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«Тілдерді оқытудың инновациялық тәсілдері: теория мен практиканы ұштастыру» атты II көктемгі халықаралық ғылыми-практикалық конференция материалдар жинағында шетел тілдерін оқыту саласындағы озық тәжірибелермен алмасуға, мәдениетаралық қарым-қатынасты нығайтуға, цифрлық дәуір жағдайында шетел тілдерін оқытудағы инновациялық технологияларды таратуға, сондай-ақ халықаралық ғылыми-академиялық ынтымақтастықты кеңейтуге бағытталған ғылыми-практикалық зерттеулердің нәтижелері енгізілген. Материалдарда білім алушылар мен жас ғалымдардың осы бағыттағы зерттеулерге белсенді қатысуын ынталандыру мәселелері қарастырылған.

В сборник материалов II весенней международной научно-практической конференции «Инновационные подходы преподавания языков: слияние теории и практики» включены результаты научно-практических исследований, направленных на обмен передовым опытом в области преподавания иностранных языков, укрепление межкультурной коммуникации, распространение инновационных технологий обучения в условиях цифровой эпохи, а также расширение международного научно-академического сотрудничества. В материалах рассматриваются вопросы стимулирования активного участия обучающихся и молодых ученых в исследованиях в данной области.

The proceedings of the II Spring International Scientific and Practical ONLINE Conference "Innovative Approaches of Language Teaching: Bridging Theory and Practice" include the results of scientific and practical research aimed at sharing advanced experience in foreign language teaching, strengthening intercultural communication, disseminating innovative teaching technologies in the digital age, and expanding international scientific and academic cooperation. The materials also address issues related to encouraging the active participation of students and young researchers in this field.

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II Spring International Scientific and Practical ONLINE Conference "Innovative Approaches of Language Teaching: Bridging Theory and Practice"

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The Main Themes of the Conference:

1. Teaching foreign languages for professional and interdisciplinary purposes.
2. Innovative technologies in foreign language teaching methodology.
3. Language training in the context of multilingualism and lifelong learning.
4. Language education based on digital technologies and artificial intelligence.

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INNOVATIVE METHODS OF TEACHING CHEMISTRY USING ARTIFICIAL INTELLIGENCE: COMBINING THEORY AND PRACTICE

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Introduction

The current stage of scientific development is characterized by the active integration of artificial intelligence (AI) into diverse research domains, including chemistry education. Global digitalization trends, as reflected in UNESCO strategic documents, underscore the necessity of training specialists proficient in advanced technologies [1]. The integration of AI into the educational process is becoming a key factor in building the competencies of future experimental chemists. This approach aligns with international standards of innovative pedagogical design. Of particular relevance is the development of adaptive learning systems capable of simulating real chemical processes in virtual environments. Such solutions make it possible to overcome the geographical and resource constraints inherent in traditional education. Recent research demonstrates improved material acquisition rates when interactive simulations are used, confirming the promise of this direction [2]. These findings create preconditions for the transformation of educational paradigms in the natural sciences.

Traditional chemistry teaching confronts systemic challenges, including a deficit of laboratory equipment and difficulties in demonstrating abstract concepts. Students find topics related to quantum-chemical representations of molecular and crystal-lattice structures particularly demanding. Limited means for visualizing molecular orbitals or the mechanisms of complex reactions create a cognitive barrier between theoretical knowledge and its practical application. These factors negatively affect student motivation and depth of understanding [3]. The problem is compounded by the inflexibility of classical educational models, which adapt poorly to individual learning differences. Standardized laboratory sessions frequently fail to account for varying levels of student preparation, leading to a formalized learning process. Consequently, a substantial gap forms between foundational knowledge presented in classical textbooks and contemporary demands for experimental skill. Bridging this imbalance requires fundamentally new methodological solutions.

The aim of this study is to develop an innovative educational model that synthesizes classical theoretical approaches with adaptive AI-based tools. The proposed methodology is designed to foster a holistic understanding of chemical processes through interactive simulations of molecular interactions. The concept rests on the integration of fundamental principles from the works of leading chemists with the capabilities of modern digital platforms for visualization and modelling.

To achieve this aim, four research objectives were formulated. First, a critical analysis of the limitations of traditional chemistry teaching methods is conducted in the context of theory-practice integration. Second, the architecture of AI-based virtual laboratories capable of simulating chemical processes in real time is developed, with particular attention to the design of adaptive learning scenarios for students of varying preparation levels. Third, digital tools — Avogadro and ChemDoodle 3D — are trialled on complex curriculum topics such as three-center four-electron bonds and crystal-lattice structures. Fourth, the effectiveness of the proposed model is evaluated through material-acquisition metrics, and recommendations for scaling the approach are formulated.

The methodological basis of the study is a combination of LLM-based tutors for personalizing the educational process and virtual laboratories (PhET, Labster) that simulate molecular interactions. The platforms employed are integrated into the curricula of Kazakhstan universities, ensuring continuity with classical didactic principles. This approach preserves the rigour of chemistry education while simultaneously introducing innovative technologies commensurate with the challenges of the contemporary educational environment.

Research methods

Virtual Laboratories for Modelling Molecular Interactions: Overview of Tools (PhET, Avogadro, ChemDoodle 3D)

The PhET Interactive Simulations platform (University of Colorado Boulder) provides interactive simulations for visualizing fundamental chemical processes. The simulations cover a broad range of topics, from atomic structure to chemical reaction kinetics. Interactive controls allow experimental parameters to be varied in real time. Platform accessibility through a web browser ensures its wide adoption in educational institutions [4]. A distinctive feature of PhET is its implementation of the discovery-learning principle, promoting independent student enquiry. For example, the Build an Atom simulation vividly demonstrates how changes in the number of protons and neutrons affect element properties. Such tools are especially effective for building understanding of chemical bonding and intermolecular interactions. Research confirms increased student motivation when interactive simulations are incorporated into instruction.

Avogadro is oriented towards precise molecular structure modelling and analysis of geometric parameters. Automatic geometry-optimization algorithms yield energetically stable molecular configurations. Integration with quantum-chemical packages extends the possibilities for calculating electronic properties of compounds [5]. These functions make Avogadro an indispensable tool for studying stereochemistry and conformational analysis. Advanced features include visualization of molecular orbitals and electrostatic potentials. Users can conduct comparative analysis of the energy characteristics of different isomers or reaction intermediates. Support for XYZ and PDB file formats ensures compatibility with other computational platforms, enabling the software to serve both educational and research purposes.

ChemDoodle 3D specializes in creating highly detailed three-dimensional molecular models. Its intuitive interface enables the rapid construction of complex organic and inorganic compounds. Realistic visualization encompasses ball-and-stick, space-filling, and wireframe representations. The tool supports interactive rotation of structures for examining the spatial arrangement of atoms. An important function of ChemDoodle 3D is the analysis of stereochemical interactions, including chirality and conformational transitions. The ability to export models in 3D-PDF and VRML formats broadens their application in education. The programme allows the dynamics of molecular systems to be modelled, demonstrating changes in geometry over time — making it an effective instrument for studying reaction mechanisms.

Integration of AI Platforms and Virtual Laboratories: Creating an Adaptive Learning Environment

The architectural integration of AI algorithms with virtual laboratories is grounded in the principles of modularity and scalability. A key aspect is the development of unified interaction interfaces between simulation systems and AI components. Such architecture enables bidirectional real-time data exchange, ensuring continuous adaptation of the learning process. Technical implementation of synchronization uses specialized APIs and middleware solutions that ensure platform compatibility [6]. For example, integration modules for PhET and Avogadro employ IMS LTI and xAPI standards for transmitting user-action data. This allows AI systems to receive structured information about the progress of experiments and to adjust instructional scenarios accordingly. Stream data from virtual laboratories are processed through distributed computing systems, minimizing latency. Machine learning algorithms analyze experimental parameters — time on task, measurement accuracy, and action sequence. On the basis of this analysis, the system dynamically optimizes task difficulty and provides contextual hints.

Personalization of instructional scenarios is achieved through continuous analysis of students' cognitive patterns. The AI performs dynamic analysis of the learner's language proficiency, learning style, rate of progress, and typical errors,

automatically adapting the content and difficulty of materials [7]. The system classifies learners by preparation level using cluster analysis of task-performance data. In chemistry education, adaptive algorithms adjust the parameters of virtual experiments based on diagnosed difficulties. For example, when problems with stereochemistry visualization are detected, the system offers additional 3D models in Avogadro or adjusts the level of detail in ChemDoodle 3D. Such differentiation ensures an optimal balance between theoretical complexity and practical orientation of tasks.

Methodology for Evaluating the Effectiveness of Innovative AI-Assisted Chemistry Teaching

Evaluation of the effectiveness of innovative AI-assisted chemistry teaching requires a comprehensive approach combining quantitative and qualitative criteria. Quantitative indicators include results from standardized tests on theoretical chemistry sections and practical-task completion in virtual laboratories. Achievement analysis enables objective measurement of the level of mastery of fundamental concepts such as atomic structure and chemical bonding. These data serve as the basis for comparing traditional and innovative teaching methods [8].

Qualitative criteria focus on the development of practical molecular-modelling skills and the interpretation of experimental data. Structured observation of student work in PhET and Avogadro simulators is used for this purpose. Questionnaires and in-depth interviews are additionally conducted to identify changes in motivation and cognitive engagement. This approach makes it possible to assess not only academic results but also the formation of research competencies.

Data collection is carried out through comparative analysis of control and experimental groups using pre-tests and post-tests. Control groups are taught by the traditional method relying on classical textbooks, while experimental groups work with AI tutors and virtual laboratories. Pre-tests record baseline knowledge before the experiment begins, and post-tests measure progress after completion of the instructional module [9]. Experimental protocols include tasks involving the modelling of xenon fluoride molecular structures in ChemDoodle 3D and the analysis of their reactivity. Data are automatically captured by the Labster and PhET platforms, excluding subjective assessment bias. To minimize external factors, groups are formed by random sampling with reference to baseline performance. The duration of the experiment covers a full semester, allowing long-term effects of AI-tool implementation to be tracked.

Statistical processing of data includes correlation analysis between AI-platform use and student academic achievement. Student's t-test with a 95% confidence interval is used to assess the significance of differences between groups. Regression models help to identify the influence of individual AI-system components — adaptability and feedback — on final learning outcomes. The resulting metrics serve as the evidential basis for demonstrating the effectiveness of the proposed innovative methods.

Table 1. AI Tools Used in Chemistry Education: Comparative Overview

AI Tool / Platform	**Application in Chemistry Teaching**	**Concrete Examples of Use**	**Key Pedagogical Benefit**
PhET Interactive Simulations (Univ. of Colorado)	Visualization of atomic structure, bonding, kinetics	"Build an Atom": students alter proton/neutron count and observe element properties in real time	Discovery learning; improves conceptual grasp of abstract quantum models
Avogadro 2 (open-source)	Molecular modelling, orbital visualization, conformational analysis	Geometry optimization of XeF_4; comparison of isomer energies; electrostatic-potential maps	Bridges theory and 3-D spatial understanding; compatible with QM packages
ChemDoodle 3D (iChemLabs)	Stereo-chemistry, reaction mechanisms, crystal lattices	Rendering linear XeF_2 vs octahedral XeF_6; animation of conformational transitions	Intuitive interface; export to 3D-PDF/VRML for assignments and reports
Labster (cloud virtual lab)	Synthesis protocols, spectroscopy, safety training	Virtual NMR/IR spectroscopy; transition-metal salt synthesis with automated yield feedback	Safe rehearsal of hazardous experiments; instant analytical feedback; no equipment cost
LLM-based AI Tutors (e.g., GPT-4 / Khanmigo)	Personalized explanations, adaptive feedback, error diagnosis	Tutor detects stoichiometry errors and provides targeted Socratic hints; adjusts difficulty in real time	Available 24/7; reduces cognitive load; supports students of varying preparation levels
Adaptive ITS (e.g., ALEKS Chemistry)	Bayesian knowledge tracing, mastery-based progression	Maps each student's knowledge state across 600+ topics; selects optimal next task	Maximizes individual learning gain; documented +0.47 SD exam advantage [6]
Machine Learning Analytics (Gradescope AI, ChemML)	Automated grading, reaction-yield prediction, performance analytics	CV algorithms identify NMR patterns; regression reveals kinetic-curve regularities; auto-	Objectivizes assessment; reduces marking load; identifies at-risk students early

		generated improvement reports	

Results and discussion

Visualization of Fundamental Concepts of Atomic Structure and Chemical Bonding Theory (based on J. Huheey) Using PhET Simulations

PhET simulations provide tools for the interactive study of quantum-mechanical atomic models. They visualize the distribution of electron clouds and energy levels in a dynamic mode. Students can alter the parameters of atomic systems and observe corresponding changes in electron configuration [10]. This approach promotes the formation of accurate representations of the probabilistic character of electron distribution. Energy diagrams and three-dimensional orbital models in PhET allow theoretical propositions to be paired with intuitive images. Students are given the opportunity to explore the Pauli exclusion principle and Hund's rule in an interactive format. Visualization of transitions between energy levels during photon absorption or emission reinforces understanding of the quantum nature of the atom, establishing a foundation for the meaningful assimilation of complex abstract concepts.

PhET simulations demonstrate the mechanisms by which different types of chemical bonds form through interactive models. Covalent bonds are visualized as the overlap of atomic orbitals to form shared electron pairs. Ionic interactions are represented through models of electron transfer and electrostatic attraction. Metallic bonding is illustrated as a delocalized "electron sea" between metal cations. Comparative analysis of bond types in PhET corroborates the theoretical positions set out in the works of J. Huheey [3]. Interactive models allow the dependence of compound properties on bond character to be observed. Visualization of energy curves as atoms approach one another demonstrates the balance of attractive and repulsive forces, providing a deep understanding of the fundamental principles of chemical bonding on an experimental-theoretical basis.

Modelling Molecular Structures and Reactions with Avogadro and ChemDoodle 3D: the Xenon Fluoride Case Study

The Avogadro and ChemDoodle 3D software packages provide tools for the precise construction of three-dimensional models of xenon fluorides. These platforms enable visualization of the spatial arrangement of atoms and the electronic structure of compounds [11]. Particular attention is paid to analysis of the geometric parameters of molecules, including bond lengths and valence angles. Visualization of stereochemical features contributes to better understanding of chemical behavior. The xenon fluoride case demonstrates the programmes' capabilities for rendering different types of molecular geometry. The linear structure of XeF_2, the square-planar structure of XeF_4, and the octahedral structure of XeF_6 are visualized with account taken of atomic orbital hybridization. Three-dimensional models allow analysis of electron density distribution and steric effects, providing a clear representation of the relationship between molecular structure and reactivity.

Modelling the synthesis reactions of xenon fluorides in Avogadro and ChemDoodle 3D reveals the influence of conditions on compound stability. The programmes allow temperature, pressure, and reagent concentrations to be varied for studying thermodynamic parameters. Visualization of transition states helps to understand the mechanisms of XeF_2, XeF_4, and XeF_6 formation. Analysis of reaction energy profiles demonstrates the dependence of product yields on external factors [12]. Kinetic studies using these tools reveal the specific features of xenon fluorination reactions. Modelling shows differences in compound formation rates under direct elemental interaction and catalytic processes. Visualization of molecular collisions and activation barriers explains the selectivity of synthesis, enabling prediction of optimal conditions for obtaining target compounds with account taken of their thermodynamic stability.

Virtual Experiments in Synthesis and Spectroscopy with Labster: Deepening Understanding

The Labster platform provides virtual laboratory sessions that accurately replicate inorganic compound synthesis techniques. Students can adjust key reaction parameters, including temperature, reagent concentration, and reaction time. The system automatically calculates theoretical and actual product yields, demonstrating how results depend on chosen conditions [13]. This approach enables students to rehearse synthesis techniques without the risk of errors characteristic of real laboratories. Virtual experiments include modules on the synthesis of complex compounds and transition-metal salts. Each simulation is accompanied by detailed instructions and the possibility of repeating reaction steps multiple times. The platform records deviations from the protocol and provides analytical feedback, building learners' skills in precise control of chemical process parameters.

Spectroscopic modules in Labster train students to interpret IR and NMR spectra for structural determination of synthesized compounds. Students work with virtual spectrometers, adjusting measurement parameters and analyzing the resulting data. The system generates spectra with characteristic signals corresponding to functional groups and atomic nuclei. This approach develops structural-analysis skills essential for research work.

Application of AI Tutors to Support Practical Sessions and Result Analysis

AI tutors demonstrate high effectiveness in providing targeted support to students during chemistry laboratory sessions. Deep-learning-based systems analyze learner actions in real time and deliver personalized recommendations for correcting synthesis techniques [7]. This makes it possible to minimize typical errors related to reagent dosing or temperature control. The adaptive nature of the hints promotes the formation of correct practical skills without direct instructor intervention.

Machine learning enables automated processing of experimental data obtained during practical sessions. Computer vision algorithms identify patterns in NMR and IR spectra, while regression models reveal regularities in reaction kinetic curves. Such analytics objectivize the assessment of student results, reducing marking time. AI-based systems generate detailed reports indicating areas for improvement in experimental techniques.

Recommendations for Further Development and Scaling of AI-Integrated Educational Models

Optimizing AI algorithms for educational purposes requires expansion of training datasets. Existing models demonstrate limited effectiveness in explaining rare chemical processes and compounds due to insufficient representativeness of training samples [14]. The inclusion of specialized cases — such as noble-gas reactions or exotic coordination compounds — will improve prediction accuracy and AI-system explainability. This is particularly relevant for advanced chemistry courses where traditional visualization methods encounter conceptual difficulties. Building expanded training datasets should involve collaboration with research centers and industrial laboratories.

Scaling of the models entails the development of cloud platforms with open access for integration into university educational programmes [8]. Implementation of such solutions must account for bandwidth and data-security requirements when operating virtual laboratories. A key aspect is ensuring cross-platform compatibility to support different operating systems and devices. Standardization of interfaces will simplify the integration of AI components into existing educational ecosystems.

Conclusion

The integration of artificial intelligence into chemistry teaching has made it possible to overcome the key limitations of traditional instructional methods associated with a deficit of laboratory equipment and the difficulty of visualizing molecular processes. The deployment of adaptive virtual laboratories and LLM-based AI tutors has created conditions for the effective combination of theoretical knowledge with practical skills, fulfilling the original research aim of developing an innovative model enabling deep understanding of chemical reactions through real-time simulations.

The practical application of digital tools — PhET, Avogadro, and ChemDoodle 3D — in combination with AI platforms demonstrated improved mastery of complex topics such as electron configurations and three-center bonds. Pilot implementations in Kazakhstan universities confirmed that modelling the molecular structures of xenon fluorides and crystal lattices improves students' spatial reasoning. The verification results are consistent with the research objectives directed at integrating classical

instructional approaches with modern technologies.

The developed hybrid instructional model is recommended for scaling within the higher education system, with emphasis on the synthesis of foundational theories from established chemistry textbooks with interactive AI tools. Successful implementation requires adaptation of curricula and enhancement of teachers' digital competency. The proposed educational process architecture closes the gap between abstract knowledge and its practical application, identified at the outset as the central problem.

Prospects for model development are associated with the creation of personalized AI algorithms for predicting educational trajectories and the expansion of virtual laboratory capabilities in the field of quantum-chemical modelling. These directions align with the global digitalization trends in education cited in the rationale for this work. Further research may deepen the integration of artificial intelligence technologies with classical pedagogical approaches, thereby amplifying the outcomes of the objectives originally set.

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ИННОВАЦИОННЫЕ ПОДХОДЫ К ФОРМИРОВАНИЮ ЛЕКСИЧЕСКОЙ КОМПЕТЕНЦИИ У СТУДЕНТОВ ЯЗЫКОВЫХ ВУЗОВ ПОСРЕДСТВОМ МОБИЛЬНЫХ ПРИЛОЖЕНИЙ

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Аннотация

В статье анализируются инновационные подходы к формированию лексической компетенции у студентов языковых вузов посредством мобильных приложений. Аргументируется значимость введения в образовательный процесс мобильного обучения при цифровизации. Даются определения «лексической компетенции» и «мобильного обучение (M-learning)». Значительное внимание акцентируется на психологических механизмах усвоения лексики, включая метод интервального повторения и эффект кривой забывания. Изучается вклад геймификации и цифровых технологий в увеличении продуктивности усвоения лексического материала. Формируется вывод о том, что мобильные приложения могут использоваться как эффективный инструмент при развитии лексической компетенции .

Ключевые слова: лексическая компетенция, мобильное обучение, M-learning, цифровые технологии, геймификация, интервальное повторение, изучение лексики, иностранный язык.

Введение

Процессы изучения и обучения иностранным языкам в последние годы