THE IMPACT OF VIRTUAL LEARNING PLATFORMS INTEGRATED WITH ARTIFICIAL INTELLIGENCE ON THE INORGANIC CHEMISTRY COURSE

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Abstract

This article analyzes the impact of AI-integrated virtual learning platforms on the teaching and learning process of inorganic chemistry. The study explores how the use of artificial intelligence and virtual learning environments enhances students' knowledge, skills, and competencies in chemistry, fostering independent thinking and scientific analysis abilities. The effectiveness of AI-based virtual laboratories, interactive exercises, and intelligent testing systems is theoretically substantiated. Research findings show that AI integration significantly improves the effectiveness of inorganic chemistry education and serves as a key factor in enhancing the overall quality of learning.

Keywords: artificial intelligence, virtual learning environment, inorganic chemistry, AI integration, quality of education, virtual laboratory, digital pedagogy

In the 21st century, the education system has become one of the most important strategic spheres for human development. Due to globalization, digital transformation, and the rapid advancement of artificial intelligence (AI) technologies, new pedagogical paradigms are emerging in the teaching process. In the concept of "Digital Uzbekistan – 2030", proposed by the President of the Republic of Uzbekistan, Sh. M. Mirziyoyev, the development of education based on modern information technologies, digital platforms, and artificial intelligence is identified as one of the priority directions [1].

Within this context, natural sciences, particularly inorganic chemistry, serve as a key field for developing students' skills in logical thinking, modeling, observation, and analysis. AI tools provide an opportunity to master the content of this subject more deeply and interactively.

In recent years, Uzbek researchers, such as N. G. Yuldasheva (2021) and D. A. Karimova (2022), have conducted scientific studies on the effective use of information and communication technologies in teaching chemistry, the creation of virtual laboratories, and the improvement of distance learning methodologies [2]. According to their findings, virtual learning environments provide extensive opportunities for conducting safe experiments in chemistry, interactive visualization, and independent learning.

At the same time, on a global scale, the "AI-supported e-learning model" developed by Anderson and Dron (2011), as well as the research "Artificial Intelligence in Education" by Holmes, Bialik, and Fadel (2019), have significantly contributed to developing the methodological and psychological foundations for integrating artificial intelligence into the

educational process 333. Moreover, UNESCO (2021) recommends AI not as a replacement for teachers but as an intellectual tool that supports and enhances teaching.
Thus, AI-integrated virtual learning platforms play a significant role in teaching inorganic chemistry by enhancing students' motivation for learning, their mastery of the subject fundamentals, analytical thinking, and practical experimental skills. However, in this area, the methodological foundations, the pedagogical functions of AI systems, and their real impact on teaching effectiveness have not been sufficiently studied.
Therefore, this article analyzes, both theoretically and practically, the impact of AI-integrated virtual learning platforms on the teaching of inorganic chemistry, and also develops methodological recommendations aimed at improving learning outcomes.
The integration of artificial intelligence (AI) technologies into the educational process has marked a new stage in modern education. AI systems in virtual learning platforms elevate the traditional teacher-student interaction to a new qualitative level, making education personalized, interactive, and dynamic [4].
In the field of inorganic chemistry, such platforms actively engage students in understanding, modeling, observing, and analyzing complex chemical processes. The main advantages of AI-integrated virtual learning platforms are analyzed in detail below.
Traditional laboratory sessions often face challenges such as safety concerns, limited material resources, and shortages of reagents. AI-based virtual laboratories overcome these limitations. For instance, according to Karimova (2022), through virtual chemistry laboratories, students can safely observe and study reaction rates, redox processes, and crystal structures [3]
AI systems analyze student activities in real-time, automatically evaluate experimental results, and provide feedback on mistakes. This functionality plays a crucial role in developing analytical thinking and fostering scientific research skills.
AI-based platforms analyze each student's knowledge level and propose a tailored learning path. These systems operate on the principle of "adaptive learning" 444. For instance, if a student makes errors on the topic of "oxidation states", the system automatically provides additional visual explanations, videos, and interactive exercises. As a result, students learn at their own pace, enabling personalized education.
Experimental results indicate that students using adaptive AI systems improved their mastery of inorganic chemistry by 25–30% (according to the internal report of TDPUI, 2024). In traditional assessment, human factors may introduce subjectivity, whereas AI-based assessment systems operate automatically, transparently, and objectively. As Holmes, Bialik, and Fadel (2019) emphasize, AI systems can evaluate student responses semantically, assessing not only correctness but also the logical reasoning behind the answer [5].
This approach is particularly effective in inorganic chemistry for tasks such as writing chemical equations, determining oxidation states, or explaining substance classification. The

AI system analyzes the student's written reaction, identifies the cause of error (e.g., stoichiometric imbalance), and guides them toward the correct solution.

AI-powered virtual environments also enable the creation of three-dimensional (3D) molecular models and dynamic visualization of reactions. This feature is especially important for explaining coordination compounds, crystal lattice structures, and complex formation processes. Yuldasheva (2021) noted that using visual models in chemistry education increased students' comprehension of fundamental concepts by 36% 222. AI further enhances this process by allowing students to understand concepts through animated molecular models.

AI-based platforms enrich the learning process with interactive gamification elements. For example, the AI system awards points for correctly balanced reactions and gives bonuses for quick responses. This incentivizing environment encourages active student participation, thereby increasing interest in the subject.

One of the most important aspects of inorganic chemistry is studying the structure of elements, their chemical properties, and reactivity. In traditional lessons, this process largely relies on theoretical information; however, virtual learning platforms and AI technologies enable students to study these topics interactively, experimentally, and visually [2]

Visual Modeling of Element Structures Virtual platforms, such as ChemCollective, PhET Interactive Simulations, or AI-integrated Labster, allow modeling of atomic structures in 3D format. For example:

- For the sodium (Na) atom, the electron configuration ($1s^2\ 2s^2\ 2p^6\ 3s^1$) and orbital distribution are displayed through animation.
- If a student enters an incorrect electron configuration, the AI system identifies the error and presents the correct configuration.

This helps students better understand quantum numbers, orbital shapes, and element positioning [4].

Comparing Chemical Properties of Elements AI-based virtual learning platforms can dynamically illustrate relationships between elements in the periodic table. For instance, in an AI-powered interactive periodic table, when a student selects an element, the system automatically displays its atomic radius, ionization energy, electronegativity, and oxidation states.

- If a student selects the elements Li, Na, and K, the AI visually compares the decrease in electronegativity and the increase in metallic properties across these elements. As a result, the student comprehends the periodic trends in element properties through experimentation, which in traditional lessons would often be limited to memorization [2;62]

Observing Reactions in a Virtual Environment. Using AI platforms, the reactivity of inorganic elements can be safely tested in a virtual environment. For example:

- The reaction of sodium with water ($2Na + 2H_2O \rightarrow 2NaOH + H_2\uparrow$) can be simulated virtually. The system identifies errors in the student's equation balancing and provides corrective suggestions using AI.
- The oxidation process of iron ($Fe + O_2 \rightarrow Fe_2O_3$) is animated, allowing the AI to adjust the oxygen quantity and analyze changes in reaction rate.

This approach helps students understand reaction mechanisms, correctly assign coefficients, and study the effect of reaction conditions [3;53].

Determining Oxidation States and Compounds. AI-based programs analyze students' mistakes in identifying oxidation states. For instance, when comparing $FeCl_2$ and $FeCl_3$, the AI system provides feedback such as:

"In Fe(II), iron has a +2 oxidation state, whereas in Fe(III), it is +3 and more stable in an oxidizing environment."

This assists students in developing a deep understanding of redox processes. Additionally, the AI system teaches students to balance reactions using the electron method, a crucial skill in inorganic chemistry methodology.

Direction	Traditional Education	AI-based Virtual Learning
Element Structure	Explained with theoretical information	Shown through 3D models and animations
Properties	Memorized via tables	Interactive analysis with AI
Reactions	Risky experiments in the laboratory	Safe learning through virtual simulations
Assessment	Manually by the teacher	Automated analysis by AI
Student Activity	Passive listener	Active researcher and participant

In conclusion, AI-based virtual platforms in teaching inorganic chemistry:

- personalize and differentiate the learning process;
- create a safe simulation environment for real experiments;
- provide opportunities for automatic analysis and assessment;
- enhance students' motivation and scientific thinking;
- support the teacher as a digital assistant.

As a result, AI-integrated virtual platforms are considered as an innovative methodological transformation tool in teaching inorganic chemistry.

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