Designing a matrix training for teacher professional development in a digital environment

Oksana V. Ovcharuk[1], Nataliia V. Soroko[1] and Oksana Ye. Kravchyna[1]

[1]*Institute for Digitalisation of Education of the NAES of Ukraine, 9 M. Berlinskogo Str., Kyiv, 04060, Ukraine*

Abstract

In the 21st century, a digital society is rapidly evolving, driven by the influence of artificial intelligence and other information and communication technologies (ICTs). As a result, education requires technical updates and significant methodological modernisation in the teaching and learning processes. The emergence of tools like ChatGPT, Copilot, Canva AI, Google Gemini, and others is changing the role of teachers, the methods and sources of knowledge and the forms of interaction between participants in the educational environment.

The paper examines approaches to the professional development of teachers in a digital environment through artificial intelligence. The paper aims to present the Matrix, which ensures the conduct of teachers' training with the possible revision of options and addition of necessary topics. The Matrix serves as a planner for professional development, utilising AI tools. The levels along which the teacher moves towards acquiring the necessary competencies using AI are identified: knowledge, skills, soft skills, activity, and result. A practical sample of the realisation of the 1st level of AI use in the introductory stage is presented. We propose the use of matrix learning, which has received positive feedback from teachers, as it anticipates their needs and the flexibility of learning. The Matrix presented in this paper is aimed at developing teachers' competence in using AI at three levels – familiarisation, use, and transformation – which ensures gradual training and practice of teachers in using AI in the classroom.

Keywords

educational environment, teacher training, matrix, teacher professional development

1. Introduction

Modern teachers are involved in the use of digital technologies and solving complex tasks that are posed to them by circumstances that affect the educational process, namely the transition to distance and remote forms of interaction with students and colleagues, the need to use those means of organising learning that are not always updated and modern, and the need to quickly adapt to the needs of students and their parents. This is particularly evident, especially in Ukraine, where the ongoing conflict has disrupted education systems, with many schools having been destroyed or closed, especially in occupied territories. Therefore, considerable attention is paid to teachers' support and professional development today. The needs for the professional development of teachers lie in the need to use modern educational digital resources and tools that contribute to the formation of key competencies in students, particularly critical thinking, and the development of soft skills that contribute to their successful learning. Recently, teachers have been paying attention to the possibilities of using artificial intelligence as a tool that helps them organise the educational process and complements the range of possible tools for diversifying forms of learning.

The professional development of teachers is a complex task, and that is why it is necessary to pay attention to matrix learning, which is becoming a popular approach to planning, organising and implementing teachers' professional development today. This approach is justified because matrix learning enables teachers to determine and plan their development process independently, be flexible, and choose the necessary work opportunities. The reform of the New Ukrainian School involves changing approaches to student education and developing a new generation of teachers who can be

DigiTransfEd 2025: 4th Workshop on Digital Transformation of Education, (September 24, 2025, Kyiv, Ukraine)

ovcharuk@iitlt.gov.ua (O. V. Ovcharuk); soroko@iitlt.gov.ua (N. V. Soroko); kravchyna@iitlt.gov.ua (O. Ye. Kravchyna)

https://iitlt.gov.ua (O. V. Ovcharuk); https://iitlt.gov.ua (N. V. Soroko); https://iitlt.gov.ua (O. Ye. Kravchyna)

0000-0001-7634-7922 (O. V. Ovcharuk); 0000-0002-9189-6564 (N. V. Soroko); 0000-0002-3903-0835 (O. Ye. Kravchyna)

independent, competent, and motivated in performing their professional tasks.

This article proposes the Matrix model for teachers' professional development, which can be used equally by teacher training institutions and teachers themselves to upgrade their use of AI in professional contexts.

2. Literature review

The development of matrix training for teachers is the subject of works by M. Korsager, B. Reitan, M. Gaare Dahl, and others [1], who investigate the professional development of math and science teachers through the use of a matrix, representing a framework. This matrix contains methods for enactment, which can help teachers to realise the theory in practice. S. M. Wilson proposes a systemic approach to reform to enhance the effectiveness of professional development for science teachers. She identifies the top five characteristics of effective professional development: duration, active learning, collective participation, coherence, and content focus [2]. J. Crowell asserts that a successful teacher has the necessary resources and tools to provide students with the best learning experience. She emphasises that effective teacher professional development should go beyond a one-time training session for science teachers. Instead, it should incorporate a comprehensive professional development matrix that includes all the essential components for positively impacting student learning. These components include the science curriculum, strategic planning, leadership reform, community building, and educational sustainability programs [3]. The authors A. Brandão, L. Pedro, and N. Zagalo consider teachers' professional development using integrative artificial intelligence as a key trend in modern education. In their work, the authors guide teachers on the safe and ethical use of artificial intelligence by reviewing relevant practices and literature. They emphasise the importance of fostering literacy in generative AI, developing critical and creative thinking skills, and considering humanistic, ethical, and social factors [4]. The works of V.Slyusar, Y.Kondratenko, A.Shevchenko, and T.Yeroshenko address the key aspects of the artificial intelligence development strategy for mobile technologies. The authors propose how to use the set of mobile technologies, devices, software, and communication standards that allow users to access information, communicate, and perform various tasks using mobile devices [5]. Moreover, the authors discuss the implementation of national AI strategies and perspectives on applying AI systems [6].

The article by Marienko et al. [7] examines the issue of using adaptive technologies for personal development of teachers in a digital environment. The authors investigate this issue in the context of the continuous development of teaching and the challenges associated with digital transformation. The work mainly focuses on using learning management systems (LMS), which include artificial intelligence algorithms, to create personalised learning. The article by M. Popel [8] presents a conceptual model of a training system aimed at developing professional competencies of mathematics teachers using the CoCalc cloud service. The author investigated the development and empirically tested the effectiveness of this system, which is built on the principles of a matrix approach to learning, considering such elements as goals, content, tools, methods, results, and levels of competence. The work of S. Lytvynova and O.Melnyk [9] examines the issue of integrating cloud services into the informal education system of teachers to improve their digital competence. O. Chubrei et al. [10] examine the process of creating an adaptive digital environment for the professional growth of teachers in higher education institutions. The authors emphasise the importance of developing a flexible, technologically rich educational system that provides personalised learning through the modular organisation of educational content. The need for professional development in the use of ICT is also confirmed by surveys of teachers conducted in Ukraine in 2023-2024 [11]. Approximately 26,000 teachers were surveyed about their readiness to use digital tools and the challenges they face. The survey also outlined their needs and perspectives on how to help improve their digital competencies.

3. Learning matrix for teachers' professional development

The learning matrix is a strategic tool that helps manage the educational process and is designed to track, plan, and manage learning and teachers' skills development. Its main purpose is not only to identify learning needs but also to monitor progress in acquiring teachers' skills and competencies in accordance with educational goals. We propose using such a matrix to structure the learning process using artificial intelligence.

Matrix learning consists of several steps. First, a matrix is developed with two or more dimensions, with the target skill components isolated on each axis (for example, actions on one axis and results on another axis). The proposed matrix contains learning components on one axis (vertical) and levels on another (horizontal). This makes it possible to track the educational progress of professional development and, if necessary, supplement the matrix with new components or add new descriptors to the level. In this case, the combinations of components can be flexibly changed [12].

Our special interest mulated into thin-called TPACK model or approach to professional development. This model consists of four components: technological, pedagogical, content, and knowledge. The proposed framework by P. Mishra and J. Koehler for teachers' professional development is focused on using ICTs [13].

For the development of soft skills of teachers in the use of artificial intelligence tools, the draft recommendations 'Instructional and methodological recommendations on the use of artificial intelligence capabilities in secondary education institutions', a joint work of the Ministry of Education and Science of Ukraine and the Ministry of Digital Transformation of Ukraine, are useful [14].

Table 1 presents a generalised example of a Matrix training "Integration of AI tools into teaching". The main task is to promote the professional development of teachers by building an individualised trajectory of the formation of digital and interdisciplinary competencies through a matrix training focused on integrating artificial intelligence tools into the educational process.

Table 1
Matrix table by levels of application of AI tools.

Component/ Level	Level 1 (Familiarization)	Level 2 (Use)	Level 3 (Transformation)
Knowledge	What is AI, its capabilities in learning	How AI learning tools work	How to create AI educational content
Skills	Navigating AI services	Creating practical tasks with AI	Development of proprietary integrated solutions
Soft skills	Digital flexibility	Critical thinking, responsibility	Creativity, ethical awareness
Activity	Studying the instructions	Participation in workshops, creation of lessons	Microproject + peer facilitation
Result	Completed introductory course	A fragment of a lesson on AI has been developed	Presentation of our own AI project was made

At the first level in the matrix, the "Knowledge" component includes introducing teachers to the theoretical foundations of artificial intelligence, its key functions, and potential for use in education, which is the stage of teachers' initial understanding of AI. At this stage, the "Skills" component covers the understanding and use of navigation in AI services, while any AI platform can be taken as an example. Xiao Tan and Gary Cheng and Man Ho Ling, who conducted an analysis of SCOPUS and WEB of Science articles from 2015 to 2024 on the problem of using AI in the professional activities of teachers [15], particularly pay attention to the relevance of Conversational AI (e.g., Dialogflow, IBM Watson, ChatGPT, SnatchBot) for the use of such platforms in the learning process and professional development of teaching staff. When considering navigation and further study of AI, a teacher can use ChatGPT and SnatchBot. Thus, at the first stage, the teacher learns to navigate the interfaces of AI services, find the necessary tools, and understand the logic of their functioning in the educational process. The first level's "Soft skills" component involves forming digital flexibility in the student, that is, the ability to

freely adapt to new digital conditions and technologies. The "Activity" component at the familiarisation stage includes the teacher reading instructions, attending webinars or consultations on implementing AI in the educational process. The result of this stage is a completed introductory course, which can be represented by a test for self-assessment of the knowledge that the teacher has mastered at the first level of training. At the second level of "Use" when considering the "Knowledge" component, it should be noted that the teacher begins to understand the principles of operation of specific AI tools, such as text generators, adaptive learning systems or automatic assessment services. At the same time, the teacher's knowledge of how specific AI tools work (for example, ChatGPT, adaptive LMS, AI material designers, etc.) deepens. The "Skills" component expands to the ability of the teacher to use AI to create practical tasks, taking into account the individual learning paths of students. The "Soft skills" component at this stage involves the development of critical thinking, responsibility and ethical use of AI in the teacher. The "Activity" component covers the teacher's participation in workshops, creation of lessons, educational projects and other activities using AI. The result of this stage can be the development of a lesson, educational project, etc., using AI. At the third level, "Transformation", the teacher is able not only to use, but also to create or customise AI solutions for the needs of educational content, for example, to generate didactic materials or create chatbots to support learning. The "Knowledge" component covers the teacher's understanding and acquired knowledge of how to create AI to form and expand educational content. The "Skills" component expands to the teacher's ability to develop original integrated solutions, analyse AI proposals, and adapt them to the educational process. When considering the "Soft skills" component, the teacher can be offered a test that involves analysis and self-analysis of the teacher's creativity and ethical awareness regarding AI use in the educational process.

The need to develop Soft skills for teachers is stated in Ukrainian regulatory documents. Thus, the professional standard of a teacher adopted in 2020 defines professional competencies that relate to Soft skills, including: linguistic and communicative, informational and digital, psychological, emotional and ethical, pedagogical partnership competence, inclusive, health-preserving, design, prognostic, organisational, evaluative and analytical, innovative, lifelong learning ability, reflective. This professional standard is taken into account for the development of the New Ukrainian School. Since the development of these skills is considered a necessary component of preparing children for a successful future, attention is focused on the need to integrate these skills into curricula, which will contribute to both academic achievements and social development of the personality, self-regulation, self-awareness and empathy. Accordingly, teachers need to develop soft skills. The order on approval of the Conceptual Principles of Reforming Specialised Secondary Education (Academic Lyceums), adopted in 2024 by the Ministry of Education and Science of Ukraine, states the need for measures to develop the soft skills of teachers and students, including training and workshops on teamwork, leadership, communication, time management, etc. In this context of soft skills development, it is important to focus on developing qualities such as digital flexibility, critical thinking, responsibility, creativity and ethical awareness. These skills are particularly effective and necessary for using artificial intelligence tools in a teacher's educational activity. For example, the ability to adapt to new technologies is most important at the familiarisation stage, analysing information and ethically applying AI are necessary at the use stage, and the ability to develop innovative approaches to learning at the transformation level. All these soft skills allow teachers to effectively integrate AI into the educational process, thereby contributing to forming a responsible attitude towards modern technologies in students.

Within the framework of the matrix table we have proposed, we propose three levels of Soft skills for teachers to use artificial intelligence effectively in the educational process. At level 1 (familiarisation), the teacher becomes familiar with various artificial intelligence tools (chatbots, content generators, and analytical platforms) while developing Digital flexibility to adapt to new digital technologies. At this level, the teacher needs to understand artificial intelligence's opportunities for educational activities and be ready to experiment with these technologies. At level 2 (use), the teacher begins to use artificial intelligence to solve his needs actively (for example, text analysis or creating interactive exercises and chatbots) while developing his critical thinking and assessing the reliability and quality of AI results and is also responsible for the ethical use of these results when creating practical tasks. At level 3

(transformation), the teacher integrates AI into the educational process by developing their products (personalised learning trajectories or interdisciplinary projects, etc.). At the same time, the development of unique approaches by the teacher is ensured by his creativity, and the use of AI must comply with ethical principles (avoidance of plagiarism, respect for copyright, and awareness of the moral and social consequences of the use of AI).

The "Activity" component covers the organisation of interaction between participants in the educational process using AI. As a result, the teacher must present his own AI project for implementing a lesson, educational project, and other events in the educational process. It should be noted that it is worth determining the level of digital competence of the teacher to build a matrix of individual learning. It can be determined using special tests such as, for example, the test "Digital Grammar for Teachers" offered by the web portal "Diya", developed by the Ministry of Transformation of Ukraine (designed for 30-40 minutes); the test "SELFIE for TEACHERS" developed by the European Commission together with a group of education experts from all over Europe (designed for 30 minutes) [16] and questionnaires that are focused on identifying problems, obstacles and other risks when using ICT by teachers in the educational process according to certain teaching goals in general secondary education institutions.

Let us take a closer look at the proposed Level 1 (Introduction) of the matrix for applying artificial intelligence tools for teachers (figure 1).

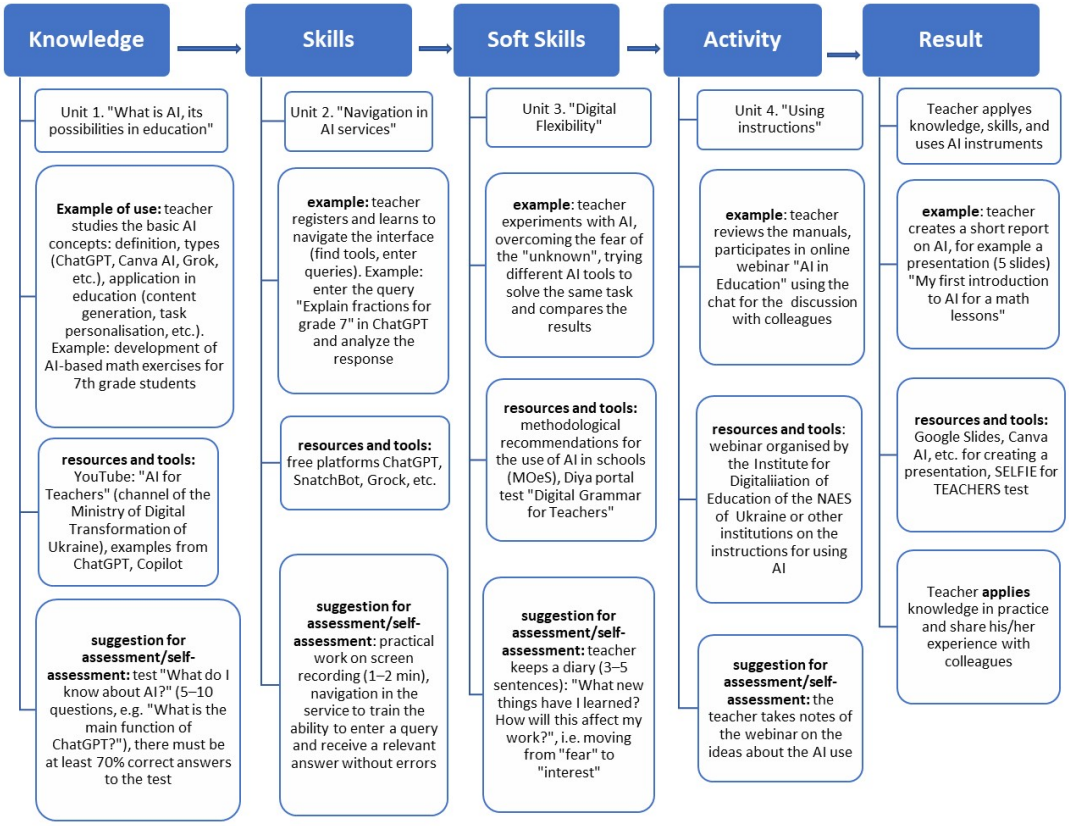

Figure 1: Example of a practical implementation of the AI tools matrix for teachers at Level 1 (Introduction).

The "Knowledge" component allows the formation of a theoretical basis for studying and using AI as a teacher's tool. It includes understanding AI capabilities, ethical aspects of its application, and benefits for personal and professional development. The main topic of this component is "What AI is and its potential in education. A teacher should know the definition of AI (machine learning algorithms), its types (generative: ChatGPT, Canva AI; conversational: Google Gemini), capabilities (content generation, task personalisation), as well as ethical aspects (avoiding plagiarism, ensuring responsibility for quality), and ways of adapting them to students' needs.

We suggest the teacher develop a mathematics exercise for 7th-grade students on the topic "Fractions:

Addition and Subtraction, using AI. For example, entering a prompt into ChatGPT: "Create five exercises on adding fractions for 7th grade with answers, at different difficulty levels (basic, intermediate, advanced)", checking accuracy, adding personal explanations, and avoiding direct copying. To prepare for this task, the teacher can review videos and online resources such as the YouTube course "Big Course on AI in Education" (Ministry of Digital Transformation of Ukraine, Ministry of Education and Science of Ukraine), and use tools such as ChatGPT (for exercise generation), Canva AI (for visualisation), Grok (for creative ideas), etc.

To assess progress, we propose designing a test "What do I know about AI?" with 5–10 questions (multiple choice and open-ended), lasting 15–20 minutes, using Google Forms (at least 70 percent correct answers should be achieved; if less, it is recommended to repeat the topic). For self-assessment, teachers may take the "Digital Grammar for Teachers" test on the Diia portal and answer reflection questions such as: "What did I learn from this material? How can I deepen my knowledge of AI?"

In the next component, "Skills", the teacher develops practical abilities related to navigating and basic use of AI services, following the principles of step-by-step learning. The main theme here is "Navigation in AI Services", as hands-on experience with AI interfaces helps transition from theoretical understanding to active application. This includes registration, finding tools, entering prompts, and analysing results. For example, a teacher may be asked to prepare an explanation of fractions for 7th grade, completing all stages – from registration, entering a query, analysing the answer, to refining the prompt (e.g., "Add an example with different denominators") to test flexibility.

For this task, the teacher may use ChatGPT for prompt input and analysis, SnatchBot to explore conversational bots, and Grok to generate creative responses. To evaluate progress, it is recommended to record a short screen capture (1–2 minutes) of the navigation process: logging into the platform (e.g., ChatGPT), entering the query "Explain adding fractions for 7th grade", receiving the response, and briefly commenting on its relevance (1–2 sentences). For self-assessment, the teacher can review the recording, evaluate their own actions (e.g., "Did I easily find the input field? Was the answer clear?"), and note achievements and difficulties.

The "Soft Skills" component is about developing digital flexibility through adapting to new technologies in education. At this stage, teachers overcome psychological barriers such as the fear of the "unknown" by completing one task using multiple platforms, comparing results, and preparing for confident AI use. At Level 1, the teacher becomes familiar with different AI platforms, evaluates their potential, and develops a positive attitude toward innovative technologies. A suggested task: compare AI tools for explaining fractions for 7th grade. For example, enter the query "Explain adding fractions 1/2+1/4=? for 7th grade" into ChatGPT and Grok, compare results, and create a visual diagram in Canva AI. To prepare, teachers are encouraged to consult the "Instructional and Methodological Guidelines for Using AI in Schools" issued by the Ministry of Education and Science of Ukraine and the Ministry of Digital Transformation, and to take the "Digital Grammar for Teachers" test on the Diia portal to assess digital competence and identify growth areas. Teachers may keep a journal for personal reflection to record their insights and ideas, answering questions such as: "What new things have I learned? How will this impact my work?" with a focus on shifting from "fear" to "interest".

The "Activity" component involves teachers working with methodological materials, manuals, and instructions on using AI tools, participating in webinars and discussions, consolidating theoretical knowledge and preparing them for practical application. This also allows teachers to share and discuss experiences with colleagues. For example, teachers may review AI-generated instructions for creating fraction exercises, consult the "Instructional and Methodological Guidelines for Using AI in Schools", which provide basic prompts, and in a Telegram group for math teachers, share their own AI-generated fraction tasks (e.g., creating five exercises on fractions for 7th grade using ChatGPT), then discuss ideas with colleagues and receive feedback.

For self-assessment, teachers may keep notes documenting how they applied ideas from the guidelines (e.g., in Google Docs or Word) and create a short report about their AI exploration, such as a presentation in Google Slides or Canva AI entitled "My First Experience with AI for a Math Lesson".

The "Result" component reflects the completion of the introductory stage of professional development, showcasing achievements and readiness to progress further. At this level, the teacher synthesises

acquired knowledge (basic AI concepts), skills (AI navigation), and activities (using instructions) into a practical product, demonstrating readiness to integrate AI into the teaching process. This may include preparing a report or presentation about initial AI experiences. The teacher is also prepared to share knowledge with colleagues and receive feedback, building confidence for independent AI use in the classroom. Teachers are encouraged to take the online course "Teacher's Digital Competence" on the Diia for further development and self-assessment – education platform, which includes a self-check module.

4. Conclusions

The article examines approaches to teacher professional development in a digital environment using artificial intelligence. The authors proposed and developed a Matrix of Teacher Professional Development using artificial intelligence, which allows teachers to be flexible in their choice of professional development. The outlined matrix contains components such as knowledge, skills, soft skills, activity, and result, as well as three levels of teacher acquisition of these qualities. Skills and soft skills are correlated with levels to measure outcomes. The blocks of the proposed matrix aim to develop in teachers a critical attitude towards the use of AI in their work, an application of a creative approach to teaching, and the ability to find solutions and be independent in the choice of methods. An example of a practical implementation of the AI tools matrix for teachers at Level 1 (Introduction) was developed (figure 1). This example demonstrates the completion of the introductory stage of professional development related to teachers' use of AI tools. Possible limitations in using matrix learning to enhance skills in using AI may be related to teachers' reliance on self-assessment, their access to online resources, and a lack of necessary technical support, among other factors. The matrix outlined in the article is currently in the preliminary stages of development. It will undergo careful refinement and enhancements based on comprehensive discussions with the identified target groups. This collaborative approach ensures that the matrix effectively addresses the needs and perspectives of all interested groups. The authors consider further developing the problem of using the matrix as a planner for teachers' professional development using AI tools, studying practical examples and experience, and conducting surveys to determine teachers' opinions on the effectiveness of using this tool in the professional development system.

Author contributions

Conceptualization, Oksana Ovcharuk, and Nataliia Soroko; methodology, Oksana Ovcharuk; formal analysis, Nataliia Soroko; investigation, Oksana Kravchyna, Oksana Ovcharuk and Nataliia Soroko; resources, Nataliia Soroko and Oksana Kravchyna; data curation, Oksana Ovcharuk; writing – original draft preparation,Oksana Ovcharuk; writing – review and editing, Oksana Ovcharuk; visualization, Nataliia Soroko. All authors have read and agreed to the published version of the manuscript.

Data availability statement

No new data were created or analyzed in this study. Data sharing is not applicable.

Conflicts of interest

The authors declare no conflict of interest.

Declaration on Generative AI

During the preparation of this work, the author(s) used Grammarly to check grammar and spelling.

References

[1] M. Korsager, B. Reitan, M. Dahl, A. Skår, M. Frøyland, The art of designing a professional development programme for teachers, Professional Development in Education 50 (2024) 1286–1300. doi:10.1080/19415257.2022.2038234.

[2] S. M. Wilson, Professional Development for Science Teachers, Science 340 (2013) 310–313. doi:10.1126/science.1230725.

[3] J. Crowell, Welcome to the Matrix: Teacher Professional Development in a Complex Educational System, 2020. URL: https://ssec.si.edu/stemvisions-blog/welcome-matrix-teacher-professional-development-complex-educational-system.

[4] A. Brandão, L. Pedro, N. Zagalo, Teacher professional development for a future with generative artificial intelligence – an integrative literature review, Digital Education Review (2024) 151–157. doi:10.1344/der.2024.45.151-157.

[5] V. Slyusar, Y. Kondratenko, A. Shevchenko, T. Yeroshenko, Some aspects of artificial intelligence development strategy for mobile technologies, Journal of Mobile Multimedia 20 (2024) 525–554. doi:10.13052/jmm1550-4646.2031.

[6] Y. Kondratenko, A. Shevchenko, Y. Zhukov, V. Slyusar, G. Kondratenko, M. Klymenko, O. Striuk, Analysis of the Priorities and Perspectives in Artificial Intelligence Implementation, in: 2023 13th International Conference on Dependable Systems, Services and Technologies (DESSERT), 2023, pp. 1–8. doi:10.1109/DESSERT61349.2023.10416432.

[7] M. Marienko, Y. Nosenko, A. Sukhikh, V. Tataurov, M. Shyshkina, Personalization of learning through adaptive technologies in the context of sustainable development of teachers' education, E3S Web of Conferences 166 (2020) 10015. doi:10.1051/e3sconf/202016610015.

[8] M. V. Popel, Using cocalc as a training tool for mathematics teachers' pre-service training, Information Technologies and Learning Tools 68 (2018) 251. doi:10.33407/itlt.v68i6.2404.

[9] S. Lytvynova, O. Melnyk, Professional Development of Teachers Using Cloud Services During Non-formal Education, arXiv (2018). doi:10.48550/arxiv.1807.05987.

[10] O. Chubrei, H. Mudrenko, O. Shepel, Formation of professional competence of students in the conditions of the adaptive-digital environment of the institution of higher education, Humanities Science Current Issues 2 (2021) 185–193. doi:10.24919/2308-4863/46-2-30.

[11] O. Ovcharuk, Challenges, Opportunities and Readiness for Using Digital Instruments by Ukrainian Teachers: 2024 Survey Results, in: Futureproofing Engineering Education for Global Responsibility, Springer Nature Switzerland, Cham, 2025, pp. 169–175. doi:10.1007/978-3-031-83520-9_16.

[12] M. Korsager, B. Reitan, M. G. Dahl, A. R. Skår, M. Frøyland, The art of designing a professional development programme for teachers, Professional Development in Education 50 (2022) 1286–1300. doi:10.1080/19415257.2022.2038234.

[13] P. Mishra, M. J. Koehler, Technological Pedagogical Content Knowledge: a framework for teacher knowledge, Teachers College Record the Voice of Scholarship in Education 108 (2006) 1017–1054. doi:10.1111/j.1467-9620.2006.00684.x.

[14] O. P. Pinchuk, Instructional and Methodological Guidelines on the Implementation and Use of Artificial Intelligence Technologies in Secondary Schools, Ukrainian Electronic Encyclopedia of Education, 2025. URL: https://lib.iitta.gov.ua/id/eprint/742889.

[15] X. Tan, G. Cheng, M. H. Ling, Artificial intelligence in teaching and teacher professional development: A systematic review, Computers and Education: Artificial Intelligence 8 (2025) 100355. doi:10.1016/j.caeai.2024.100355.

[16] K. Tzafilkou, M. Perifanou, A. A. Economides, Assessing teachers' digital competence in primary and secondary education: Applying a new instrument to integrate pedagogical and professional elements for digital education, Education and Information Technologies 28 (2023) 16017–16040. doi:10.1007/s10639-023-11848-9.