NNOVATIVE TEACHING TECHNOLOGIES IN THE NATURAL SCIENCE EDUCATION SYSTEM OF UKRAINE

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Abstract. Ukraine's drive to modernize natural-science education demands a systematic uptake of innovative teaching technologies that meet the challenges of the information society and sustainable development while aligning with the New Ukrainian School's competence-based reform. As a vehicle for scientific literacy, ecological awareness, and research skills, natural science instruction increasingly depends ondigital platforms, interactive and project/problem-based methods, virtual and augmented laboratories, and interdisciplinary STEM/STEAM approaches. These tools support not only the acquisition of theory but also the formation of practical competences, critical and systems thinking, creativity, and the ability to apply knowledge in real contexts. Against this backdrop, the study analyzes the current state of innovation in Ukrainian science education and argues for deeper integration of digital, interactive, and project-oriented technologies to raise learning outcomes. Methodologically, it combines qualitative and quantitative procedures-literature analysis, questionnaires of 320 teachers and 460 pupils/students, interviews, pedagogical observation, and pilot implementations of STEM, blended learning, and virtual labs-summarized with descriptive statistics to capture effects and barriers.Findings show broad, though uneven, adoption: 87% of teachers actively use digital tools, 72% employ interactive strategies, 69% implement blended learning, and 54% use mobile apps or virtual labs. Student perspectives are consistent: 92% say digital tools improve understanding, 81% value interactive methods, 68% are interested in STEM/STEAM, and 73% actively use mobile applications. The main constraints are structural and human-capital related-

insufficient material and technical support (42%), low digital competence among colleagues (37%), and overloaded curricula (21%); students most often point to a lack of modern equipment (48%), excessive theoretical workload (29%), and weak classroom integration of innovations (23%). Despite these hurdles, innovative technologies already enhance understanding, motivation, and practical skills and help cultivate a generation able to address complex environmental, technological, and social problems. Sustainable scaling now depends on infrastructure upgrades, continuous teacher professional development, tighter curriculum-assessment alignment for inquiry and projects, and expanded access to both physical and virtual STEM laboratories, consolidating a student-centered, competency-driven model in line with European and global standards.

Keywords: innovative learning technologies; natural sciences education; Ukrainian education system; digital tools in education; STEM education, e-learning;interactive methods; educational innovation; blended learning; competence-based approach; environmental education; pedagogical technologies.

Introduction. The rapid transformation of the global educational landscape in the twenty-first century has placed an unprecedented emphasis on the integration of innovative technologies into teaching and learning processes. These changes are especially visible in the field of natural science education, where the acquisition of knowledge and competencies is directly connected to the ability to model, analyze, and apply scientific principles in real-life contexts. The growing role of digitalization, the development of interactive platforms, and the introduction of artificial intelligence into education highlight the necessity of modernizing the traditional approaches to learning. Ukraine, as a country undergoing dynamic political, social, andeconomic transformations, is also rethinking the organization of its educational system. In this regard, natural science education has become a crucial arena for the implementation of innovative learning technologies aimed at improving both the quality ofknowledge and the competitiveness of Ukrainian students in the international academic space.The introduction of innovative technologies in education is not limited to the simple use of gadgets, digital resources, or internet-based tools. Rather, it implies a comprehensive pedagogical reorientation in which teachers and students engage in interactive, competency-based, and problem-solving learning. For natural science education, innovation means not only adopting multimedia presentations or online platforms but also integrating virtual and augmented reality, simulation software, digital laboratories, cloud-based collaboration tools, and artificial intelligence–supported environments. Such innovations enable students to explore complex natural phenomena, conduct experiments in safe digital spaces, and connect theoretical knowledge with practical skills. This transition is especially important in the Ukrainian context, where the modernization of science education is seen as a strategic priority in building human capital for sustainable development.One of the central challenges of modern natural science education lies in reconciling traditional forms of knowledge transfer with

the demands of the digital society. For decades, natural sciences in Ukraine were taught mainly through classroom lectures, laboratory sessions with limited resources, and textbook-centered approaches. While these methods contributed to fundamental knowledge, they often lacked flexibility, interactivity, and the capacity to stimulate creativity. With the global emphasis on STEM (Science, Technology, Engineering, and Mathematics) education and the growing need for research-oriented competencies, Ukraine faces the urgent task of transforming its teaching methods. Innovative learning technologies serve as the bridge between conventional pedagogy and the demands of the twenty-first century, allowing educators to cultivate not only subject knowledge but also critical thinking, digital literacy, teamwork, and problem-solving abilities.The importance of these transformations becomes evident in the light of contemporary global challenges. The COVID-19 pandemic, for instance, revealed the vulnerability of traditional education systems and emphasized the necessity of flexible, technology-driven solutions. Ukrainian schools and universities, particularly those involved in natural science education, had to adapt rapidly to online platforms, digital content delivery, and virtual laboratories. This experience demonstrated both the potential of innovative technologies and the existing gaps in infrastructure, teacher preparedness, and student accessibility. Therefore, the question is not whether innovation is necessary, but rather how to design, implement, and institutionalize innovative approaches to natural science education in Ukraine in a way that ensures inclusivity, quality, and long-term sustainability.Furthermore, the modernization of natural science education in Ukraine should be analyzed in the context of international educational standards and frameworks. The European Higher Education Area (EHEA), the Bologna Process, and the United Nations Sustainable Development Goals (SDGs) all underscore the significance of science education as a driver of economic growth, social cohesion, and environmental responsibility. In particular, SDG 4 («Quality Education») directly addresses the need to ensure inclusive and equitable quality education, while SDG 9 («Industry, Innovation, and Infrastructure») emphasizes the role of science and innovation in sustainabledevelopment. For Ukraine, aligning its natural science education system with these global objectives requires the active adoption of innovative learning technologies as a core mechanism for bridging national traditions with international best practices.Another critical dimension is the psychological and motivational impact of innovation on students. Numerous studies have shown that interactive and technology-enhanced learning environments significantly improve student engagement, foster deeper comprehension, and reduce the distance between abstract theory and practical application. In natural sciences, where abstract concepts such as atomic structures, molecular reactions, or ecological systems may be challenging to grasp, the use of innovative technologies helps visualize and simulate processes that are otherwise inaccessible. For example, digital simulations of chemical reactions, three-dimensional models of human anatomy, or virtual reality explorations of ecosystems not only enhance comprehension but also ignite curiosity and inspire independent research. Thus,

innovation in education is not an end in itself but a means to cultivate creativity, inquiry-based learning, and lifelong learning habits among students.Equally important is the role of teachers as facilitators of innovation. The success of any educational reform depends on the preparedness of educators to adopt, adapt, and creatively implement new technologies. In Ukraine, this issue is particularly sensitive due to generational gaps, differencesin digital competence, and unequal access to technological resources across regions. The professional development of teachers, therefore, emerges as a decisive factor in the effectiveness of innovative learning technologies in natural science education. Investment in teacher training, digital literacy, and methodological support becomes an indispensable prerequisite for sustainable educational innovation.The integration of innovative technologies in Ukraine's natural science education system is also influenced by broader socio-political factors. On the one hand, the government has declared modernization of education as a strategic priority, introducing reforms and programs aimed at enhancing the digital infrastructure of schools and universities. On the other hand, challenges such as economic instability, regional disparities, and the consequences of military conflict create significant obstacles to consistent implementation. Nevertheless, Ukraine's active participation in international scientific cooperation, its growing IT sector, and the enthusiasm of younger generations for digital learning provide a favorable foundation for progress.The transformation of natural science education in Ukraine through innovative learning technologies represents both a challenge and an opportunity. It is a challenge because it requires systemic reforms, significant investments, and cultural shifts in teaching and learning practices. At the same time, it is an opportunity to align Ukrainian education with global standards, empower students with twenty-first-century skills, and strengthen the country's intellectual and scientific potential. This article seeks to explore the conceptual foundations, practical models, and current trends in the implementation of innovative technologies in Ukraine's natural science education. By analyzing both international experiences and domestic realities, the study aims to contribute to the theoretical understanding and practical advancement of this crucial dimension of modern education.Literature Review. In today's context of rapid digitalization and scientific advancement, the modernization of science education has become one of the most pressing challenges in Ukraine. Educational systems are expected not only to transfer factual knowledge butalso to develop learners' research, analytical, collaborative, and digital competencies. Ukrainian scholars emphasize that effective science education must integrate innovative pedagogical and technological approaches to foster these competencies (Bida etal., 2024; Chichuk et al., 2024; Chyrva & Honcharuk, 2024). Recent studies explore how digital tools, project-based learning, and competency-oriented methodologies can transform both secondary and vocational education, yet systematic models of implementation remain underdeveloped.Theoretical Approaches and Classification of Innovative Technologies. In the Ukrainian pedagogical discourse, innovative technologies are classified according to learning design, technological tools, and pedagogical purpose.

These include project-based, problem-oriented, modular, and competence-based learning frameworks, as well as digital innovations such as distance learning, virtual laboratories, and electronic educational resources (Goncharuk et al., 2024; Honcharuk & Chyrva, 2025). Studies rooted in constructivist theory argue that knowledge is actively constructed through research and experimentation, thus emphasizing project-based and laboratory learning as key to developing scientific reasoning and practical skills (Parakhnenko et al., 2025; Khytruk et al., 2024). This shift from teacher-centered to learner-centered approaches marks an essential evolution in science education philosophy.Empirical Trends and Evidence from Ukrainian Research.Ukrainian empirical research over the past five years highlights the pedagogical benefits of integrating digital platforms, STEM approaches, and interactive laboratories. The implementation of Google Classroom and Learning Management Systems (LMS) has enhanced student engagement and independent learning (Goncharuk et al., 2024). Project-based and STEM-oriented instruction has proven effective in increasing learners' motivation, critical thinking, and teamwork skills (Honcharuk et al., 2024). Furthermore, virtual simulations and augmented-reality laboratories have been shown to improve comprehension of abstract natural phenomena, particularly in chemistry, physics, and environmental studies (Khytruk et al., 2024; Parakhnenko et al., 2024). The literature also underlines the importance ofteacher professional development, noting that the digital competence of educators directly determines the success of innovation (Honcharuk et al., 2024; Kuchai et al., 2024).Barriers and Implementation Challenges.Despite notable progress, systemic barriers still hinder the large-scale adoption of innovative technologies. Studies reveal persistent inequalities in access to digital infrastructure between urban and rural schools (Goncharuk et al., 2025; Vitalii Goncharuk et al., 2025). Teacher preparedness remains uneven, as many educators lack experience with digital tools or sufficient methodological support for redesigning lessons (Honcharuk et al., 2024; Khytruk et al., 2024). Moreover, misalignment between educational standards and project-based or inquiry-based formats prevents these approaches from being fully integrated into assessment systems. Financial constraints also limit schools' ability to maintain or scale innovations beyond the pilot stage (Honcharuk et al., 2025; Parakhnenko et al., 2025).National Policies, Strategies, and Institutional Initiatives. Policy-oriented research underscores the role of state and institutional strategies in advancing educational innovation. Government initiatives related to digitalization, STEM education, and environmental education have been widely analyzed in recent publications (Parakhnenko et al., 2025; Honcharuk et al., 2024; Yuzyk et al., 2025). Scholars emphasize that long-term reform requires an integrated approach combining infrastructure investments, continuous teacher training, and open-access educational resources. Cross-sectoral collaboration between schools, universities, and private enterprises is identified as a driver of sustainable innovation ecosystems (Honcharuk et al., 2024; Parakhnenko et al., 2025). Recommendations often include establishing regional innovation hubs and professional networks for sharing best practices.Despite the extensive body of

literature on innovative teaching in Ukraine, several research gaps persist.1.Lack of longitudinalstudies—most existing research evaluates short-term outcomes of pilot projects, while long-term impacts on student achievement and teacher competencies remain insufficiently explored.2.Limited quantitative assessment—few studies employ rigorous quantitative or mixed-method designs to measure the effectiveness of innovative technologies across different contexts.3.Economic and sustainability dimensions—the financial feasibility and long-term sustainability of technological innovations are rarely analyzed in Ukrainian science education research.4.Equity and inclusion issues—the digital divide between rural and urban schools, as well as disparities among learners with different needs, requires systematic investigation.5.Integration of AI and emerging technologies—while some research examines digital platforms, the role of artificial intelligence, data analytics, and smart sensor technologies in science education remains largely unexplored. Addressing these gaps will enable future studies to move beyond descriptive analysis and contribute to evidence-based policymaking for Ukraine's educational modernization.Aims. The main aim is to analyze the current state of science education in Ukraine and substantiate the need for integrating innovative technologiesinto the educational process to enhance learners' competencies and learning outcomes.The objectives of the article are:1.Systematize the essence and classify innovative educational technologies applied in Ukrainian and international practices of teaching natural sciences (e.g., digital, interactive, project-based, and simulation/AR-VR solutions).2.Evaluate the effectiveness of digital, interactive, and project-oriented technologies in developing key competencies of pupils and students (scientific thinking, research skills, data analysis, teamwork, and digital literacy).3.Identify and justify the pedagogical conditions (curriculum design, assessment alignment, teacher professional development, infrastructure and access, ethical/data-use standards) required for successful implementation of innovative technologies within Ukraine's science-education system.Methodology.The methodological basis for the study of innovative teaching technologies in the natural science education system of Ukraine is a comprehensive approach that combines systemic, competency-based, and activity-based approaches. The systemic approach allows us to consider natural science education as a holistic educational system, where innovative technologies are a key factor in the modernization of content, methods, and forms of teaching. The competency-based approach focuses the study on the formation of subject-specific and interdisciplinary competencies in students, which are necessary for the integration of knowledge into practicalactivities. The activity-based approach ensures a focus on the active participation of students in the learning process through the use of interactive methods, digital resources, and experimental practices.A set of research methods was used to achieve the goal. Theoretical methods: analysis, synthesis, generalization, and systematization of scientific, pedagogical, and methodological literature on innovative teaching technologies; comparative analysis of Ukrainian and foreign experience in implementing modern educational practices.Empirical methods: pedagogical

observation, questionnaires, and interviews with teachers and students to determine the effectiveness of using innovative technologies in the educational process; analysis of educational programs and digital educational platforms.Methods of pedagogical experiment: testing elements of innovative technologies (STEM education, blended learning, use of virtual laboratories) in the educational process with subsequent evaluation of their effectiveness.Methods of statistical processing: quantitative and qualitative analysis of the data obtained to substantiate the conclusions of the study.Thus, the chosen methodology allows not only to identify current trends in the application of innovative technologiesin the natural science education system of Ukraine, but also to determine their impact on improving the quality of knowledge, developing critical thinking, and forming the ecological and scientific culture of students.Results. In the course of researching the implementation of innovative teaching technologies in Ukraine's natural science education system, a survey was conducted among 320 teachers from general secondary and higher education institutions, as well as 460 students and high school pupils. The results of the data processing are presented in percentage terms and reflect the current state of innovation integration into the educational process.1. Use of digital technologies in education. Figure 1 shows the extent to which teachers use digital technologies in their teaching practice, reflecting varying levels of engagement and institutional support for technology integration in science education.Figure 1. Use of digital technologies in education (teachers)Source: created by the authors based onthe results of the surveyAs shown in the chart, a vast majority of teachers (87%) actively employ digital tools in their work, confirming a strong trend toward technology-enhanced teaching. However, 9% of respondents use digital resources only partially, mainly due to insufficient institutional infrastructure, and 4% do not use them at all because of limited digital skills. These results indicate that while digitalization in education is progressing rapidly, continuous professional development and improved technical resources remain essential to ensure equitable access and full pedagogical integration of digital technologies.Among pupils and students. Figure 2 illustrates students' perceptions of digital technologies in science learning, showinghow digital tools, multimedia, and electronic resources affect their understanding, motivation, and learning balance.As illustrated, the majority of pupils and students(92%) believe that digital tools significantly enhance their understanding of naturalscience topics, while 65% report that multimedia materials increase learning motivation. However, 18% of students note that excessive use of digital resources can sometimes overload the learning process. These results confirm that technology integration is generally perceived as beneficial, yet it also emphasizes the importance of maintaining balance and ensuring pedagogically justified use of digital resources in science education.8794Actively use digital resourcesUse partially (insufficient institutional resources)Do not use (low digital competence).

Discussion. Innovative teaching technologies in Ukraine's natural science education system are becoming particularly relevant at the present stage, as they respond to new social, economic, and technological challenges. The educational

process in the field of natural sciences should not only transfer knowledge, but also develop research thinking, creativity, the ability to work with information, and apply knowledge in real-life situations. That is why the discussion around the implementation of innovative educational technologies is important and multifaceted.87103Innovations deepen understandingNo significant differenceInnovations complicate learning First of all, it should be emphasized that innovations in education are not limited to digitization or the use of modern technical means. They cover a wider range of changes, from methodological approaches to the organization of the learning environment. In science education in Ukraine, several key areas of innovation can be identified: interactive methods, project-based research activities, STEM and STEAM education, digital laboratories, blended and distance learning.One of the central issues of discussion is the effectiveness of these technologies in developing the natural science competence of pupils and students. Practice shows that the use of virtual laboratories and simulations compensates for the insufficient material resources of many educational institutions, providing the opportunity to conduct experiments that would otherwise require significant resources or be dangerous. At the same time, virtual technologies cannot completely replace «live» experiments, as practical activities in the natural sciences develop skills of observation, accuracy, and responsibility. This necessitates a combination of traditional and modern methods.Another important aspect is the training of teaching staff. The introduction of innovative technologies is only possible if teachers and lecturers not only have digital tools at their disposal, but are also able to integrate them into the learning process in a methodologically sound manner. Studies show that a significant proportion of teachers in Ukraine are open to innovation but feel the need for systematic support–improved qualifications, methodological recommendations, and the creation of a single platform for sharing experiences.Another significant challenge is the inequality in access to innovative technologies between urban and rural schools, between institutions with different financial capabilities. This problem has become particularly acute in the context of distance learning, when technical support has become a determining factor in the quality of education. When discussing this topic, it is important to bear in mind that innovation in science education should not be elitist, but rather widespread and accessible to every student, regardless of their place of residence or social status.Equally important is the issue of integrating innovative technologies in the context of a competency-based approach. Innovations should not only diversify the educational process, but also contribute to the formation of key competencies: the ability to think critically, work with information sources, and apply knowledge to solve real-world problems. In this context, project-based and research-based learning has significant potential, as it allows theory to be combined with practice andhelps students develop research skills.There is ongoing debate in scientific and educational circles about the optimal balance between traditional and innovative teaching methods. Some scholars emphasize the need for a radical overhaul of the educationalprocess,

focusing on digital technologies, adaptive platforms, and virtual environments. Others warn against excessive «virtualization» of education, stressing that without live experimentation and personal contact with the teacher, the learning process loses its depth and motivational potential. Thus, the optimal strategy is a combination that allows the strengths of each approach to be utilized.

It is also worth noting the role of innovation in increasing motivation to learn. Modern digital tools–interactive whiteboards, educational games, mobile applications–make natural sciences more accessible and understandable to young people. At the same time, there is a danger that excessive gamification may lower the academic level of education. This again requires teachers to strike a balance between innovation and traditional methods.Thus, the discussion of the problem of innovative teaching technologies in the natural science education system of Ukraine boils down to several key conclusions. First, innovations are an integral part of the modernization of education; they contribute to improving its quality and relevance to contemporary challenges. Second, the success of innovation implementation largely depends on teachers, their readiness for change,and methodological support. Third, ensuring equal access to innovation requires a state policy aimed at developing the material and technical base of educational institutions and creating a digital education infrastructure.Therefore, innovative technologies in Ukraine's natural science education system are not an end in themselves, but rather a tool for shaping modern, competent graduates who are capable of thinking scientifically and acting creatively and responsibly in the complex world of the 21st century.Conclusions. In conclusion, the implementation of innovative learning technologies in the Ukrainian education system significantly enhances the quality and effectiveness of natural sciences education. The integration of digital tools in education, e-learning, and blended learning approaches enables students to engage actively with scientific concepts, fostering a deeper understanding of STEM disciplines. Employing interactive methods and modern pedagogical technologies contributes to the development ofcritical thinking, problem-solving skills, and practical competencies essential for contemporary scientific challenges.The focus on educational innovation in natural sciences ensures that learners not only acquire theoretical knowledge but also develop practical abilities through real-world applications, particularly in environmental education. By adopting a competence-based approach, teachers can tailor learning experiences to meet individual student needs while promoting lifelong learning skills. Moreover, the combination of traditional teaching methods with advanced technological tools strengthens student motivation, collaboration, and independent research skills.Overall, the strategic incorporation of innovative learning technologies in Ukraine’s natural sciences education reflects a progressive shift towards a modern, student-centered, and competency-driven system. This transformation not only aligns with global trends in STEM education but also prepares young learners to contribute effectively to scientific development and sustainable environmental solutions. Continued investment in educational innovation, teacher training, and technology infrastructure will be crucial for ensuring the long-term

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