сам по собі, але також супроводжується значними проблемами, спричиненими умовами війни, зокрема дефіцитом електроенергії, обмеженим доступом до Інтернету та цифровою нерівністю, особливо в охоплених війною країнах і сільській місцевості. Питання цифрової грамотності, локалізації контенту, кібербезпеки та психологічного благополуччя студентів і викладачів створюють додаткові ускладнення.

Розробка та розширення доступу до актуального, локалізованого навчального контенту з хімії має важливе значення для усунення освітнього розриву та підтримки довгострокової стабільності. У післявоєнний період доцільно запровадити модель змішаного навчання, яка поєднує цифрові інструменти та офлайн лабораторії, що має вирішальне значення для розвитку практичних навичок студентів, сталого відновлення, сприяння відбудові громади, та сталості української системи освіти загалом.

**Ключові слова:** освітні технології; онлайн-навчання з хімії; цифрове навчання; віртуальні лабораторії; змішане навчання.

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