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PEDAGOGICAL ANALYSIS OF TEACHING THE COURSE “ARTIFICIAL INTELLIGENCE IN CHEMISTRY” TO PROSPECTIVE CHEMISTRY TEACHERS

Abstract

This research paper examines the implementation and perceived outcomes of a practice-oriented course focusing on the application of artificial intelligence in the professional training of prospective chemistry teachers. The study, which took place during the 2025-26 academic year, involved 48 third-year undergraduate chemistry education students (n = 48) at a pedagogical university. The experimental work was carried out as part of the course «Using Artificial Intelligence in Chemistry Teaching» and was delivered exclusively through practical classes.

The research employed an exploratory one-group study, a questionnaire survey, an analysis of students' learning products, and qualitative methods. The findings indicated predominantly positive self-reported levels of students' digital, methodological, and professional skills. Quantitative results revealed a predominance of good and very good levels across most indicators, while qualitative analysis indicated of a reflective, pedagogically grounded approach to using artificial intelligence in chemistry teaching.

These results suggest the potential educational value and feasibility of integrating AI-oriented courses into the professional training of future chemistry teachers in the context of digital transformation in education.

Key words: artificial intelligence, chemistry education, prospective chemistry teachers, AI literacy, digital competence, technological pedagogical content knowledge (TPACK), professional training.

Introduction. The rapid digitalisation of education means that artificial intelligence (AI) is now one of the key factors in transforming higher teacher education. Modern AI technologies are being introduced into the educational process to provide personalised learning, automate routine pedagogical tasks, visualise complex concepts, and support learning analytics. AI is particularly relevant in chemistry education, where studying abstract, microscopic, and dynamic processes requires intelligent digital tools and models.

Current research shows that integrating AI into chemistry education can lead to a deeper understanding of learning materials, the development of research skills, and increased motivation among learners [1]. However, the effectiveness of AI applications depends heavily on the professional preparedness of teachers, particularly future chemistry teachers. Insufficient preparedness for the pedagogically sound use of AI can result in the formal, fragmented, or unethical use of these technologies in educational practice.

Scientific research pays special attention to training future chemistry teachers and developing their digital and AI competence. Empirical studies show that, while students of pedagogical specialities generally have a positive attitude towards the use of artificial intelligence in teaching, they demonstrate different levels of knowledge, practical experience, and confidence in using AI tools [2, 3]. However, there are also risks associated with a potential decline in critical thinking, reliance on AI systems, and the inadequate preparedness of future teachers to utilise these tools effectively.

In the context of the professional training of chemistry teachers, the concept of technological pedagogical content knowledge (TPACK) is of particular importance, as it considers the integration of subject content, pedagogy, and technology as a holistic process. Studies show that developing TPACK in future chemistry teachers is necessary for effectively implementing innovative

technologies, including AI, in a digitalised education system [4]. However, the development of TPACK in relation to AI remains insufficiently studied and systematised.

Additionally, analysis of the current state of pedagogical education reveals insufficient digital competence among future teachers, hindering the integration of AI technologies into teaching [5]. This highlights the need for the intentional design of educational disciplines that not only equip students with the technical skills to work with AI, but also provide them with a pedagogical understanding of its possibilities, limitations, and ethical implications.

Despite the growing interest in using artificial intelligence in chemistry education, there is still a scientific gap between AI's potential capabilities and the actual pedagogical readiness of future chemistry teachers to apply it. This gap highlights the importance of developing and implementing a special training course that fosters a comprehensive understanding of the pedagogically sound use of artificial intelligence in chemistry among students.

This study is relevant because of the need to modernise the professional training of future chemistry teachers in an era of the active implementation of artificial intelligence in educational practice. Including the discipline 'Using Artificial Intelligence in Chemistry' in pedagogical university curricula enables the intentional development of students' AI literacy, digital competence, and TPACK knowledge, ensuring they are prepared for effective and responsible pedagogical activities in digital educational environments.

This article aims to provide a theoretical justification and pedagogical analysis of teaching this discipline to third-year students on the «Chemistry» programme, as well as identify its role in developing the professional and digital competencies of future chemistry teachers.

The theoretical significance of the study lies in clarifying the pedagogical foundations for integrating artificial intelligence into the training of future chemistry teachers, as well as expanding scientific ideas about developing TPACK knowledge and AI competence in chemical education.

The study's practical significance lies in its potential to inform the development and enhancement of academic disciplines, teaching materials, and educational programmes at pedagogical universities, with the aim of fostering the pedagogical and ethical application of artificial intelligence in educational practice among future chemistry teachers.

Literature review.

The rapid development of artificial intelligence (AI), including generative models (GenAI), is shaping a new educational landscape. The ways in which information is retrieved, materials are prepared, and assessments are conducted are changing, as are the nature of learning tasks and classroom communication. In pedagogy, this shift is accompanied by the transition from sporadic use of digital tools to the systematic integration of AI as a means of personalising learning, supporting teachers, and developing learners' competencies.

AI is a transformative factor in education and pedagogical approaches.

In the Kazakhstani and regional discourse, it is considered not only a technological trend but also a basis for rethinking pedagogical approaches in higher education. This emphasises the need to shift the focus from reproductive learning to models in which students actively construct knowledge, solve practical problems, and use digital tools for analysis and decision-making. In this context, AI acts as a 'catalyst' for updating teaching methods and training content for future specialists, as well as strengthening the teacher's role as an educational environment designer and mentor [6].

At the same time, it is acknowledged that the implementation of AI in education necessitates the development of digital literacy and an understanding of associated risks, such as those relating to ethics, authenticity, academic integrity, and data security. Additionally, the development of regulatory mechanisms at the course/programme level is required. Review papers on AI in education emphasise that successful implementation depends not on the number of «tools», but on the correct methodological approach to their application and on teachers' readiness to manage learning activities in a digital environment [7].

Kazakh-language research on primary education emphasizes that the systematic use of digital technologies can increase the interactivity and visibility of learning materials, strengthen students' motivation, cognitive engagement, creativity, and critical thinking, and support more flexible

organization of the learning process [8]. At the same time, their educational effectiveness depends on teachers' digital competence and the methodologically sound integration of digital tools into classroom practice

AI in teaching chemistry: functional literacy and practice-oriented learning.

As a fundamental discipline, chemistry is oriented towards developing logical reasoning, analytical and critical thinking, and research skills, as well as a practical approach to learning. In the context of digital transformation, the development of functional literacy the ability to apply knowledge and skills in educational, professional, and everyday situations is particularly important. Tusupbekova & Orazbayeva's (2025) [9] research demonstrates that integrating AI into chemistry teaching expands the toolkit for developing functional literacy. AI can support the personalisation of learning, the automation of assessment, the visualisation of complex processes, the intellectual support of learning activities, and the simulation of realistic situations.

This approach is important because it shifts the focus from «knowledge for knowledge's sake» to the practical application of chemical concepts. Students learn to interpret data, explain phenomena, justify conclusions, analyse experimental results, and make evidence-based decisions. Here, AI and digital tools become an environment that can enhance the research and design component of learning, rather than a substitute for thinking.

Broader publications forecasting the future of chemical education emphasise the need to update educational content and methods to incorporate digital technologies and AI, as well as strengthening the practical element and interdisciplinarity. Such works generally convey the message that chemical education must address contemporary challenges by training specialists who can work with data, modelling, and modern digital environments while maintaining scientific rigor and experimental culture [10].

Linking AI research in chemistry and learning objectives: what matters for didactics.

Another area of interest is the discussion of how the application of AI to chemical research is changing the training requirements of students and future teachers. Berber et al. (2025) [11] argue that AI in chemical research inevitably affects teaching and learning and that it is necessary to educate students in the principles of AI, the limitations of algorithms, the interpretability of results, and the correct handling of data. Consequently, chemistry teaching should include tasks that do not simply provide students with answers but encourage them to verify correctness, compare results, draw reasoned conclusions, and grasp the limitations of numerical solutions.

This thesis highlights the importance of disciplines that promote the competent and ethical use of AI in teaching. A future chemistry teacher should know how to apply AI capabilities to didactic scenarios, including visualisation, simulations, analysis of experimental data, and preparation of teaching materials.

Competence of the future teacher in the digital age: from 'digital skills' to GenAI competences.

The readiness of teachers, especially future teachers, is a key condition for the effective integration of AI. Works on the didactics of the digital age note that the professional training of future chemistry teachers can no longer be conceived without modern digital technologies. The focus of education is shifting towards the development of digital literacy and skills, while the fundamental objective of knowledge, skill, and experience acquisition remains unchanged. The authors emphasise the need to integrate digital technologies into traditional learning, providing examples of tools that contribute to the development of general professional competencies, such as digital/virtual laboratories, video content creation, and the use of the university's digital learning environment.

But there are also rules: digital independent work needs teaching control and keeping up the quality of the content, and the choice of technology should be based on the learning goals and the features of the learning material [12].

The concept of GenAI competence emerges at the next level of discussion. Xia et al. (2025) [13] propose and validate the Generative Artificial Intelligence Competency Self-Efficacy Scale for Teachers and Researchers (GAICS-TR) in higher education. They emphasise that existing digital/AI competency frameworks often fail to consider the impact of GenAI on assessment and research activities sufficiently. The authors highlight the domains and dimensions of competence: a basic

understanding of GenAI and ethics; teaching with GenAI (student interaction, instructional design, and assessment); research with GenAI; and professional engagement. The scale itself is seen as a tool for diagnosing professional development needs and developing institutional policies. In terms of training future chemistry teachers, it is not enough to simply teach them how to 'use the tool'; it is also important to develop their ability to design learning tasks that promote academic integrity, data security, accurate assessment, and critical thinking.

Literature findings and identified research gap.

The analysis of sources enables us to identify several consistent themes:

- AI establishes a new context for higher education, necessitating a revision of pedagogical approaches, particularly in the training of future teachers [6, pp. 83-87; 7, p. 7; 8, pp. 79-84].
- In chemistry teaching, AI shows promise as a means of developing functional literacy through visualisation, modelling, analysis, and supporting learning activities [9, pp. 186-203].
- The development of AI in chemical research emphasises the importance of incorporating AI topics into teaching in a didactic manner [11, pp. 1445-1456].
- The key condition for effectiveness is teacher competence, ranging from digital skills and tool proficiency to comprehensive GenAI competence [12, pp. 222-226; 13, p. 12].

However, there is a practical deficit in the literature: while many works describe possibilities and general directions, comparatively few present modular, discipline-specific solutions for training future chemistry teachers where AI is integrated into the teaching process through clearly defined objectives, tasks, assessment methods, and criteria. Consequently, there is an urgent need to describe and validate real-life training courses and syllabuses for future chemistry teachers that aim to develop the skills needed to meaningfully apply AI in teaching scenarios.

The scientific novelty of this study lies in the development and empirical implementation of a discipline-specific, practice-oriented model for integrating artificial intelligence into the professional training of prospective chemistry teachers. Unlike studies that primarily examine general perceptions of AI or the use of individual digital tools, this study presents an integrated course design that combines chemistry content, AI-supported learning-product development, pedagogical reflection, and the evaluation of digital, methodological, and professional skills. The authors' contribution consists in specifying the course structure, practical lesson sequence, AI-supported tasks, and assessment indicators that can be adapted for chemistry teacher education.

Methods and materials

Organisation and basis of the study. The research was conducted during the 2025/26 academic year (first semester, fifth semester of study) at South Kazakhstan Pedagogical University, Faculty of Natural Sciences, Department of Chemistry.

The experiment was implemented within the framework of the «Use of artificial intelligence in teaching chemistry» discipline, which is studied by third-year students on the «6B01504 - Chemistry teacher training» educational programme.

This applied discipline was implemented exclusively in the format of practical classes due to its content and objectives, which are oriented towards forming the digital, methodological and professional competencies of future chemistry teachers.

Study participants. The experiment involved 3rd year students enrolled in the specified educational program. Classes were held in several academic groups. The distribution of the study participants by academic group and gender is presented in Table 1. The study followed a one-group design, and the participants were not divided into experimental and control groups.

Table 1. Characteristics of the study participants

Groups	Total number of students	female	male
1507-13A	19	4	15
1507-23	12	3	9
1507-33	17	2	15
Total	48	9	39

Source: developed by the author

All participants had previously studied subjects related to digital and information technologies in education, but they did not have special training in the use of artificial intelligence in chemistry education.

Characteristics of the discipline and format of lessons.

The discipline «Use of Artificial Intelligence in Chemistry Teaching» aims to develop the pedagogical skills of future chemistry teachers in the application of AI tools in the teaching process. This includes the development of teaching tasks, visualisation of chemical processes, creation of teaching videos, analysis and interpretation of experimental data, and design of interactive teaching methods.

All classes are conducted as practical sessions, during which students perform individual and group tasks using AI tools.

The following digital and AI tools were used during the practical exercises, which are summarised in Table 2.

Table 2. Digital and artificial intelligence tools used in the experiment

Tool	Developer and access	Function
ChatGPT	OpenAI; web version available during the first semester of 2025–2026	Generation of text explanations, lesson scenarios, and methodological comments
Gemini	Google; web version available during the first semester of 2025–2026	Preparation of alternative explanations and examples on chemistry topics
Grok	xAI; web version available during the first semester of 2025–2026	Generation of visual and video materials illustrating chemical processes
CapCut	ByteDance; application version available during the first semester of 2025–2026	Creation and editing of educational videos
Canva and other online services	Web-based platforms available during the first semester of 2025–2026	Support for visualization, presentation, and demonstration of results

Source: developed by the author

These tools were all used in one practical session or a series of interrelated sessions, thus ensuring the integrity of the training scenario.

Scenario of practical training sessions.

The practical lessons were based on a unified scenario, comprising the following stages:

- Formulation of a learning task on a specific chemistry topic.
- Selection of AI tools to solve the task.
- Development of a learning product (e.g., text, infographics, or video).
- Presentation and discussion of the results.
- Reflection on and methodological analysis of the possibility of applying the created product in school practice (table 3).

Table 3. Example of the structure of a practical lesson

Stage	Content of the activity	Tools used
Setting the task	Statement of the lesson's purpose and topic	Teacher
Designing	Developing a scenario for explaining the topic	ChatGPT, Gemini
Realization	Creating a video or visualization	CapCut, Grok
Performance	Demonstration of the results	Multimedia (Canva)
Analysis	Discussion and pedagogical assessment	Group discussion

Source: developed by the author

Videos as part of the experimental basis:

1. During practical classes, students developed educational videos reflecting the content of chemical topics and the methodology used to explain them, with the help of AI tools.

2. The videos were used exclusively for educational purposes and do not disclose the personal data of the students.

3. Examples of the videos are available via external links (Google Drive) and are intended to illustrate and support the experimental work.

Research methods.

The pedagogical experiment comprised three stages: preparatory, implementation, and diagnostic-analytical. The final assessment included a questionnaire and analysis of students' learning products, while no separate initial diagnostic assessment was conducted. The independent variable was the implementation of the practice-oriented AI course, and the dependent indicators were students' self-reported digital, methodological, and professional skills.

The research methods used in this study are systematically presented in Figure 1. They include pedagogical experimentation, observation of students' learning activities, analysis of learning products, comparative analysis of practical work results, and qualitative analysis of skills development.

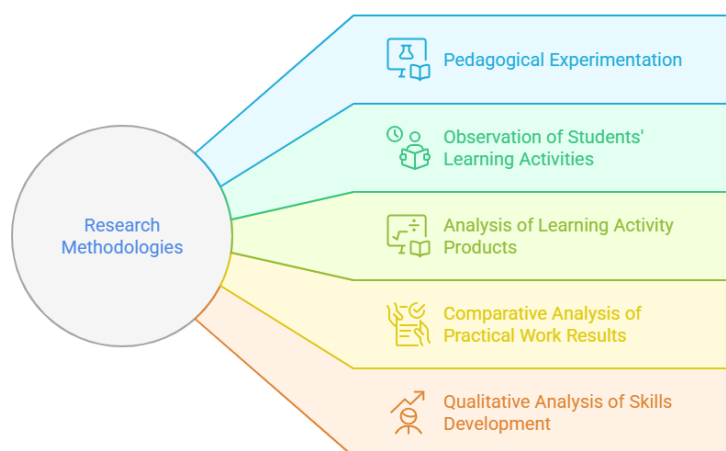


Figure 1. Research methodologies

Source: developed by the author

These research methods were chosen due to the specific objectives and the practice-oriented nature of the discipline. The pedagogical experiment, the leading method, allowed us to study the formation of professional and digital competencies in students in the real conditions of the educational process. This approach is in line with modern methods of analyzing the quality of educational products in higher education systems [14]. Observation and analysis of learning activity products provided a comprehensive review of practical lesson results, including student-developed videos, lesson scripts, and visual learning products. Qualitative analysis was employed to examine the role of digitalization in the development of general professional competencies in future chemistry teachers, with a particular focus on the practical application of digital tools and the reflection on learning experiences [12, p. 61-68].

The author-developed questionnaire was designed in accordance with the course learning outcomes and covered three dimensions: digital, methodological, and professional skills. As the questionnaire was used as an exploratory descriptive instrument, its psychometric validity and internal consistency were not independently tested.

This study is particularly interested in the work of Kolyada and Bugaeva (2019) [15], which considers artificial intelligence (AI) as a driving force for the innovative development of education even at an early stage of its development. The authors emphasize that introducing intelligent systems into the educational process requires technological readiness and a rethink of pedagogical approaches, teaching methods, and assessment of learning outcomes. Formulated before the widespread adoption of generative AI tools, this thesis confirms the relevance of applying qualitative research methods to analyze the pedagogical feasibility of using artificial intelligence in education and is fully aligned with the logic of the present study.

Statistical analysis. Due to the exploratory one-group design of the study and the absence of pre-test and control-group data, the quantitative findings were analysed using descriptive statistics. Frequencies and percentages were calculated for each response category, and the combined proportion of “good” and “very good” responses was used as a descriptive indicator of positive course outcomes. No inferential statistical tests were performed; therefore, the results are interpreted as descriptive evidence of students’ perceived skill levels after completing the course rather than as proof of statistically significant improvement or a causal effect of the course.

Results and discussion. To quantitatively assess the results of the pedagogical experiment, the distribution of students’ responses to ten closed questions in the questionnaire was analyzed. Each question was evaluated on a four-point scale: «low» (0-49 points), «average» (50-64 points), «good» (65-84 points) and «very good» (85-100 points) (Appendix). This gradation enabled us to determine the level at which the learning material was mastered and the quality of the future chemistry teachers’ professional and digital skills.

The generalized results of students’ responses to each question are presented in Table 4.

Table 4. Distribution of students’ responses to closed questions by performance level (N = 48)

Question	Low (0-50)	Average (51-65)	Good (66-85)	Very good (86-100)	Quality (%)
Q1	4 (8.3%)	6 (12.5%)	22 (45.8%)	16 (33.3%)	79
Q2	3 (6.3%)	5 (10.4%)	24 (50.0%)	16 (33.3%)	83
Q3	5 (10.4%)	7 (14.6%)	20 (41.7%)	16 (33.3%)	75
Q4	2 (4.2%)	6 (12.5%)	23 (47.9%)	17 (35.4%)	83
Q5	4 (8.3%)	8 (16.7%)	21 (43.8%)	15 (31.3%)	75
Q6	3 (6.3%)	7 (14.6%)	22 (45.8%)	16 (33.3%)	79
Q7	2 (4.2%)	6 (12.5%)	24 (50.0%)	16 (33.3%)	83
Q8	5 (10.4%)	6 (12.5%)	21 (43.8%)	16 (33.3%)	77
Q9	4 (8.3%)	7 (14.6%)	22 (45.8%)	15 (31.3%)	77
Q10	3 (6.3%)	6 (12.5%)	23 (47.9%)	16 (33.3%)	81

Note: Q1–Q4 assess digital skills; Q5, Q6, and Q9 assess methodological skills; Q7, Q8, and Q10 assess professional skills. Quality (%) = Good + Very good.

Source: developed by the author

The generalized results of the students’ responses presented in Table 4 are interpreted in Figure 2.

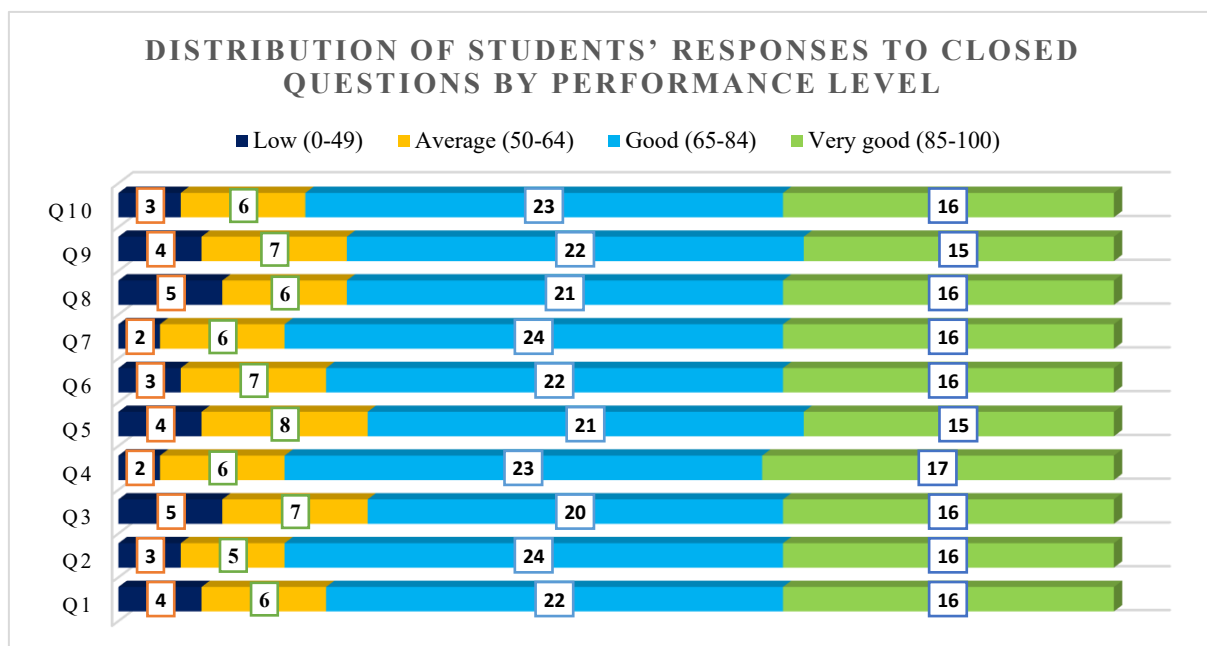


Figure 2. Distribution of students’ responses to closed questions by performance level

Source: developed by the author

As the data in Table 4 and Figure 2 show, the majority of responses to all questions in the questionnaire were at good or very good levels. On average, between 70% and 83% of students achieved a positive result in each indicator, indicating predominantly positive self-reported levels of digital, methodological, and professional skills by the end of the course. To identify differences in learning outcomes between study groups, a comparative analysis of student responses was conducted. The percentage of students who achieved good or very good grades was used as an overall indicator of the quality of education.

The percentage indicators of the quality of education for each study group are presented in Table 5.

Table 5. Comparative results of learning quality by academic groups (%)

Group	Low + Average (%)	Good + Very good (%)
1507-13A	26	74
1507-23	33	67
1507-33	24	76
Average	28	72

Source: developed by the author

Analysis of the data in Table 5 shows that, in all study groups, the proportion of students demonstrating a good or very good level exceeds the proportion demonstrating a low or average level. The percentage of positive results ranges from 67% to 76%, indicating the discipline's comparable effectiveness in different study groups.

Figure 3 provides a visual interpretation of the comparative results by group, clearly showing the differences and general trends in learning quality.

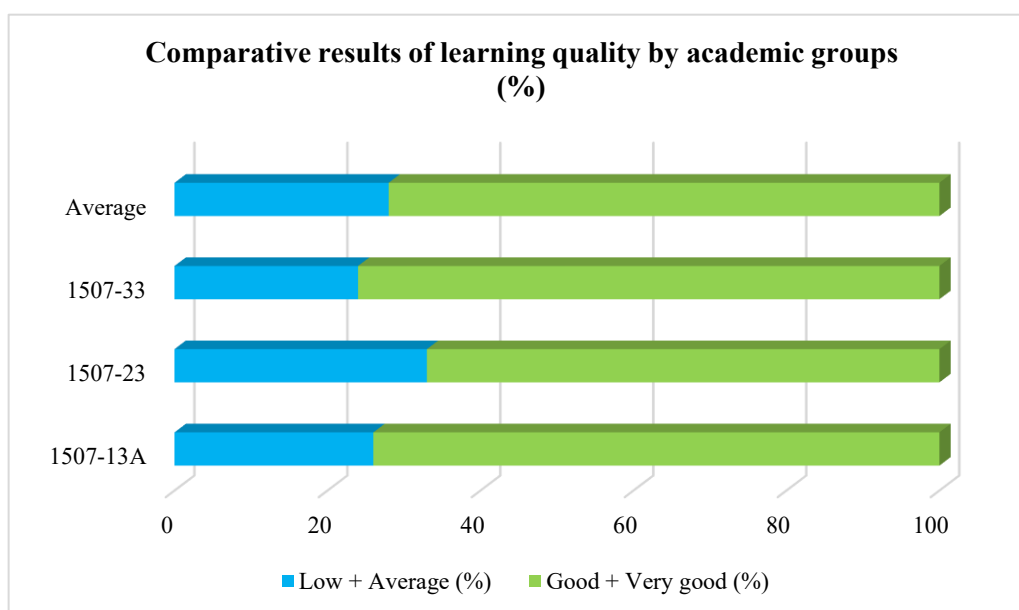


Figure 3. Comparative results of learning quality by academic groups (%)

Source: developed by the author

To ensure a comprehensive assessment of learning outcomes, the study was conducted using a questionnaire comprising both closed and open-ended questions. This combination enabled a combination of quantitative and qualitative approaches to analyze the effectiveness of the discipline.

The structure of the questionnaire and the distribution of question types are shown in Table 6.

Table 6. Structure of the questionnaire

Type of questions	Number	Purpose
Closed questions	10	Assessment of digital, methodological, and professional skills
Open questions	5	Qualitative analysis of students' learning experience
Total	15	Comprehensive evaluation of learning outcomes

Source: developed by the author

As illustrated in Table 6, closed questions enabled the quantitative assessment of skill development, while open questions facilitated the identification of individual perceptions of the course and its professional impact.

To gain a deeper understanding of the results of the pedagogical experiment, a qualitative analysis of students' responses to the open-ended questionnaire was conducted. This analysis included students' most typical and meaningful statements about the teaching process and its outcomes.

Examples of students' responses are presented in Table 7.

Table 7. Examples of students' responses to open-ended questions

Student	Key idea of the response
Student A	AI tools helped structure explanations of chemical concepts and lesson planning
Student B	Visualization improved understanding of abstract chemical processes
Student C	Creating videos enhanced confidence and pedagogical thinking
Student D	Emphasized the need for critical evaluation of AI-generated content
Student E	Course changed perception of digital tools in chemistry teaching

Source: developed by the author

Analysis of the statements shows that students recognize the pedagogical value of using artificial intelligence in chemistry teaching. They note that it develops methodological thinking, increases the visibility of teaching materials, and fosters a reflective attitude towards digital tools.

A summary analysis of the quantitative and qualitative data from the study was conducted to summarize the findings and formulate final conclusions.

Summary indicators of discipline effectiveness are presented in Table 8.

Table 8. Summary of learning outcomes

Indicator	Result
Students demonstrating good and very good levels	67-76%
Students requiring further development	24-33%
Overall effectiveness of the discipline	High

Source: developed by the author

The summarized data in Table 8 indicate that the implementation of the discipline «Using artificial Intelligence in Chemistry teaching» was associated with predominantly good and very good self-reported levels of students' professional and digital skills and may have potential value as an element of the professional training of future chemistry teachers.

The descriptive findings indicated that implementing the discipline 'Using Artificial Intelligence in Chemistry Teaching' in a practical was associated with predominantly positive self-reported levels of the digital, methodological, and professional skills of future chemistry teachers. Quantitative data indicate a high prevalence of good and very good levels for most evaluation indicators, with an average integral indicator of teaching quality (good + very good) of over 70%. This suggests that using artificial intelligence tools in practical classes may support students' perceived learning outcomes and the development of applied pedagogical skills.

These results are consistent with studies on the development of TPACK knowledge and the digital competence of future teachers. Bakazhanova et al. [4, pp. 40-51] therefore emphasize that the effectiveness of digital technologies in chemistry teacher training is determined by their methodologically sound integration into the teaching process rather than by the number of tools used. In our study, AI tools were used to solve specific didactic tasks, such as developing lesson scenarios, visualizing chemical processes, and creating training videos. This illustrates the relevance of the TPACK approach in the context of the digitalization of teacher education.

The results also correlate with international data on the perceptions and use of AI among future teachers. Iyamuremye et al. (2024) [1, p. 10] found that AI is most effectively used in chemistry education to visualize and analyze learning activities, with pedagogical readiness of learners remaining a key factor. Similar findings are presented in Harianti et al. [2, pp. 5-12], who note that practical work with AI increases future teachers' confidence and promotes the informed use of digital technologies in teaching.

Of particular note is the comparison of the present study's findings with those of earlier research papers. For instance, even before the widespread adoption of generative AI, Kolyada and Bugayeva [15, pp. 21-30] considered artificial intelligence to be a driving force in innovative educational development. They emphasized the importance of educators adopting a critical and methodologically sound approach to its use. The descriptive findings of the present study are consistent with these arguments and suggest that systematically including AI in pedagogical programs may contribute to the modernization of future chemistry teachers.

Recent international studies provide a broader context for interpreting the present findings. Ramnarain et al. [16] found that AI literacy, attitudes, perceived behavioral control, subjective norms, and perceived usefulness significantly influenced preservice science teachers' intentions to use GenAI in inquiry-based teaching, demonstrating that technical familiarity alone is insufficient without pedagogical readiness. Perceived usefulness, ease of use, and self-efficacy were also identified as significant predictors of preservice teachers' intentions to adopt GenAI after participation in a structured AI-integrated activity [17]. The systematic review by Ponomarenko et al. [18] further showed that initially limited AI knowledge and skills among preservice teachers could improve through targeted training and hands-on experience, although concerns related to academic integrity, data privacy, and fairness remained. In chemistry teacher education, Akaygun & Kilic [19] found that preservice teachers valued GenAI-generated visuals for their attractiveness and instructional potential but also identified scientific, pedagogical, and representational limitations, emphasizing the need for critical evaluation through PCK and TPACK perspectives. GenAI adoption among preservice chemistry teachers was additionally found to depend on performance and effort expectancy, social norms, facilitating conditions, and perceived behavioral control, with behavioral intention emerging as the strongest predictor of actual use [20]. Taken together, these studies support the practice-oriented focus of the present course while indicating that positive self-reported outcomes should be interpreted as perceived readiness rather than conclusive evidence of course effectiveness.

Several *limitations* should be considered when interpreting the findings. First, the study involved a relatively small sample of 48 students from a single pedagogical university, which limits the generalizability of the results. Second, the absence of a control group and pre- and post-course measurements prevents causal conclusions regarding the effectiveness of the discipline. Third, the quantitative analysis was based on aggregated self-reported responses and descriptive statistics; therefore, statistically significant changes or differences between groups could not be established. Future research should employ larger and more diverse samples, validated assessment instruments, control groups, and longitudinal or pre-test–post-test designs to evaluate changes in prospective chemistry teachers' AI-related competencies more rigorously.

Conclusion. During the research, the practice-oriented discipline «Using Artificial Intelligence in Chemistry Teaching», which aimed to develop the digital, methodological and professional skills of future chemistry teachers, was tested in practice. The descriptive results indicated that, after participating in the practical classes, students reported predominantly positive levels of digital,

methodological, and professional skills, a reflective attitude towards the use of digital technologies, and readiness to apply them pedagogically in school practice.

Quantitative and qualitative data from the study indicate predominantly positive self-reported levels in professional confidence, methodological thinking, and the visualization of teaching materials. Analysis of students' responses to open-ended questions suggested that the participating students generally perceived artificial intelligence not as a substitute for pedagogical activity, but as a tool to support and expand the didactic possibilities of chemistry teaching.

Consequently, the findings of this study suggest that further consideration may be given to incorporating disciplines centered on the practical application of artificial intelligence into the professional training program for prospective chemistry teachers. Implementing such courses would contribute to the modernization of pedagogical education in the context of digitalization and could be considered an effective way to update the content and methods of teaching at pedagogical universities.

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**БОЛАШАҚ ХИМИЯ МҰҒАЛІМДЕРІНЕ «ХИМИЯДАҒЫ ЖАСАНДЫ ИНТЕЛЛЕКТ»
КУРСЫН ОҚЫТУДЫҢ ПЕДАГОГИКАЛЫҚ ТАЛДАУЫ**

Аңдатпа

Мақалада болашақ химия мұғалімі мұғалімдерін кәсіби даярлауда жасанды интеллектті қолдануға бағытталған тәжірибеге бағдарланған курсты енгізу үдерісі мен білім алушылардың қабылдауына негізделген нәтижелері қарастырылады. Зерттеу 2025–2026 оқу жылында педагогикалық университеттің химия мұғалімдерін даярлау білім беру бағдарламасында оқитын үшінші курс студенттерінің қатысуымен жүргізілді ($n = 48$). Зерттеу жұмысы тек практикалық сабақтар форматында өткізілген «Химияны оқытуда жасанды интеллектті қолдану» курсы аясында жүзеге асырылды.

Зерттеуде бір топқа негізделген барлау сипатындағы зерттеу дизайны, сауалнама, студенттердің оқу әрекеті өнімдерін талдау және сапалық әдістер қолданылды. Нәтижелер студенттердің цифрлық, әдістемелік және кәсіби дағдыларын өзіндік бағалауы негізінен оң деңгейде болғанын көрсетті. Сандық нәтижелер көрсеткіштердің басым бөлігінде «жақсы» және «өте жақсы» деңгейлерінің басымдығын анықтаса, сапалық талдау химияны оқытуда жасанды интеллектті қолдануға рефлексивті және педагогикалық тұрғыдан негізделген тәсілдің қалыптасқанын көрсетті.

Алынған нәтижелер білім берудің цифрлық трансформациясы жағдайында жасанды интеллекті бағдарланған курстарды болашақ химия мұғалімдерін кәсіби даярлау жүйесіне кіріктірудің ықтимал білімдік құндылығы мен орындылығын көрсетеді.

Түйінді сөздер: жасанды интеллект, химиялық білім беру, болашақ химия мұғалімдері, жасанды интеллект сауаттылығы, цифрлық құзыреттілік, технологиялық-педагогикалық пәндік білім (TPACK), кәсіби даярлау.

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ПЕДАГОГИЧЕСКИЙ АНАЛИЗ ПРЕПОДАВАНИЯ КУРСА “ИСКУССТВЕННЫЙ ИНТЕЛЛЕКТ В ХИМИИ” БУДУЩИМ УЧИТЕЛЯМ ХИМИИ

Аннотация

В статье рассматриваются процесс внедрения и воспринимаемые результаты практико-ориентированного курса, направленного на применение искусственного интеллекта в профессиональной подготовке будущих учителей химии. Исследование проводилось в 2025–2026 учебном году с участием 48 студентов третьего курса ($n = 48$), обучающихся по образовательной программе подготовки учителей химии в педагогическом университете. Работа осуществлялась в рамках курса «Использование искусственного интеллекта в обучении химии», реализованного исключительно в формате практических занятий.

В исследовании применялись одно-групповой разведочный дизайн, анкетирование, анализ продуктов учебной деятельности студентов и качественные методы. Результаты показали преимущественно положительные уровни самооценки цифровых, методических и профессиональных умений студентов. Количественные данные выявили преобладание уровней «хороший» и «очень хороший» по большинству показателей, а качественный анализ указал на формирование рефлексивного и педагогически обоснованного подхода к использованию искусственного интеллекта в обучении химии.

Полученные результаты свидетельствуют о потенциальной образовательной ценности и целесообразности интеграции курсов, ориентированных на искусственный интеллект, в систему профессиональной подготовки будущих учителей химии в условиях цифровой трансформации образования.

Ключевые слова: искусственный интеллект, химическое образование, будущие учителя химии, грамотность в области искусственного интеллекта, цифровая компетентность, технологическое педагогическое предметное знание (TPACK), профессиональная подготовка.

Appendix

A1. Closed questions (10 questions)

The answers were evaluated on a scale from 0 to 100 points and interpreted as follows:

0-49 – low level;

50-64 – average level;

65-84 is a good level;

85-100 is a very good level.

When analyzing the results, the indicators «good» and «very good» were considered as a positive result (100%).

Closed questions of the questionnaire

1. Evaluate your proficiency with AI tools (ChatGPT, Gemini) to prepare training materials.
2. How much has AI helped you better understand chemical processes and concepts?
3. Evaluate your chemical material visualization skills after completing the course.

4. How capable are you to create digital educational products (videos, visualizations, scripts) on your own?
5. How consciously do you choose AI tools depending on the learning task?
6. To what extent did the course help you understand the pedagogical possibilities of using AI in chemistry?
7. Evaluate your willingness to use AI when preparing school chemistry lessons.
8. To what extent has the use of AI contributed to the development of your critical thinking?
9. To what extent do you take into account the didactic purpose when using digital tools?
10. To what extent did the course affect your professional confidence as a future chemistry teacher?

A2. Open questions (5 questions)

1. Which AI tool has proved to be the most useful for you and why?
2. Describe how using AI has changed your understanding of chemistry teaching.
3. What difficulties have you encountered when working with AI tools?
4. To what extent do you think the materials you have created are applicable in school practice?
5. What professional and digital skills did you develop during the course?

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