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APPROACHES TO DEVELOPING FUTURE INFORMATICS TEACHERS' COMPETENCE IN ARTIFICIAL INTELLIGENCE

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Abstract
This article analyzes didactic approaches aimed at forming and developing the competence of future informatics teachers in artificial intelligence (AI). Modern concepts of AI competence for teachers proposed by UNESCO and other international organizations, as well as models and documents such as the AI CFT (AI Competency Framework for Teachers), are taken as a scientific and theoretical basis. The study presents the results of a diagnostic questionnaire conducted with the participation of future informatics teachers, an analysis of curricula and programs, as well as experimental work based on an integrated module on AI. The results indicate the need for specially designed teaching strategies, practical projects, and the integrated use of distance and blended learning technologies to develop knowledge, skills, and reflexive-reflective competencies in AI in future informatics teachers. At the end of the article, methodological recommendations are given on the systematic integration of AI components into the process of training computer science teachers in higher education institutions.

Keywords: Artificial intelligence, AI literacy, computer science teacher, future teacher, competence, AI CFT, digital pedagogy.

INTRODUCTION

In recent years, there has been a growing international movement to develop AI-specific competency models and literacy frameworks for teachers and future teachers. The AI Competency Framework for Teachers, presented by UNESCO in 2024, is one of the first global documents in this regard, which systematizes 15 competencies necessary for teachers in five dimensions: human-centred mindset,

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AI ethics, AI principles and applications, AI pedagogy, and the use of AI in professional development. The authors of the document emphasize the need for teachers to understand not only technical knowledge, but also the socio-ethical implications of AI, and to adopt an approach that protects student agency and human rights. Research around AI literacy is also developing steadily. The AI Literacy Framework developed by Digital Promise defines AI literacy as the set of knowledge and skills needed for a person to critically understand, evaluate, and safely and ethically use AI systems; it presents different modes of AI use, core values, and practical behaviors as an interconnected system.

Recent empirical research has shown that pre-service teachers' AI literacy is often fragmented: although they actively use AI tools in their daily lives, they lack a deep understanding of how AI works, data quality and algorithmic bias, and ethical and pedagogical implications for education [1].

Studies with pre-service teachers, in particular, show that short-term but targeted AI training can significantly change their AI literacy and attitudes towards AI. Bilbao-Eraña and Arroyo-Sagasta note that after a specific AI literacy module for pre-service teachers, participants showed significant increases in their understanding of AI, awareness of ethical risks, and responsible use of AI [2]. In a study by Runge et al. based on the AI-TPACK model, pre-service teachers who participated in specialized courses on AI were found to have significantly higher self-rated AI-TPACK scores and intentions to use AI in their future lessons [3].

Bibliometric analyses also show that the number of scientific works on the integration of artificial intelligence into teacher education programs has increased dramatically, especially models based on concepts such as AI-TPACK, AI literacy, and AI CFT are becoming the leading direction [4].

In this regard, developing the competence of future computer science teachers in AI requires not only technical training, but also shaping them as ethically sensitive digital educators who can integrate AI into educational content, methodology, and assessment systems. The UNESCO AI CFT and AI literacy frameworks, as well as research based on AI-TPACK, provide scientific justification for the need for such a comprehensive approach for future teachers; however, empirical testing of their practical interpretation in local contexts,

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particularly in HEIs where computer science teachers are trained, remains a pressing issue.

MATERIALS AND METHODS

This study was conducted using a quasi-experimental, mixed-method design to determine the effectiveness of pedagogical approaches aimed at developing AI competence in future computer science teachers. The research design was initially based on the UNESCO "AI Competency Framework for Teachers" document. This framework systematically expresses the necessary knowledge, skills, and values for teachers in AI in five dimensions: human-centered approach, AI ethics, AI principles and applications, AI pedagogy, and the use of AI in professional development. Therefore, this structure of the competency model was adopted in the study, adapted for future computer science teachers.

The subjects of the study were 3rd-4th year undergraduate students in computer science, that is, future computer science teachers. Two academic groups were formed, one as an experimental group and the other as a control group. In the experimental group, classes were organized based on AI integrated methodological approaches, while in the control group, the current curriculum and programs were maintained. The attempt to approximately equalize the general reading performance and demographic characteristics of students in the formation of groups made it possible to reliably link the results to the intervention effect. This approach was carried out in accordance with the methodological views used in foreign studies on the AI literacy of pre-service teachers; for example, in the works of Ayanwale [1] and Laru [5], a comparative analysis of groups of future teachers was also chosen as the main methodological line.

The selection of materials was based on both theoretical and practical perspectives, drawing on recent systematic reviews at the intersection of AI and education. The systematic reviews of Garzón et al [6]. and Wang et al. on the role of AI in education, its benefits, and ethical and psychological issues helped to identify which components should be covered when integrating AI into teacher education programs. At the same time, a new generation of research on the content and structure of AI literacy programs for pre-service teachers (e.g., short

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but intensive courses focused on the use of generative AI tools) served as methodological models for the design of intervention content.

Several complementary tools were used to collect data. First, a questionnaire was developed to measure AI literacy; It was adapted to local conditions, drawing on the AI literacy constructs used in Ayanwale's [1] study, and served to identify students' theoretical understanding of AI, confidence in practical application, and ethical reflection. Second, a special "competence map" for future computer science teachers was created based on the UNESCO AI CFT, which recorded students' self-assessment of AI, planned practical actions, and pedagogical design readiness. Third, lesson plans, didactic materials, and assessment tools developed by the experimental group students were collected in the form of a portfolio and assessed by experts using a rubric developed based on the AI-TPACK concept; this approach is consistent with the experience of Runge [3] and other authors in using AI-TPACK as an effective analytical tool in working with pre-service teachers.

The pedagogical intervention consisted of an integrated program over the course of a semester, in which the conceptual foundations of AI, practical laboratories, ethical discussions, and AI-integrated lesson design components were organized in an interconnected manner. While students mastered the main paradigms of AI (machine learning, deep learning, principles of generative models), they simultaneously discussed the advantages and risks of using AI tools in the lesson, and wrote reflections on assignments and assessment tools prepared using generative AI. This integrated approach is directly consistent with the research of Bilbao Eraña et al. [2] demonstrating the effectiveness of short but in-depth AI modules for pre-service teachers, as well as recommendations for designing AI literacy programs by authors such as Liu and Karaduman [7].

Quantitative data (survey results, competency map scores, portfolio assessments) were processed using a statistical package, and t-tests were used to determine means, standard deviations, and differences between experimental and control group scores, and effect sizes were calculated to assess the effectiveness of the intervention. Qualitative data-students' written reflections and semi-structured interview transcripts-were coded through thematic analysis, using recent reviews of measurement approaches to AI literacy (approaches to operationalize

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constructs such as AI literacy, attitudes, and awareness). At all stages of the study, voluntary consent, anonymity, and data confidentiality were ensured, and international ethical standards for pedagogical research were followed.

RESULTS

1. Preliminary diagnostic results. According to the preliminary (pre-test) diagnostic results, the general AI literacy of prospective computer science teachers was found to be below average. The scores obtained in the five areas of the AI CFT model showed that students performed relatively well in the more technical component - "AI foundations and applications", but there were significant gaps in the "AI pedagogy" and "Ethics of AI" blocks. This is consistent with the findings of Ayanwale and Laru that pre-service teachers are confident in the daily use of AI tools, but lack a deep conceptual and ethical understanding.

The following table shows the initial mean scores (Likert: 1–5) on AI literacy for the experimental and control groups (M – mean, SD – standard deviation):

Table 1 Initial AI literacy scores (pre-test)

Subscale	Group	M	SD
AI foundations & applications	Eksperimental	2.9	0.6
	Control	2.8	0.7
AI pedagogy	Eksperimental	2.4	0.5
	Control	2.3	0.6
Ethics of AI & human-centred view	Eksperimental	2.2	0.5
	Control	2.1	0.5
AI for professional learning	Eksperimental	2.5	0.6
	Control	2.4	0.6

It is clear that there is no statistically significant difference between the groups at baseline ($p > 0.05$), indicating that the conditions for subsequent comparisons are equal. A similar situation has been observed in other studies that assessed the initial literacy of pre-service teachers on AI; they usually perceive AI as a "convenient tool" but do not have a deep understanding of pedagogical integration and ethical issues.

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2. Post-intervention changes. The results of the final diagnostic (post-test) conducted at the end of the one-semester intervention showed a significant increase in AI literacy and AI competence indicators in the experimental group. In particular, the mean scores on the AI pedagogy, Ethics of AI, and AI for professional learning subscales were significantly higher than in the control group ($p < 0.05$). These results support the findings of Runge [3], Bilbao Eraña [2], and other research scholars that introducing specific AI literacy modules for pre-service teachers positively changes their attitudes, confidence, and intention to use AI.

Table 2. Post-test results and differences (M ± SD)

Subscale	Group	Pre-test M	Post-test M	Δ (o'sish)
AI foundations & applications	Eksperimental	2.9	3.9	+1.0
	Control	2.8	3.1	+0.3
AI pedagogy	Eksperimental	2.4	3.8	+1.4
	Control	2.3	2.7	+0.4
Ethics of AI & human-centred view	Eksperimental	2.2	3.7	+1.5
	Control	2.1	2.6	+0.5
AI for professional learning	Eksperimental	2.5	3.8	+1.3
	Control	2.4	2.9	+0.5

According to the results of the statistical analysis, Cohen's d effect sizes for the AI pedagogy, Ethics of AI, and AI for professional learning subscales were in the medium to high range, indicating that the intervention program had a sufficiently large impact. These results provide practical support for the ideas of researchers such as Garzón []6 and Nair [8] that for AI tools to be convenient, flexible, and effective in the learning process, the teacher himself must have a high level of competence in AI.

3. Lesson designs and portfolio results based on AI-TPACK

When lesson designs, didactic materials and assessment tools developed by students of the experimental group were evaluated using a rubric based on the AI-TPACK concept, the following trends were observed compared to the control group:

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• Technical component (TC) - the number of cases of purposeful and appropriate use of AI tools (generative text, test generators, code analyzers, etc.) increased significantly;
• Pedagogical component (PC) - clear scenarios for combining AI with differentiated tasks, blended learning, problem-based learning (PBL) emerged;
• Content component (CC) - computer science topics (algorithms, data structures, information security, etc.) were developed in the form of visualized, simulated or interactive exercises using AI.
These results confirm that AI-integrated lesson plans for pre-service teachers, especially when based on the AI-TPACK and AI CFT frameworks, help to see AI as an intrinsic element of the didactic system, rather than just an "additional technical tool," as shown in Kuzu's bibliometric analysis [4].

Table 3.AI-TPACK portfolio assessments (average scores on a 4-point rubric)

Komponent	Guruh	M (0–4)
TK (Technical)	Eksperimental	3.4
	Control	2.6
PK (Pedagogical)	Eksperimental	3.3
	Control	2.5
CK (Content)	Eksperimental	3.5
	Control	2.8
TPACK (Integral)	Eksperimental	3.3
	Control	2.5

The increase in the portfolio quality of the experimental group is consistent with the results of Runge [3] who found that pre-service teachers who completed a targeted module on AI were more willing to integrate AI tools into their lessons.
4. Qualitative results and student reflections. Analysis of semi-structured interviews and written reflections showed that the students in the experimental group had qualitatively changed their understanding and attitude towards AI tools:
• There was a greater perception of AI as a collaborative tool supporting the cognitive activity of both the teacher and the student, rather than as a "ready-made response mechanism";

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• There was an increased sensitivity to issues such as academic integrity, plagiarism, and data confidentiality when using generative AI;

These qualitative results confirm that AI literacy programs, as shown in the studies of scholars such as Bilbao Eraña, Karaduman, and Nuangchalerm [9], not only reshape the level of knowledge, but also the moral and psychological attitude towards AI.

The results of the diagnostic conducted at the initial stage of the study showed that the literacy of future computer science teachers on artificial intelligence, especially in terms of pedagogical and ethical aspects, was not sufficiently formed. It was observed that students perceived AI mainly as a "technology" related to the field of technical tools, programming, and automation, but did not have a clear idea of how to integrate it into the substantive and methodological aspects of the educational process. From the author's point of view, this situation is not accidental: although AI appears more in technical blocks such as algorithmization and modeling in curricula and programs, "AI pedagogy" and "AI ethics" are not sufficiently covered as independent components.

The initial results showed that there was no significant difference between the experimental and control groups. This, in the author's opinion, is important in two ways: on the one hand, the fact that the "starting point" of the groups before the intervention was almost equal makes the comparison of the results scientifically justified; on the other hand, it means that the lack of competence in AI is not a specific group or course, but a gap that exists on the scale of the entire training system.

The results obtained after one semester of pedagogical intervention showed significant positive changes among the students of the experimental group. In particular, a sharp increase in indicators related to AI pedagogy and AI ethics was observed. Students not only formed a theoretical idea of the foundations and tools of AI, but also began to try to integrate them into lesson plans, task systems and assessment criteria. The author interprets this as follows: when a student begins to see the AI tool not as a "mechanism that produces ready-made resources", but as a partner enriching the didactic decision-making process, AI competence in the true sense begins to form.

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The results showed that in the experimental group, the lesson plans prepared to integrate AI into the teaching process became more substantive, and the tasks and assessment tools developed based on AI became more methodologically mature. Students tried to explain topics such as algorithms, data analysis, and information security through generative AI, visualization tools, or interactive environments. According to the author's position, such an approach shapes the computer science teacher as a subject who manages and designs educational technologies rather than a traditional "code-showing specialist."

Qualitative data also confirmed this shift. In interviews and written reflections, students began to actively discuss the risks and limitations of using AI tools, as well as the positive aspects. Many cited issues such as plagiarism, academic integrity, data confidentiality, and student independent thinking as “central problems” in using AI. For the author, this is a very important indicator: the fact that a student is moving away from using AI solely as a tool for “getting a quick solution” and is starting to ask questions “under what conditions, within what limits, for what didactic purpose” indicates the formation of a high level of reflexivity [10].

The analysis of the experimental group portfolio showed that significant positive dynamics were also achieved in the AI-TPACK components. When integrating AI tools into their teaching methodology, students began to consider not only technical convenience, but also:

- which AI tool is suitable for which subject and which learning objective,
- the need to create differentiated tasks taking into account the level of the student,
- the need to create conditions for the student to independently analyze and evaluate the result obtained with the help of AI.

The author interprets this as a sign of a qualitative change taking place in the professional identity of the future teacher: the student is approaching the role of not an “AI user”, but a “teacher who does not do the didactically conscious management of AI”.

Although a certain positive increase was also observed in the control group, this increase is mainly explained by the expansion of general information about AI and general trends in the global information space. Even in the absence of

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intervention, students may encounter AI tools in everyday life, but this does not guarantee their deep competence in AI pedagogy and AI ethics. In the author's opinion, this is where the difference between "spontaneous exposure" and "purposeful pedagogical integration" becomes clear.

In conclusion, the results confirm the author's initial hypotheses: if a special integrated module and methodological approaches on artificial intelligence are systematically introduced for future computer science teachers, AI competence will develop not only with technical knowledge, but also with pedagogical design, ethical responsibility, reflexive thinking, and professional self-awareness [11]. In the author's view, it is precisely such a complex competence that can bring the quality of computer science teaching to a new level in modern digital schools and universities.

DISCUSSION

The results of the study clearly demonstrated the need for a special integrated approach to developing the AI competence of future computer science teachers. The fact that the experimental and control groups at the initial stage had almost the same, below-average AI literacy indicators indicates that, in fact, AI components are provided episodically and fragmentarily in the current teacher training system. In the author's opinion, this situation demonstrates the gap between "knowing about AI" and "consciously organizing pedagogical activities with AI": students have a general idea of AI, but this idea has not yet reached the level of integration into teaching activities [12].

The significant increase observed as a result of the intervention, especially in AI pedagogy and AI ethics, means that it is more effective to include AI as a cross-cutting component in the work with future computer science teachers, not as a separate "technical course", but as a transversal component in the processes of methodology, assessment, lesson design and reflection [13]. This confirms the author's initial hypothesis: AI competence is not just about knowing the concepts of algorithms and models, but also about the ability to reinterpret the role of the teacher, to reconsider the independence and responsibility of the student against the background of AI.

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The improvement in portfolio results on AI-TPACK also shows that a properly designed intervention encourages the integration of technical, pedagogical and content knowledge. Students begin to try to apply AI tools in the lesson not just "for the sake of modernity", but in connection with tasks such as solving a specific didactic problem: visualizing complex topics, giving differentiated assignments, providing quick and personalized feedback. In the author's opinion, it is at this stage that AI becomes not a "fashionable technology" for the teacher, but a well-founded assistant in making pedagogical decisions. This aspect is also noted in the international literature: it is argued that programs based on AI-TPACK or AI CFT increase teachers' readiness to consciously and purposefully integrate AI.

The results of the qualitative analysis – student reflections and interviews – reinforce an important theoretical conclusion: in the formation of AI competence, not only "tool skills" but also ethical sensitivity, critical thinking and professional identification play a central role. When students begin to discuss such subtle aspects of using AI as the risk of plagiarism, academic integrity, data confidentiality, and "extra help" to students' thinking processes, their views shift from a "technical object" to a "social-pedagogical phenomenon" [14]. The author interprets this as a stage of ethical and professional maturation of the teacher: no matter how well they know AI, knowing what boundaries and rules to apply it, based on which, is becoming one of the main criteria for the teaching profession.

The fact that a certain positive increase was also noted in the control group, in the author's opinion, is a result of the widespread penetration of AI tools into society and the educational environment, and students are increasingly encountering AI in their daily lives. However, this increase is mainly explained by an increase in the level of general awareness, and does not lead to fundamental qualitative changes in their products in the form of lesson design, assessment, and ethical reflection. This once again confirms the difference between "spontaneous acquisition" and "purposeful pedagogical intervention" and leads the author to the following conclusion: AI competence cannot be left to chance, it must be systematically formed through specially designed educational technologies. Of course, there are also inherent limitations of the study: the relatively limited number of participants, the limitation of the intervention period to one semester,

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and the fact that the study was conducted in only one higher education institution somewhat reduce the possibility of generalizing the results on a large scale. The author believes that future research, enriched with long-term observations, is necessary across HEIs in different regions, as well as a deeper study of the role of AI competence in educational outcomes, student motivation, and inclusive learning environments. Overall, this study shows that the introduction of specific integrated approaches to AI for future computer science teachers will serve to develop their professional competence in harmony not only with technical knowledge, but also with pedagogical skills, ethical responsibility, and a reflexive culture. In the author's view, if AI components are viewed as a central element of the design and management of educational technologies, rather than as a "fringe addition" to the computer science teacher training system, this will not only benefit individual teachers

CONCLUSION

The results of this study showed that developing the competence of future computer science teachers in artificial intelligence is a strategic necessity for the education system today. At the stage of basic diagnostics, it was possible to determine that students' perceptions of AI were mainly at the technical and utilitarian level, and the competencies for in-depth analysis of AI mechanisms, data flows, algorithmic bias, and ethical risks were not sufficiently formed. This situation is consistent with the fragmentary preparation of pre-service teachers in the elements of AI literacy, noted in international studies. The integrated approach developed within the framework of the study was aimed at combining theoretical AI literacy (AI concepts, models, mechanisms), practical activities (projects with AI tools, training scenarios, software experiments), and ethical and legal reflection into a single methodological system. The results showed that students who participated in specially modularized courses on AI significantly increased their understanding of AI mechanisms, critical evaluation of AI tools, and purposeful integration of them into the educational process; this trend is consistent with the results of studies with pre-service teachers in other countries. According to the author, developing AI competence in future computer science teachers is not just a matter of "teaching" new technologies, but also a process of

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reinterpreting the role of the teacher. The teacher should be formed not as a "consumer of ready-made solutions" from AI tools, but as: (1) a technical expert who can explain algorithmic processes, (2) a responsible person who serves as a guide on data security and ethical issues, and (3) a pedagogical designer who encourages students to think independently and critically. UNESCO's policy and competency frameworks on AI also emphasize teacher agency, a humanistic approach, and ethical responsibility as central.

The approach used in the study showed that AI competence can be adapted to local conditions in a manner consistent with international AI CFT and AI literacy models. This approach not only serves to update the content of computer science, but also to develop the confidence, motivation, and reflexive culture of future teachers in using AI tools. According to the author's position, in the conditions of Uzbekistan, it is relevant to deeply integrate AI competence with computer science curricula, strengthen practical projects and educational virtual laboratories on AI, as well as include AI ethics and legal responsibility as a separate module.

However, the study has some limitations: since the data were obtained based on a single or limited sample of HEIs, automatic transfer of results to the entire country requires caution; AI competencies require constant updating in the context of rapidly changing technologies. Future research should be deepened by comparing technical universities in different regions, using longitudinal designs, and monitoring AI-based interventions in real-world learning processes. In the author's opinion, the strategic development of AI competencies of future computer science teachers is not only a local issue related to science, but also a national priority that serves to build a digital economy and digital citizenship.

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