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UPDATING TEACHERS' PROFESSIONAL COMPETENCES IN THE ERA OF ARTIFICIAL INTELLIGENCE: STRATEGIES AND REGULATION

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In the modern conditions of digital transformation of education and active implementation of artificial intelligence (AI) technologies, the requirements for the professional activity of a teacher are changing significantly. The integration of artificial intelligence into the educational process and the constant updating of relevant digital tools necessitate a rethinking of the traditional role of the teacher. Under these conditions, the need to update the content and structure of teachers' professional competence in accordance with the new requirements for professional development and advanced training in the postgraduate period is becoming more urgent.

Purpose. The purpose of the article is to research and substantiate strategies and mechanisms for updating teachers' general and professional competencies in the context of the rapid development of artificial intelligence (AI).

Methods. The study used theoretical analysis of scientific literature and sources on the topic of the research, content analysis of articles and publications dedicated to the introduction of artificial intelligence into the educational process, generalization and modeling of teacher's competencies that intersect with competencies in the field of AI, as well as synthesis of the information obtained to form conclusions and recommendations.

Results. The importance of digital skills and competencies among teachers is constantly growing, and mastery of artificial intelligence technologies is becoming one of the key components of modern education. This provision is confirmed by a number of international documents. In particular, in the UNESCO Recommendations on the Ethics of Artificial Intelligence (2021), in the European Union strategic document «Digital Education 2030». The OECD report also emphasizes that the integration of AI into the educational environment requires not only technical adaptation, but also the formation of new professional competencies for teachers. It is about critically reflecting on the opportunities and challenges associated with the application of algorithmic solutions, personalized learning, and digital analytics in educational practice.

The development of digital and artificial intelligence literacy of teachers is gaining the status of one of the priority areas of educational policy, which involves systematic support for the professional growth of teachers, revision of state educational standards, and updating of advanced training programmes. It has been established that AI competencies are integrated into the general and professional competencies of teachers described in the framework documents and are a key element of the training and advanced training of specialists. Particular attention is paid to updating the content of informational-digital, organizational, social and emotional-ethical competences, taking into account the specifics of learning in the era of AI. The analysis of curricula and content modules of the in-service training courses revealed a high level of integration of elements aimed at developing teachers' digital competence, as well as existing forms and types of activities aimed at implementing AI in the educational process.

The results of the study indicate that AI literacy is closely related to other digital skills and competencies of professionals and requires special attention in the context of teachers' professional development. The conclusions drawn become the basis for further research aimed at improving and expanding the tools for forming AI literacy of specialists, developing targeted professional development programmes, and preparing teachers for the challenges and opportunities that the use of AI in education opens up.

Conclusions. Based on the results of the study, it can be concluded that effective updating of teachers' professional competencies in the context of the implementation of artificial intelligence technologies requires a systemic approach. The key conditions are: developing teachers' digital skills, integrating knowledge about AI into advanced training programmes, forming strategic mechanisms for regulating its use at the level of educational institutions, and implementing relevant provisions in state standards. The combination of centralized support, resource provision, and orientation towards international experience can ensure a balanced implementation of innovations while preserving the pedagogical value and quality of the educational process.

Keywords: *competencies in the field of artificial intelligence, digital competencies of teachers, updating the content of teacher competencies, AI in education, professional training and professional development.*

ОНОВЛЕННЯ ПРОФЕСІЙНИХ КОМПЕТЕНТНОСТЕЙ ВЧИТЕЛІВ В ЕПОХУ ШТУЧНОГО ІНТЕЛЕКТУ: СТРАТЕГІЇ ТА РЕГУЛЮВАННЯ

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У сучасних умовах цифрової трансформації освіти та активного впровадження технологій штучного інтелекту (ШІ) істотно змінюються вимоги до професійної діяльності вчителя. Інтеграція штучного інтелекту в освітній процес і постійне оновлення відповідних цифрових інструментів зумовлюють потребу у переосмисленні традиційної ролі педагога. За цих умов актуалізується необхідність оновлення змісту й структури професійної компетентності вчителів відповідно до нових вимог підготовки та підвищення кваліфікації у післядипломний період.

Мета. Метою статті є дослідження та обґрунтування стратегій і механізмів оновлення загальних і професійних компетентностей вчителів в умовах стрімкого розвитку штучного інтелекту (ШІ).

Методи. У дослідженні використано теоретичний аналіз наукової літератури та джерел із теми дослідження, контент-аналіз статей і публікацій, присвячених впровадженню штучного інтелекту в освітній процес, узагальнення та моделювання компетентностей вчителя, які мають перетин з компетентностями в сфері ШІ, а також синтез отриманої інформації для формування висновків та рекомендацій.

Результати. Значення цифрових навичок та компетентностей серед педагогів постійно зростає, а володіння технологіями штучного інтелекту стає одним із ключових компонентів сучасної освіти. Це положення підтверджено низкою міжнародних документів. Зокрема, у Рекомендаціях ЮНЕСКО щодо етики штучного інтелекту (2021), у стратегічному документі Європейського Союзу «Цифрова освіта 2030», а також у доповіді ОЕСР наголошується, що інтеграція ШІ в освітнє середовище потребує не лише технічної адаптації, а й формування нових професійних компетентностей педагогів. Йдеться про критичне осмислення можливостей і викликів, пов'язаних із застосуванням алгоритмічних рішень, персоналізованого навчання та цифрової аналітики в освітній практиці.

Розвиток цифрової та штучно-інтелектуальної грамотності вчителів набуває статусу одного з пріоритетних напрямів освітньої політики, що передбачає системну підтримку професійного зростання педагогів, перегляд державних освітніх стандартів та оновлення програм підвищення кваліфікації. Встановлено, що компетентності у сфері ШІ інтегруються в описані в рамкових документах загальні та професійні компетентності вчителів і є ключовим елементом підготовки та підвищення кваліфікації фахівців. Особлива увага приділяється оновленню змісту інформаційно-цифрової, організаційної, соціальної та емоційно-етичної компетентностей із урахуванням специфіки навчання в епоху ШІ. Проведений аналіз навчальних планів і змістових модулів курсів підвищення кваліфікації виявив високий рівень інтеграції елементів, спрямованих на розвиток цифрової компетентності вчителів, а також наявні форми й види діяльності, що спрямовані на впровадження ШІ в освітній процес.

Результати дослідження свідчать, що грамотність у сфері ШІ є тісно пов'язаною з іншими цифровими навичками та компетентностями фахівців, вона потребує спеціальної уваги в контексті професійного розвитку вчителів. Визначені висновки стають основою для подальших досліджень, спрямованих на вдосконалення й розширення інструментів формування ШІ-грамотності фахівців, розробку цільових програм професійного розвитку та підготовку вчителів до викликів і можливостей, які відкриває використання ШІ в освіті.

Висновки. На основі отриманих результатів дослідження можна зробити висновок, що ефективне оновлення професійних компетентностей учителів в умовах впровадження технологій штучного інтелекту потребує системного підходу. Ключовими умовами є: розвиток цифрових навичок педагогів, інтеграція знань про ШІ у програми підвищення кваліфікації, формування стратегічних механізмів регулювання його використання на рівні закладів освіти, а також впровадження відповідних положень у державні стандарти. Поєднання централізованої підтримки, ресурсного забезпечення та орієнтації на міжнародний досвід здатне забезпечити збалансоване впровадження інновацій, зберігаючи педагогічну цінність і якість освітнього процесу.

Ключові слова: *компетентності в сфері штучного інтелекту, цифрові компетентності вчителів, оновлення змісту компетентностей вчителя, ШІ в освіті, професійна підготовка і підвищення кваліфікації.*

Introduction. In the modern conditions of digital transformation of education and active implementation of artificial intelligence (AI) technologies, the requirements for the professional activity of a teacher are changing significantly. The integration of artificial intelligence into the educational process and the constant updating of relevant digital tools necessitate a rethinking of the traditional role of the teacher. The teacher no longer acts exclusively as a carrier and translator of knowledge, but instead increasingly acts as a facilitator, mentor, and curator of students' individual educational trajectories. Under these conditions, the need to update the content and structure of teachers' professional competence in accordance with the new requirements for professional development and advanced training in the postgraduate period is becoming more urgent.

The concept of AI literacy is gaining increasing attention in scientific discourse, defined as the basic level of knowledge, skills, and attitudes necessary to understand the principles of AI and its conscious use (Long & Magerko, 2020; Tenberga & Daniela, 2024). At the same time, «AI competence» is interpreted as a broader category that includes not only elements of AI literacy but also the ability to integrate artificial intelligence into the professional activities of a teacher, ensuring its ethical, pedagogically appropriate, and safe application (Ng et al., 2023; UNESCO, 2024/2025). In this study, these concepts are considered in relation to each other: AI literacy is the foundation for the formation of comprehensive competence in the field of AI.

Scientists point out that artificial intelligence, especially generative (GenAI), is rapidly penetrating every aspect of our lives, stimulating an accelerated evolution of how we work, relax, and learn, and actualizing the need for the formation and development of new competencies in teachers and students (Filo, et al., 2024). The level of teachers' readiness to use AI is directly related to the effectiveness of its implementation in the educational process and the development of relevant competence in students (CHIU, 2024). At the same time, researchers are paying attention not only to the potential benefits of using AI in education, but also to the associated risks (Vasiliev, 2025) and the challenges of the digital educational environment (Goncharova, 2023).

The research describes the possibility of developing teachers' competence in the field of artificial intelligence using self-assessment tools; considers the key criteria for evaluating tools for developing literacy in the field of artificial intelligence, and analyzes existing scales for assessing this literacy (Tenberga & Daniela, 2024). The digital competencies of teachers necessary for the implementation of AI in the educational process have been analyzed in detail, emphasizing the need for interdisciplinary knowledge, communication, collaboration, and continuous professional development (Ng, et al., 2023). The impact of the integration of artificial intelligence in pedagogical education on the formation of the competence of future teachers is studied, in particular the issue of motivation for the development of digital competence in this area (Lee & Bryan, 2024).

Therefore, the relevance of the study is due to the need to take into consideration constructive approaches to updating the content and structure of teachers' professional competencies, taking into account the modern capabilities of the era of artificial intelligence, preventing potential risks of its implementation, as well as developing and implementing innovative programmes for training and advanced training of teachers in the context of the digitalization of education.

The purpose of the article is to research and substantiate strategies and mechanisms for updating teachers' general and professional competencies in the context of the rapid development of artificial intelligence (AI).

Methods. In the research process, a complex of interrelated methods was used, which ensured a deep and systematic study of the problem. Theoretical methods encompass analysis and synthesis of scientific literature, regulatory legal acts and international documents on teacher professional competencies and the use of AI in education, generalization and systematization of the obtained data in order to identify key trends and strategic guidelines. The method of content analysis is the study of the content of educational programmes, professional standards and strategic documents in order to determine the place of competence in the field of AI in the structure of the professional competences of a modern teacher. Generalization and modeling methods cover formation of recommendations and models of updated professional competencies of a teacher in the context of integrating AI into the educational process. Empirical methods include questionnaires, interviews, surveys to identify the current state of development of digital and innovative competencies in teaching staff, as well as to identify teachers' requests for the development of IT competencies.

Results. Competence in the field of artificial intelligence has become one of the important technological skills of the 21st century. With AI competencies, people can critically evaluate AI technologies, effectively communicate and collaborate with AI, and use AI as a tool online at home and in the workplace (Long & Magerko, 2020). Acquiring the appropriate competence is especially important for teachers, who must not only possess digital tools, but also be able to form a responsible attitude towards AI in their students. In view of this, teachers' digital competence in the field of AI, its content and structure remain a topic of active discussion in the scientific community and society.

At the international level, the importance of AI development for teachers is recognized in the UNESCO Recommendations of the Ethics of Artificial Intelligence (2021), the Digital Education Action Plan (2021–2027), and the European Union's Digital Education 2030. In particular, the document «Recommendation of the Ethics of Artificial Intelligence» (UNESCO. 2021) outlines that AI ethics should also be applied in the field of education, including teacher training. In the OECD Report «What should teachers teach and students learn in a future of powerful AI? » (2025), it is noted that the integration of AI into the educational environment requires not only technical adaptation, but also the formation of new professional competencies among teachers. The document examines how learning goals and pedagogical competencies are changing with the rapid development of AI. The international discussion is logically complemented by the OECD document «Nurturing a thriving teaching profession in an AI enhanced world» (2025), which emphasizes the importance of supporting teachers in the context of experimental implementation of AI, personalization of education, and rethinking the content of professional activity.

Of particular importance is the report of the European Commission (2017) on the importance of digital skills and competences in the everyday life of educators and the need for continuous development of skills and competences. The «DigCompEdu» framework identifies a broad range of skills and competencies that educators must possess to effectively use digital technologies in their professional field. The framework categorizes 22 competences into six main parts: professional engagement, digital resources, teaching and learning, assessment, student empowerment, and promoting the development of students' digital competence (European Framework for the Digital Competence of Educators: DigCompEdu, 2017). Instead, the UNESCO document «AI Competency Framework for Teachers», published in August 2024 and updated as of June-July 2025 identifies five key areas: worldview, ethics, AI foundations, pedagogy, and professional development in the context of AI.

In the scientific space, the resource developed by UNESCO ICT «Competency Framework for Teachers» (2018) is noted as being important, defining the knowledge, skills and values that teachers should possess in the AI era in the amount of 15 competencies in five dimensions: human-centeredness, AI ethics, AI fundamentals and applications, AI in pedagogy and AI for professional development. This is an excellent basic document for understanding key aspects (Miao, et al., 2024). The article by CHIU, T. (2024) «Teacher Education for AI Competency» presents an AI competency framework consisting of the four main components: pedagogical content knowledge for AI (IPACK), ethical teaching knowledge, professional knowledge for AI, and an affective component. It is emphasized that a teacher with strong AI competence should demonstrate a positive attitude, self-reflective thinking, and a strong capacity for professional learning (CHIU, 2024).

The study by Filo, Y., Rabin, E., & Mor, Y. (2024) entitled «An Artificial Intelligence Competency Framework for Teachers and Students: Co-created with Teachers» proposes an AI competency framework for teachers and students that was developed in collaboration with teachers. In particular, it suggests identifying the four key skills: identification of AI mechanisms and their functioning; effective and informed use of AI; AI agency (proactive and value-oriented use of AI); and ethical use of AI (Filo, et al., 2024). Researchers Tenberga, I., & Daniela, L. (2024) dedicate their work «Artificial Intelligence Literacy Competencies for Teachers through Self-Assessment Tools» to studying the key components of teachers' AI literacy and their correspondence to existing digital literacy frameworks. The study categorizes 22 competencies into six main parts, including professional engagement, digital resources, teaching and learning, assessment, student empowerment, and developing students' digital competence (Tenberga & Daniela, 2024).

The study by Simuț, R., Simuț, C., Bădulescu, D., & Bădulescu, A. (2024) reveals teachers' perceptions of their role in the formation of competencies and key challenges associated with the development of AI systems. A significant positive relationship has been found between teachers' attitudes towards AI and competency development, in particular with the most pronounced impact on educational management competencies. According to the results of the work of Tenberga, I., & Daniela, L. (2024) «Artificial Intelligence Literacy Competencies for Teachers through Self-Assessment Tools», differences in literacy components in the field of AI and digital competencies were identified, and the intersection of competencies in some aspects, for example, in the management of digital resources, is revealed. At the same time, it is stated that AI literacy competence forms a separate and important category. Therefore, while aligning AI literacy with other digital skills and competencies, there is a need to simultaneously focus on professional development of AI-specific competencies.

The above-mentioned discussions indicate some of the opportunities and challenges of using AI for teaching by teachers, the need for modern frameworks and recommendations that would inform teachers about what specific digital competencies are needed to help teachers become leaders for students in the use of AI.

At the national level in Ukraine, the official document defining the mandatory requirements for a teacher's professional activity and his or

her competencies is the Professional Standard of «Teacher of a General Secondary Education Institution» (2024). This document formalizes the professional competencies of a modern teacher, defines the structure of the competency model, and outlines professional functions, qualification requirements, and guidelines for the content of educational programmes for the training and advanced training of teaching staff. In particular, the professional development of Ukrainian teachers involves the development of a whole complex of teacher competencies: general (civic, social, cultural, leadership, entrepreneurial) and professional (language and communicative, subject-methodical, information and digital, psychological, emotional and ethical, pedagogical partnership, inclusive, health-preserving, design, prognostic, organizational, evaluative and analytical, innovative, reflective competencies, the ability to learn throughout life).

In the Ukrainian educational space, among the strategic and methodological documents that outline the directions of digital transformation of education and integration of artificial intelligence into pedagogical practice, it is worth noting the «Recommendations on the use of artificial intelligence in higher education institutions» (2025). The document contains methodological reference points and ethical guidelines for the implementation of AI in teaching, assessment, and management of the educational process, and also outlines the role of educators in ensuring the responsible and safe use of innovative technologies. Also, a document that can serve as a guide for teachers regarding the list of necessary digital competencies in the field of artificial intelligence is the project «Instructional Recommendations for the Use of AI in Schools» (2024). The methodological recommendations outline approaches to the safe, ethical, and pedagogically appropriate use of artificial intelligence technologies, and also define the roles and tasks of teachers as mediators between new technologies and students.

The aforementioned documents identify both the potential opportunities and challenges associated with the use of artificial intelligence by teachers in the teaching and learning process. At the same time, in the New Ukrainian School teacher competency model, artificial intelligence is indirectly mentioned as one of the aspects of digital literacy, which is defined as a cross-cutting competency for all participants in the educational process (Linnik, 2021). Information-digital competence, in turn, is recognized as one of the key ones for a modern teacher, as it encompasses the ability to use digital tools, work with information, and integrate it into the content of learning. However, the effective performance of these functions in a modern educational environment is possible with at least a basic understanding of the principles of operation and capabilities of artificial intelligence. Therefore, studying the relationships between AI literacy competencies and already defined digital skills and competencies, identifying the differences and certain intersections of AI literacy and digital competencies leads us to understanding the necessary updating of the content and structure of the teacher's general and professional competencies in the AI era.

First of all, the teacher's information– digital competence reaches a new level. It involves not only the ability to effectively use various AI applications and platforms to create educational content, personalize learning, and automate routine tasks (e.g., checking assignments, generating reports), but also familiarity with generative AI (such as ChatGPT, Gemini) for developing educational materials for adaptive learning by AI assistants. It is also important to have a basic understanding of how AI works, its capabilities, and limitations, in order to critically evaluate AI solutions and effectively integrate them into your own practice. Additionally, awareness of cyber-security issues, student data protection, and ethical dilemmas associated with the use of AI (algorithmic bias, plagiarism, copyright) becomes mandatory.

Further, the teacher's subject-methodological competence is transformed. Teachers should develop new teaching methods that take into account the capabilities of AI, integrating it into the lesson architecture to improve learning effectiveness, rather than simply using it as an auxiliary tool. AI allows you to adapt educational material and tasks to the individual needs of each student, so the teacher must be able to analyze the data provided by AI and use it to create personalized learning trajectories. In an environment where routine tasks will increasingly be performed by AI, teachers should focus on developing students' critical thinking, creativity, problem-solving, collaboration, and digital literacy, which are key skills of the 21st century.

Furthermore, the organizational competence is changing. The teacher creates a learning environment where AI acts as one of the tools, and this requires the ability to effectively organize students' interaction with AI systems and monitor their work. AI can provide detailed analytics on student progress, so the teacher must be able to interpret this data for effective monitoring and objective assessment of knowledge, skills, and abilities. The role of the teacher is transformed from the main source of information to a mentor and facilitator who collaborate with AI, delegating routine tasks to it and focusing on developing students' higher cognitive skills and their social-emotional development.

Finally, social and emotional-ethical competences are gaining even greater importance. Despite automation, the role of the teacher as a person who builds relationships with stu-

dents, creates a favorable psychological climate, and provides emotional support becomes irreplaceable. AI cannot replace human communication and emotional intelligence. In an environment where AI can answer questions and provide information, the teacher's task is to motivate students to learn, build their intrinsic motivation, and support their desire for self-development.

Today, the framework characteristics defined by the professional standard for teachers are filled with specific content that is implemented in teacher training and advanced training programmes. In particular, the structure and content of advanced training programmes are formed at an interdisciplinary level. For example, an analysis of the curricula and content modules of advanced training courses organized at the Chernihiv Regional Institute of Postgraduate Pedagogical Education named after K.D. Ushynskyi confirms that they contain elements aimed at developing the teacher's digital competence. This is implemented through various forms and types of activities – interactive trainings, AI-based simulations, work with digital tools for data analysis and processing, and development of educational materials using generative systems. The topics of lectures and practical classes, regional webinars are enriched with relevant topics: «Using artificial intelligence in the Canva programme for creating effective educational materials», «Overview of useful AI services for teachers», «Artificial intelligence in tracking and correcting learning losses: opportunities and limitations», «Modern intelligent information technologies», «Artificial intelligence in education – opportunities, challenges or threats?», «Use of Google Notebook LM and Gem-bots in the professional activities of teachers», etc.

Thus, teacher training gradually integrates AI competencies as a component of digital literacy, which is an important step towards adapting the teaching community to the conditions of the digital transformation of education, as evidenced by surveys conducted among students of advanced training courses. Quantitative analysis showed that about 65% of respondents noted an insufficient level of knowledge regarding the practical application of artificial intelligence technologies in the educational process. At the same time, 72% of teachers indicated the need for systematic professional development, especially in the area of digital competencies. At the same time, 55% of teachers already use certain AI tools (in particular, ChatGPT, Canva, Grammarly, etc.), but often without sufficient awareness of ethical aspects and assessment of the pedagogical effectiveness of such solutions. Qualitative results confirmed the presence of a number of problematic aspects. During in-depth interviews, teachers expressed concerns about the automation of certain components of the educational process and the risk of reducing the level of interpersonal interaction with students.

Conclusions. The introduction of AI into education does not lead to the replacement of the teacher, but radically changes his role and the competencies of specialists necessary for the implementation of pedagogical activities. The future of pedagogy requires teachers not only to be technically savvy, but also to be able to think critically, adapt, be creative, and have a high level of emotional intelligence. The development of digital competence in the field of AI is the key to successful professional activity in the conditions of digital transformation of education.

The study is the first attempt to systematically correlate AI competence with teacher digital competencies defined in international and Ukrainian regulatory documents. New content accents of teacher competencies are identified, which are associated with the integration of artificial intelligence tools into the educational process. A refined interpretation of the relationship between the concepts of «AI literacy» and «AI competence» is proposed, which can serve as a guideline for the further development of educational programs and criteria for assessing teachers' readiness to work in the conditions of digital transformation of education.

An analysis of scientific sources has shown that the rapid spread of artificial intelligence, in particular generative intelligence, highlights the need to update the competencies of teachers and students. The effectiveness of integrating AI into education depends on the level of preparation of teachers, their digital literacy, interdisciplinary knowledge, communication skills, and readiness for continuous professional development. The research also highlights the importance of self-assessment tools and the development of clear criteria for assessing AI competence, as well as the need to motivate teachers to develop digital skills in their teaching.

The generalization of the research results shows that updating the professional competencies of teachers in the context of using artificial intelligence is an urgent need for modern education. The insufficient level of knowledge about the practical application of AI, the limited strategic regulation of its implementation and the absence of an integrated system of professional development create barriers to the effective use of technologies. International experience confirms that overcoming these challenges is possible with comprehensive state and institutional support, resource provision, and the implementation of AI in educational standards, which will increase pedagogical efficiency and ensure balanced development of teachers' digital and professional competencies.

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