Chapter III. THEORETICAL-METHODICAL FUNDAMENTALS OF PROFESSIONAL TRAINING OF FUTURE TEACHERS

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USE OF ARTIFICIAL INTELLIGENCE TECHNOLOGIES IN THE METHODOLOGICAL TRAINING OF PRE-SERVICE TEACHERS FOR TEACHING THE SCIENCE EDUCATION FIELD

Abstract. The article presents a theoretical analysis of the possibilities of using artificial intelligence technologies in the methodological training of future teachers for teaching the science education field. The relevance of the study is determined

by the rapid spread of generative artificial intelligence in educational environments, the digital transformation of teacher education, and the need to prepare teachers capable of effectively applying intelligent technologies in their professional activities. The purpose of the study is to provide a theoretical substantiation of the possibilities of using artificial intelligence technologies in the methodological training of future teachers of the science education field and to identify the pedagogical conditions for their effective implementation. To achieve this purpose, a set of theoretical research methods was employed, including literature analysis, comparison, systematization, generalization, modelling, and structural-functional analysis.

The findings demonstrate the educational potential of generative artificial intelligence in teacher education, including learning personalization, support for students' independent learning, educational content generation, preparation for teaching practice, and the development of reflective competence. The study substantiates the main directions of using artificial intelligence technologies in the methodological training of future teachers of the science education field, including lesson planning, development of teaching materials, preparation of science experiments, modelling of educational situations, organization of inquiry-based learning, development of STEM projects, and creation of educational assessment tools. Examples of methodological tasks based on generative artificial intelligence are proposed to facilitate the development of future teachers' professional competencies.

The study also identifies the major risks associated with the use of intelligent systems in education, including the generation of inaccurate information, AI hallucinations, reduced cognitive independence of students, violations of academic integrity, and ethical challenges of digital interaction. Furthermore, pedagogical conditions for the effective use of artificial intelligence technologies are substantiated, including the development of critical thinking, reflection, AI competence, and responsible attitudes toward the outputs generated by intelligent systems.

Keywords: artificial intelligence; generative artificial intelligence; methodological training; future teachers; science education field; professional training.

ВИКОРИСТАННЯ ТЕХНОЛОГІЙ ШТУЧНОГО ІНТЕЛЕКТУ В МЕТОДИЧНІЙ ПІДГОТОВЦІ МАЙБУТНІХ УЧИТЕЛІВ ДО ВИКЛАДАННЯ ПРИРОДНИЧОЇ ОСВІТНЬОЇ ГАЛУЗІ

Анотація. У статті здійснено теоретичний аналіз можливостей використання технологій штучного інтелекту в методичній підготовці майбутніх учителів до викладання природничої освітньої галузі. Актуальність дослідження зумовлена активним поширенням генеративного штучного інтелекту в освітньому середовищі, цифровою трансформацією педагогічної освіти та необхідністю підготовки вчителів, здатних ефективно використовувати інтелектуальні технології у професійній діяльності. Метою дослідження є теоретичне обґрунтування можливостей використання технологій штучного інтелекту в методичній підготовці майбутніх учителів природничої освітньої галузі та визначення педагогічних умов їх ефективного застосування. Для досягнення мети використано комплекс теоретичних методів дослідження: аналіз наукової літератури, порівняння, систематизацію, узагальнення, моделювання та структурно-функціональний аналіз.

У результаті дослідження визначено освітні можливості генеративного штучного інтелекту в професійній підготовці майбутніх педагогів, зокрема персоналізацію навчання, підтримку самостійної роботи студентів, створення навчального контенту, підготовку до педагогічної практики та розвиток рефлексивної компетентності. Обґрунтовано основні напрями використання технологій штучного інтелекту в методичній підготовці майбутніх учителів природничої освітньої галузі, серед яких розроблення конспектів уроків, створення дидактичних матеріалів, підготовка природничих дослідів, моделювання навчальних ситуацій, організація дослідницької діяльності учнів, розроблення STEM-проєктів і засобів педагогічного оцінювання. Запропоновано приклади методичних завдань із використанням генеративного штучного інтелекту, спрямованих на формування професійних компетентностей майбутніх учителів. Визначено основні ризики використання інтелектуальних систем в освітньому процесі, зокрема можливість генерування недостовірної інформації, виникнення галюцинацій штучного інтелекту, зниження пізнавальної самостійності студентів, порушення принципів академічної доброчесності та етичні проблеми цифрової взаємодії. Обґрунтовано педагогічні умови ефективного використання технологій штучного інтелекту, які передбачають розвиток критичного мислення, рефлексії, ШІ-компетентності та відповідального ставлення до результатів роботи інтелектуальних систем.

Ключові слова: штучний інтелект; генеративний штучний інтелект; методична підготовка; майбутні вчителі; природнича освітня галузь; професійна підготовка.

INTRODUCTION

The problem formulation. The current stage of educational development is characterized by an intensive digital transformation that encompasses all levels of the educational system and leads to the emergence of new approaches to the professional training of teachers. One of the most dynamic directions of these changes is the implementation of artificial intelligence (AI) technologies, which are gradually being integrated into the educational, research, and methodological activities of educational institutions. Generative artificial intelligence (GenAI) systems, capable of creating texts, visual materials, learning tasks, projects, and other educational products based on the analysis of large data sets, have become particularly widespread. The use of ChatGPT, Gemini, Copilot, and other AI tools opens up new opportunities for the personalization of learning, automation of routine operations, and support of teachers' professional development (Kasneci et al., 2023; UNESCO, 2023).

The issue of AI implementation is of particular relevance in the context of training future teachers of the science education field. The implementation of the conceptual principles of the New Ukrainian School requires teachers to be prepared to apply inquiry-based, activity-oriented, and STEM-oriented approaches, which necessitates the continuous modernization of methodological tools. AI technologies can become an effective means of developing educational materials, modelling scientific investigations, creating interactive tasks, and organizing students' project activities. At

the same time, their use requires appropriate methodological training of pre-service teachers and the development of their ability to critically evaluate the outputs generated by intelligent systems.

Analysis of recent research and publications. The issue of AI use in education has been actively investigated by both international and Ukrainian scholars. The pedagogical potential of GenAI, possibilities for its integration into the educational process, and associated risks have been highlighted in the works of Holmes et al., 2022, Kasneci et al., 2023, Laupichler et al., 2022, Long and Magerko, 2020, Tlili et al., 2023, Zhang and Magerko, 2025. Certain aspects of the digital transformation of teacher education, the development of digital competence, and the use of AI in the professional preparation of future teachers have been examined in the studies of Boiko and Morze, 2025, Honcharova, 2024, Hrebenichenko, 2024, Hunaza, 2023 and other researchers. In the context of teacher education, Kotyk (2024) also emphasizes the importance of preparing future teachers for the pedagogically appropriate integration of digital and multimedia technologies into the educational process.

At the same time, an analysis of contemporary scientific publications indicates that most studies focus on general issues of AI use in education, whereas the problem of applying AI specifically in the methodological training of pre-service teachers for teaching the science education field remains insufficiently explored. Further scientific substantiation is required regarding the possibilities of using GenAI for the development of teaching and methodological materials, the organization of inquiry-based learning, the preparation of STEM projects, and the formation of professional competencies of future teachers.

THE AIM AND RESEARCH TASKS

The purpose of the study is to provide a theoretical substantiation of the possibilities of using artificial intelligence technologies in the methodological training of pre-service teachers for teaching the science education field and to identify the pedagogical conditions for their effective implementation in the educational process of higher education institutions.

To achieve this purpose, the following research objectives were defined:

1. To analyse contemporary scientific approaches to the use of AI technologies in education and teacher training.
2. To identify the educational opportunities of generative artificial intelligence within the system of pre-service teacher education.
3. To substantiate the main directions of using AI technologies in the methodological training of future teachers of the science education field.
4. To develop examples of methodological tasks based on the use of generative artificial intelligence.
5. To determine the risks and pedagogical conditions for the effective use of AI technologies in the professional training of future teachers.

RESEARCH METHODS

To achieve the purpose of the study, a set of theoretical research methods was employed. The method of scientific literature analysis was used to examine contemporary approaches to the implementation of AI technologies in education and to determine the current state of research on the issue in both international and Ukrainian scholarship. The comparative method was applied to compare the functional capabilities of modern generative AI systems and to identify the prospects for their use in the methodological training of future teachers of the science education field. The methods of systematization and generalization were employed to classify the educational opportunities of generative artificial intelligence, identify the main directions of its use in methodological training, and determine the pedagogical conditions for the effective application of these technologies. The modelling method was used to develop a system of methodological tasks based on generative AI and to substantiate the possibilities of their implementation in the professional training of future teachers of the science education field. The structural-functional method was applied to identify relationships between the capabilities of AI technologies, the types of methodological activities performed by future teachers, and the expected outcomes of professional training.

RESULTS OF THE RESEARCH

An analysis of contemporary scientific research indicates that GenAI is becoming an important component of the digital transformation of education and teacher training. Over recent years, the possibilities for using intelligent systems in educational activities have expanded significantly due to the development of large language models and generative services. Research findings demonstrate the considerable potential of these technologies for personalizing learning, supporting students' independent work, creating educational content, and developing professional competencies (Kasneci et al., 2023; Tlili et al., 2023; UNESCO, 2023).

Unlike traditional digital resources, GenAI provides interactive communication with users, adapts responses to their needs, and supports individualized learning pathways (Kasneci et al., 2023; Tlili et al., 2023). In the field of teacher education, such GenAI tools as ChatGPT, Gemini, and Copilot have become widely used. Their application enables pre-service teachers to obtain information promptly, analyse educational materials, create methodological resources, and improve professional competencies. According to researchers, GenAI is gradually evolving from a tool for information retrieval into a digital educational assistant capable of supporting learning activities at all stages of professional training (Boiko & Morze, 2025; UNESCO, 2023; Zhang & Magerko, 2025).

One of the major advantages of GenAI is its ability to personalize learning. Intelligent systems can adapt educational content and its level of complexity to students' individual needs, provide personalized explanations of complex concepts, and generate additional examples and tasks of varying difficulty levels. As a result, future teachers are able

to study at their own pace while focusing on those aspects of professional training that require additional attention (Boiko & Morze, 2025; Honcharova, 2024; Hunaza, 2023).

Equally important is the role of GenAI in supporting students' independent learning. Modern AI tools enable automated searches for scientific information, summarization of large volumes of textual data, comparison of different scientific approaches, and generation of structured notes. Consequently, the efficiency of working with information resources increases, creating favourable conditions for the development of self-directed learning skills, which constitute an important component of a modern teacher's professional competence.

Of particular value for the methodological training of future teachers is the ability of GenAI to generate educational content. With the help of ChatGPT, Gemini, or Copilot, students can develop lesson plans, teaching materials, test items, educational cases, inquiry-based learning scenarios, and STEM projects. The effectiveness of using such tools largely depends on users' ability to formulate high-quality prompts, critically evaluate generated outputs, and verify the reliability of the information produced (Boiko & Morze, 2025; Hrebenichenko, 2024; Laupichler et al., 2022).

The synthesis of research findings allows us to conclude that GenAI is gradually becoming an important component of the digital educational environment of higher education institutions. Its application contributes to the personalization of learning, enhancement of students' independent work, expansion of opportunities for creating teaching and methodological materials, and improvement of the overall effectiveness of pre-service teacher education (Table 1).

Table 1

Educational Opportunities of Generative Artificial Intelligence in the Professional Training of Pre-Service Teachers

Educational Opportunity	Characteristics	Potential Outcome
Personalization of Learning	Adaptation of content and complexity to students' individual needs	Improved quality of knowledge acquisition
Support for Independent Learning	Consultation, explanation of concepts, and provision of examples	Development of self-directed learning skills
Information Search and Analysis	Summarization of sources, data structuring, and formulation of conclusions	Optimization of information and analytical activities
Creation of Educational Content	Generation of lesson plans, tests, exercises, and educational cases	Improvement of methodological training
Preparation for Teaching Practice	Modelling of professional situations and educational scenarios	Development of professional skills
Reflective Support	Analysis of completed tasks and provision of recommendations	Development of reflective competence

Source*: Developed by the authors based on Boiko & Morze (2025), Long and Magerko (2020), Kasneci et al. (2023), and UNESCO (2023).*

The integration of AI technologies into the system of teacher education opens new opportunities for improving the methodological component of the educational process. Their significance is particularly evident in the preparation of teachers for the science education field, as they enable the integration of scientific information, inquiry-based learning, project-based learning, and digital educational resources. Consequently, GenAI serves as a tool for supporting methodological activities that can be employed at various stages of pre-service teacher preparation.

One important area of application is the development of lesson plans and individual components of classroom instruction. By using ChatGPT, Gemini, or Copilot, students can generate lesson structures, formulate learning objectives in accordance with the State Standard of Primary Education, select teaching methods, and design stages of classroom activities. However, work with AI should not be reduced to the mechanical copying of generated materials. Future teachers must critically analyse such materials and adapt them to students' age characteristics and specific educational contexts.

Another important direction involves the creation of teaching and learning materials for science education lessons. With the help of GenAI, students can develop observation sheets, science-related tasks, interactive exercises, experiment instructions, crosswords, quizzes, and other educational resources. This significantly reduces the time required for preparing instructional materials and allows greater focus on their methodological improvement.

GenAI also demonstrates considerable potential for organizing students' inquiry-based activities. Intelligent systems can suggest procedures for conducting observations, describe possible experimental outcomes, and assist in formulating research questions and hypotheses. Particularly valuable is the use of AI in preparing future teachers to implement an inquiry-based approach, which is one of the key principles of science education within the New Ukrainian School framework. This direction is supported by empirical research demonstrating that AI literacy is among the significant factors influencing pre-service science teachers' intention to integrate generative artificial intelligence into inquiry-based teaching (Ramnarain et al., 2025).

Another important area of application is the modelling of educational situations and the development of problem-based tasks. GenAI makes it possible to create a variety of pedagogical cases that reflect real or simulated situations related to science education. Such cases can be used during practical classes in higher education institutions to foster the professional thinking of future teachers and to develop their ability to make pedagogical decisions.

A promising direction is the use of AI in the preparation of STEM projects. Modern generative systems are capable of suggesting project topics, assisting in planning implementation stages, selecting the necessary resources, and evaluating expected outcomes. This creates additional opportunities for the development of students' integrated thinking and their readiness to implement the STEM approach in primary education.

No less important is the application of AI for selecting interactive tasks and assessment tools for evaluating students' learning achievements. Intelligent systems enable the creation of test items of varying levels of complexity, tasks aimed at identifying cause-and-effect relationships, activities for formative assessment, and differentiated learning assignments. As a result, future teachers gain the opportunity to quickly generate diverse educational content in accordance with learners' educational needs.

The generalized possibilities of using GenAI in the methodological training of future teachers of the science education field are presented in Table 2.

Table 2

Use of Artificial Intelligence Tools in the Methodological Training of Future Teachers of the Science Education Field

Type of Activity	AI Tool	Expected Outcome
Development of Lesson Plans	ChatGPT, Gemini, Copilot	Formation of skills in designing educational activities
Creation of Teaching Materials	ChatGPT, Gemini, Canva AI	Development of high-quality methodological support
Preparation of Science Experiments	ChatGPT, Gemini	Improvement of students' inquiry-based training
Modelling of Educational Situations	ChatGPT, Copilot	Development of future teachers' professional thinking
Development of STEM Projects	ChatGPT, Gemini	Formation of readiness for STEM education
Selection of Interactive Tasks	ChatGPT, Quizizz AI, Kahoot AI	Diversification of students' learning activities
Organization of Inquiry-Based Activities	ChatGPT, Gemini	Development of scientific inquiry skills
Creation of Tests and Assessment Tools	ChatGPT, Copilot	Improvement of the effectiveness of assessing learning achievements

Source: Developed by the authors.

Alongside the use of AI for creating teaching and methodological materials, an important area of its application in the professional training of future teachers of the science education field is the development of specialized methodological tasks. The completion of such tasks makes it possible to integrate the capabilities of GenAI directly into the process of developing the professional competencies of future teachers and ensures the transition from simple familiarity with digital tools to their conscious and pedagogically appropriate use. As researchers emphasize, the effectiveness of GenAI implementation in education largely depends on the nature of learning activities in which students not only receive information but also analyse, evaluate, and improve the outputs generated by intelligent systems (Long & Magerko, 2020; Kasneci et al., 2023).

Tasks that involve students' critical interaction with generated content are of particular value in methodological training. Under such conditions, AI functions not as a source of ready-made solutions but as a pedagogical design tool that stimulates reflection, creative thinking, and the ability to evaluate the quality of educational materials. In particular, future teachers may use ChatGPT, Gemini, or Claude to develop lesson fragments, create inquiry-based tasks, model educational situations, prepare STEM projects, and analyse different ways of explaining scientific phenomena. Such activities contribute to the development of pedagogical design skills, digital literacy, and readiness to implement innovative technologies in school practice (Holmes et al., 2022; Tlili et al., 2023).

Taking into account current trends in the digitalization of education and the findings of contemporary research, examples of methodological tasks were developed for use in the professional training of future teachers of the science education field. Their content is aimed at integrating subject-specific, methodological, and digital training, as well as developing students' ability to critically evaluate the outputs of generative systems and apply them to the solution of professionally oriented tasks.

As can be seen from Table 3, most of the proposed tasks are focused not on obtaining a ready-made product with the help of AI, but rather on students' active cognitive engagement related to the analysis, verification, revision, and improvement of generated outputs. Such an organization of learning activities makes it possible to utilize the potential of AI for the development of future teachers' professional thinking and the formation of their readiness for pedagogical activity in the context of the digital transformation of education (Long & Magerko, 2020; Holmes et al., 2022). The implementation of these methodological tasks contributes to the integration of subject-specific knowledge, methodological expertise, and digital competence, which corresponds to the requirements for the training of specialists in the science education field.

The implementation of AI technologies in the educational process brings to the forefront a number of pedagogical, ethical, and methodological challenges. Their use cannot be regarded as an exclusively positive factor in professional training, since the outputs generated by AI systems require critical analysis, verification, and pedagogical interpretation (Kasneci et al., 2023; Tlili et al., 2023).

Table 3

Examples of Methodological Tasks Based on the Use of Generative AI Task | Learning outcome

Task	Learning Outcome
Development of a lesson fragment using ChatGPT followed by an expert analysis of its structure and content	Formation of pedagogical design skills and the ability to analyse educational content
Creation of a series of inquiry-based tasks for pupils using generative AI	Development of skills for organizing pupils' inquiry-based activities
Analysis of factual errors and inaccuracies in AI-generated explanations of scientific phenomena	Development of critical thinking and skills for verifying the reliability of information
Comparison of several explanations of the same scientific phenomenon generated by different AI systems	Development of the ability to adapt educational materials to learners' age characteristics
Development of a STEM project using generative AI tools	Formation of project-design and interdisciplinary competencies
Creation of an environmental case and modelling possible solutions to the proposed problem	Development of environmental thinking and decision-making skills
Generation of test items of different difficulty levels followed by improvement of their content	Formation of competence in educational assessment
Development of instructions for conducting a science experiment and verification of their scientific accuracy	Improvement of methodological skills related to organizing pupils' practical activities

Source: Developed by the authors.

One of the most common risks is the phenomenon of so-called AI hallucinations, manifested in the generation of inaccurate or partially incorrect responses. This is particularly dangerous in the preparation of educational materials for science disciplines, where even minor inaccuracies may lead to the formation of misconceptions and erroneous scientific understandings among learners. Researchers emphasize that large language models frequently generate non-existent facts, fabricated references, or incorrect explanations of scientific phenomena, which makes expert verification of generated outputs essential (Kasneci et al., 2023; Mesky & Topol, 2023).

Another significant risk is the reduction of students' cognitive independence. When future teachers use AI exclusively as a tool for the automatic creation of lesson plans, presentations, or methodological materials, the need for independent information searching, source analysis, and instructional design gradually decreases. Under such circumstances, there is a danger of developing a passive model of professional training in which students become consumers of ready-made content rather than its creators and critical evaluators (Holmes et al., 2022; Honcharova, 2024; Long & Magerko, 2020).

The issue of academic integrity is also of considerable importance. The use of GenAI may result in the uncritical copying of generated texts, concealed authorship, or the presentation of AI-generated outputs as one's own educational product. Therefore, teacher education should focus not only on teaching students how to use AI tools but also on fostering a responsible attitude toward their outputs, adherence to the principles of academic integrity, and transparency in educational activities (UNESCO, 2023).

A separate group of challenges includes ethical risks associated with algorithmic bias, the lack of transparency of certain AI models, potential copyright violations, and the use of personal data. Future teachers should understand the limitations of AI application in education, recognize their responsibility for pedagogical decisions, and maintain the primacy of professional judgment over automatically generated recommendations (UNESCO, 2023).

Consideration of these risks necessitates the creation of specific pedagogical conditions that ensure the effective and safe use of AI technologies in the methodological training of future teachers. First and foremost, it is important to develop students' skills in critically evaluating AI-generated responses, whereby they not only obtain information but also verify it using scientific sources, educational literature, and empirical evidence. Equally important is the integration of AI tools with inquiry-based activities, allowing AI to be used as a means of supporting scientific investigation rather than replacing it.

Another essential pedagogical condition is the development of reflective practice among future teachers. Analysis of personal experience in interacting with intelligent systems, evaluation of the strengths and weaknesses of generated outputs, and awareness of one's own mistakes contribute to the formation of a responsible professional position. At the same time, a central task of contemporary teacher education is the development of AI competence, which encompasses knowledge of the capabilities and limitations of artificial intelligence, the ability to use AI tools effectively in educational settings, the capacity to critically evaluate generated outputs, and adherence to ethical principles of digital interaction (Boiko & Morze, 2025; Laupichler et al., 2022; UNESCO, 2023).

The identified pedagogical conditions are summarized in Table 4.

Table 4

Pedagogical Conditions for the Effective Use of Artificial Intelligence Technologies in the Methodological Training of Future Teachers

Pedagogical Condition	Practical Implementation
Critical Evaluation of AI-Generated Responses	Verification of generated information using scientific sources, textbooks, and research findings
Integration of AI with Inquiry-Based Activities	Use of AI for generating hypotheses, analysing data, and developing inquiry-based tasks
Development of Reflection	Analysis of personal experience of interaction with AI, identification of errors, and determination of ways to overcome them
Adherence to Academic Integrity	Ethical use of generated outputs and acknowledgement of the role of AI in completing tasks
Formation of an Ethical Culture of AI Use	Discussion of ethical cases, copyright issues, and personal data protection
Development of AI Competence	Training in the use of generative systems and evaluation of their capabilities and limitations
Integration of AI into Practice-Oriented Training	Development of lessons, STEM projects, and inquiry-based cases using intelligent tools

Source: Developed by the authors.

CONCLUSIONS AND PROSPECTS OF FURTHER RESEARCH

The findings of the study indicate that artificial intelligence technologies are becoming an important factor in the digital transformation of teacher education and provide new opportunities for improving the methodological training of future teachers in the science education field. The most promising areas of their application include the development of lesson plans, creation of teaching materials, organization of inquiry-based learning activities, modelling of educational situations, preparation of STEM projects, selection of interactive tasks, and development of educational assessment tools. It has been substantiated that the use of generative artificial intelligence contributes to the personalization of learning, enhancement of students' independent work, development of pedagogical design skills, and improvement of the overall effectiveness of professional training.

The study has demonstrated that an important component of pre-service teacher education is the implementation of specially designed methodological tasks based on generative artificial intelligence. Such tasks encourage students to analyse, evaluate, improve, and pedagogically interpret the outputs generated by intelligent systems. This organization of the educational process ensures the integration of subject-specific, methodological, and digital training of future teachers. It has also been established that the use of AI technologies is associated with several risks, including the generation of inaccurate information, AI hallucinations, reduction of students' cognitive independence, violations of academic integrity, and ethical issues related to digital interaction. In response to these challenges, pedagogical conditions for the effective use of artificial intelligence technologies in the methodological training of future teachers have been substantiated. These include critical evaluation of AI-generated outputs, integration of AI with inquiry-based activities, development of reflection, adherence to academic integrity principles, formation of an ethical culture of digital technology use, and development of future teachers' AI competence.

Prospects for further research are associated with the development and experimental verification of a methodology for integrating artificial intelligence technologies into the methodological training of future teachers of the science education field, the identification of criteria and indicators for assessing the formation of AI competence among teacher education students, and the investigation of the impact of generative artificial intelligence on the quality of teacher preparation in the context of the digital transformation of education.

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