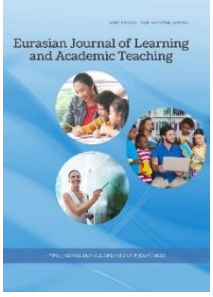

Prospects Of Using Artificial Intelligence In Providing Chemical Education To Young Engineers-Technologists

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ABSTRACT

This article analyzes the didactic and practical possibilities of using artificial intelligence (AI) in teaching chemical knowledge to young engineering technologists. The digitization of modern production processes, the complexity of technological processes, and the need to work with large amounts of data require engineering technologists to have not only fundamental chemical knowledge, but also digital and artificial intelligence competencies. The study examined the possibilities of AI tools for explaining chemical reactions, performing stoichiometric calculations, analyzing technological parameters, organizing individual training, modeling problem situations, and developing independent learning skills of young specialists. The analysis substantiated the feasibility of using AI in the process of imparting chemical knowledge not as a substitute for a teacher and engineer, but as an intellectual assistant supporting knowledge acquisition, analysis, and solving practical problems.

Keywords: artificial intelligence, engineer-technologist, chemical knowledge, generative artificial intelligence, chemistry education, digital competence, technological process, individual education, AI literacy, engineering education.

1. Introduction

The rapid development of industry and the digitalization of production processes are leading to a significant change in the professional requirements for engineering technologists. Especially in production related to chemical processes, a technologist is required to know the physical and chemical properties of substances, understand the laws of chemical reactions, control technological parameters and assess production efficiency, as well as the skills to use digital technologies. If you ask a qualified young engineer what disciplines are best to acquire in order to become a qualified specialist in this field, he will certainly answer as follows:

• **Mathematics** — one of the most important subjects for calculations, formulas, graphs and engineering problems.

• **Physics** — to understand the processes of mechanics, electricity, heat, pressure and energy.

• **Chemistry** — especially in food, chemical, oil and gas, pharmaceutical or materials technology.

• **Drawing geometry and engineering graphics** — to read and create drawings of parts and devices.

• **Computer science** — for CAD programs, modeling, calculations and automation.

• **Mechanics and materials science** — to understand how machines and structures work, the properties of materials.

• **Technological processes** — to learn how products are manufactured, how equipment is selected and how the process is controlled.

• **English** — is very useful for studying modern technical literature, programs and international standards. Of course, the role of **Artificial Intelligence (AI)** is also incomparable in today's demands. The rapid development of digital technologies in the education system in recent years has required a fundamental renewal of subject teaching methodologies.

In particular, the introduction of artificial intelligence (AI) technologies into the educational process allows for the modernization of traditional teaching approaches, individualization of students' learning processes, and increased educational efficiency. Since chemistry involves complex theoretical concepts, abstract processes, and numerous practical experiments, the use of modern technologies in the education of this subject is particularly relevant.

When analyzing scientific sources, it is clear that the use of artificial intelligence in teaching chemistry has developed significantly over the past decade. For example, Johnson et al. (2021) proposed a safe and interactive teaching model through laboratory simulations. This model allows students to work in a virtual environment similar to real experiments. At the same time, it allows for monitoring the individual learning speed of students and assessing results in real time. The resolution of the President of the Republic of Uzbekistan No. PQ–4996 dated February 17, 2021 established the development of artificial intelligence technologies at the level of state policy. Z.Z.Yakhshiyeva, Polatova S.O (2025) in their article “The role of artificial intelligence in the study of chemistry” At present, artificial intelligence technologies are making the process of studying chemistry modern, convenient and effective. With the help of artificial intelligence, the possibility of modeling complex chemical processes, predicting reactions and conducting virtual experiments is being created. This serves to deepen students' knowledge of science, facilitate analysis and research work, and shed light on such scientific ideas. Askarova N.A. and Sattarova D.M. (2026) in their article “Prospects for the use of artificial intelligence in teaching chemistry” analyzed the modern prospects for the use of artificial intelligence (AI) technologies in teaching chemistry. The work discusses the possibilities of artificial intelligence for individualizing the learning process, simulating laboratory work, conducting experiments in a safe environment, Artificial intelligence (AI) is one of the technologies that allows for large-scale data processing, pattern recognition, prediction, modeling, and individualization of the educational process in these processes. UNESCO emphasizes the need for generative AI to be used in education and scientific research in a human-centered, safe, ethical, and pedagogically based manner.

The issue of AI in chemistry education is also becoming a rapidly developing research area. In the analysis published in the Journal of Chemical Education in 2025, it was noted that, along with the pedagogical potential of generative AI tools in chemistry education, their rapid development and the need for regular revision of their methods of use are noted.

One of the important problems for young engineers-technologists in mastering chemical knowledge is the connection of theoretical knowledge with production processes. For example, knowing the equation of a chemical reaction is not enough. A specialist must be able to explain the effect of reaction rate, temperature, pressure, concentration, catalyst, heat transfer, and other factors on the technological process. In this context, SI tools are important as an additional educational tool that connects theory and practice automatically assessing the level of knowledge of students, and creating interactive educational materials.

The use of artificial intelligence in imparting chemical knowledge to young engineering technologists is very important, because in modern production, a technologist must know not only theoretical chemistry, but also how to analyze large amounts of data, optimize processes, and ensure safety.

Important prospects for using artificial intelligence:

1. Simple explanation of complex chemical concepts Artificial intelligence can explain topics such as reaction mechanisms, properties of substances, thermodynamics, and kinetics in accordance with the level of knowledge of a young specialist.
2. Analysis of chemical reactions AI can help in constructing reaction equations, performing stoichiometric calculations, and analyzing the effect of reaction conditions on the product.
3. Individual learning opportunities Each young engineer has a different level of knowledge. AI

can act as an individual teacher by identifying errors, providing additional examples and exercises.

4. Optimization of production processes Helps to organize the technological process more efficiently by analyzing data on temperature, pressure, concentration, consumption and other parameters.

5. Teaching how to solve practical problems For example, you can learn through various scenarios how product quality changes when the composition of raw materials changes or how to increase reaction yield.

6. Occupational safety AI is useful for identifying hazards when working with chemicals, explaining safety rules and creating training seminars on emergency situations.

7. Adapting to modern technologies AI, automation, data analysis and digital modeling skills are becoming increasingly important for today's engineer-technologist.

Important aspect

Artificial intelligence should not completely replace a chemistry teacher or an experienced engineer. Especially in matters related to chemicals, reactors and industrial safety, it is necessary to verify the information provided by AI with textbooks, technical regulations, SDS documents and expert recommendations.

The purpose of the study is to scientifically and methodologically substantiate the necessity, didactic possibilities and conditions for effective application of artificial intelligence in the process of imparting chemical knowledge to young engineering technologists.

The objectives of the study are:

• to determine the place of chemical knowledge in the training of engineering technologists;

• to analyze the capabilities of SI tools in chemistry education;

• to demonstrate the capabilities of SI in supporting the individual education of young engineers;

• to propose a model for teaching chemical and technological issues using SI;

• to identify the pedagogical and technical risks of using SI;

• to develop methodological recommendations for developing SI literacy for engineering technologists. The table below shows information about the capabilities of SI in the process of providing knowledge in chemistry to young engineering technologists.

Table 1. SI opportunities in providing chemical knowledge to young engineering technologists.

№	Directions for using SI	Educational tasks	Expected pedagogical result
1.	Explanation of chemical reactions	Explaining the reaction mechanism and conditions	Consolidation of theoretical knowledge
2.	Chemical calculations	Step-by-step explanation of stoichiometric and technological calculations	Development of computational competence
3.	Individual learning	Giving tasks appropriate to the student's level of knowledge	Increase in the effectiveness of independent learning
4.	Modeling of technological processes	Analyzing parameters such as temperature, pressure, concentration	Development of technological thinking

5.	Problem-based learning	Modeling real production situations	Formation of problem-solving skills
6.	Virtual experiments	Studying chemical processes in a safe environment	Enrichment of practical knowledge
7.	Control of knowledge	Creating tests, questions, and tasks	Provision of immediate feedback
8.	Professional competence	Analyzing technological data	Formation of modern engineering competence

METHODS — RESEARCH METHODS

The methodological basis of the study was the analysis of scientific and methodological sources on the use of modern pedagogical technologies, digital education, chemistry education and artificial intelligence.

The following methods were used in the study:

Theoretical analysis. Scientific sources on artificial intelligence, generative AI, chemistry education and engineering competencies were studied.

Comparative method. The possibilities of traditional chemical education and education organized using AI were comparatively analyzed.

Modeling method. A conditional educational model of using AI in imparting chemical knowledge to young engineering technologists was developed.

Pedagogical analysis. The possibilities of AI tools in individual education, independent education, problem-based learning and practical exercises were assessed.

Content analysis. The main directions in modern scientific articles devoted to the use of AI in chemistry education were analyzed. In particular, research in 2024–2026 shows the development of such areas as AI literacy, critical appraisal, prediction of molecular properties, reaction optimization, and data mining in chemistry education.

The study considered the use of the SI tool based on the "human + SI" principle. In this, the main methodological requirement was set that the final scientific and technological decision should be verified by a human - a teacher, engineer, or researcher.

3. RESULTS

3.1. Didactic opportunities of SI in the acquisition of chemical knowledge

The results of the study show that SI provides young engineers-technologists with several important opportunities in the acquisition of chemical knowledge.

First, SI allows for the explanation of complex scientific concepts at different levels. For example, topics such as "the effect of temperature on the rate of a chemical reaction", "the role of a catalyst" or "chemical equilibrium" can be explained at the elementary, secondary or engineering level.

Second, SI allows for immediate feedback to the learner. The student can analyze his solution using SI, identify errors and re-solve the problem.

Third, SI can create problems of varying complexity on the same topic. This is important for individual learning, allowing for more complex problems for students with a high level of knowledge and for students with a low level of preparation, step-by-step solutions.

3.2. Using SI in teaching chemical calculations

In the work of an engineer-technologist, stoichiometric calculations, concentration of solutions, amount of substance, mass balance, heat balance and other calculations play an important role.

SI can be an auxiliary tool for solving such problems:

• analyzing the condition of the problem;

• choosing the necessary formula;
• dividing the calculation algorithm into stages;
• explaining the result obtained;
• comparing alternative solutions

However, there is an important methodological requirement: the student should not just receive a ready-made answer, but also answer questions such as "why was this formula chosen?", "which physical and chemical law was used?". Only then will the use of SI have real educational value.

3.3. Modeling technological processes

For young engineering technologists, it is important to connect theoretical chemistry with production processes. Using SI, you can discuss various technological scenarios.

For example:

The chemical basis of each stage in the chain of raw materials → chemical reaction → technological parameters → intermediate product → finished product → quality controlis analyzed.

A student can theoretically discuss how changes in temperature, pressure, concentration or reaction time affect the result using SI.

This approach serves to form cause-and-effect technological thinking in an engineer.

3.4. Organization of individual education

In a traditional lesson, the teacher works with many students at the same time. SI allows you to ask individual questions, explain errors, and create additional exercises.

For example, if a student is having difficulty with the topic of chemical equilibrium, the SI can:

1. Re-explain the main concepts of the topic;
2. Give a simple example;
3. Offer a medium-level problem;
4. Check the answer;
5. Explain the reason for the error;
6. Move on to the next more complex problem.

Thus, the SI allows the formation of adaptive learning elements.

3.5. Building AI literacy

For a young engineer, it is important not only to use AI, but also to critically evaluate its results.

A study conducted in 2024 with the participation of chemistry students showed that one of the important aspects of AI literacy is the critical assessment of the relevance, reliability and quality of chatbot responses.

Therefore, a young engineer should have the following competencies:

• Give a clear task to AI;
• Check the answer with scientific sources;
• Identify errors that are incorrect or "seemingly plausible";
• Independently re-check calculations;
• Protect confidential production data;
• Maintain academic and professional integrity when using AI.

In research on chemistry education published in 2026, engaging students in critical evaluation of AI responses was also indicated as an important pedagogical direction.

4. DISCUSSION

The results obtained show that the use of SI in imparting chemical knowledge to young engineering technologists has a high pedagogical potential. However, the effectiveness of the use of SI depends not on the technology itself, but on the pedagogical purpose for which it is used.

While in traditional education the teacher is the main source of knowledge, in SI-based education he plays the role of a specialist who manages the educational process, creates tasks, evaluates the result and controls scientific accuracy.

Modern scientific literature on generative SI in chemistry education also shows the need to take into account the possibilities of this technology, as well as its limitations. The 2025 analysis noted the need for regular reassessment of the pedagogical value of generative SI in chemistry education, its rapid development and approaches to its use.

In particular, it is advisable to organize the use of SI in the training of engineering technologists on the basis of the following three-stage model:

Stage 1: Knowledge Acquisition. The student uses SI to learn about chemical concepts, reactions, and technological processes.

Stage 2: Knowledge Verification. The student compares SI answers with textbooks, scientific articles, technical regulations, and other reliable sources.

Stage 3: Practical Application. The student independently solves a real or simulated engineering problem using the acquired knowledge.

This model prevents the passive use of SI and serves to develop the student's independent and critical thinking.

At the same time, it is necessary to take into account some limitations of SI. Generative models can sometimes provide scientifically incorrect answers, incorrect formulas or non-existent sources. In chemical production, such errors can directly affect the safety and quality of the product. Therefore, the SI recommendation cannot be an independent basis for the final decision in production.

UNESCO also identifies the preservation of human agency, data confidentiality, ethical standards and validation mechanisms as important conditions for the use of generative SI in education.

Therefore, the main goal of introducing SI into the educational process should not be “replacing the teacher with SI”, but “expanding the capabilities of the teacher and engineer with SI”.

5. CONCLUSION

Based on the results of the study, the following conclusions were drawn:

1. In the training of a modern engineer-technologist, it is necessary to form digital and SI competencies along with fundamental chemical knowledge.

2. Artificial intelligence can be an effective auxiliary tool for mastering chemical knowledge in an individual, interactive and practical direction.

3. SI allows you to increase the effectiveness of education in explaining chemical reactions, stoichiometric calculations, technological parameters and production processes.

4. The use of SI serves to develop independent learning, problem analysis, technological thinking and digital competencies of young engineers.

5. One of the most important competencies when working with SI is AI literacy, that is, the ability to critically evaluate artificial intelligence responses and verify them based on scientific sources.

6. From the point of view of chemical production safety, the information provided by SI must be verified by a teacher, engineer or other qualified specialist.

7. In the training of young engineers and technologists, the triad of chemical knowledge + engineering competence + SI literacy should be considered as an important factor that enhances the professional training of the future specialist.

Thus, the integration of artificial intelligence into chemical education on a scientific and methodological basis is one of the promising areas of training young engineers and technologists for a modern digital production environment. In this case, the main criterion for using technology should not be its novelty, but rather its scientific basis, pedagogical expediency, safety, and application under human control.

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