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COGNITIVE APPROACH TO AI LITERACY EDUCATION FOR FUTURE TEACHERS

Sobirova M.Q.

Andijon Institute of Agriculture and Agrotechnologies, Andijon, Uzbekistan

Mirzayev A.U.

Andijon state pedogogical intitute, Andijon, Uzbekistan

Abstract

The rapid integration of artificial intelligence (AI) technologies into the educational ecosystem creates an urgent need for systematic AI literacy education in pre-service teacher training programmes. This paper presents the conceptual foundations of the cognitive approach to AI literacy education for future teachers and substantiates its methodological advantages over instrumental-technical approaches that have dominated the field. The cognitive approach positions the future teacher as an active cognitive agent who constructs knowledge about AI through information processing, schema formation, metacognitive monitoring, and critical evaluation. The study employs theoretical-conceptual analysis, comparative pedagogical analysis, and empirical diagnostics involving 156 pre-service teachers from pedagogical universities in Andijon, Tashkent, and Namangan regions. The results substantiate that the cognitive approach to AI literacy education comprises five interconnected components: cognitive understanding of AI concepts and systems, critical analysis of AI-generated content, metacognitive regulation of AI-mediated learning, schema-based knowledge construction, and reflective evaluation of AI practices. Empirical findings demonstrate that pre-service teachers trained through the cognitive approach show significantly higher levels of AI literacy compared to those trained through instrumental approaches ($\chi^2 = 32.4$, $p < 0.001$). The article concludes that the cognitive approach provides a scientifically grounded methodological basis for designing AI literacy curricula in pre-service teacher education aligned with international standards and national strategic priorities.

Keywords: AI literacy, cognitive approach, pre-service teachers, critical thinking, metacognition, schema formation, teacher education, generative AI, UNESCO AI competency framework, cognitive science.

1. Introduction

The accelerated integration of artificial intelligence (AI) technologies into educational practice has created fundamental methodological challenges for pre-service teacher education. While the strategic imperative of developing AI literacy among future teachers has been articulated in major international frameworks—including UNESCO's AI Competency Framework for Teachers (2024), the OECD AI

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Recommendation (2024), and the EU AI Act (2024/1689)—the question of which pedagogical approach should underpin AI literacy education remains insufficiently theorized.

Contemporary practice in AI literacy education predominantly follows instrumental-technical approaches that focus on teaching the operation of specific AI tools, prompt engineering techniques, and surface-level applications. However, such approaches insufficiently address the deeper cognitive transformations that future teachers need to undergo to engage with AI in pedagogically responsible and critically informed ways. This paper argues that the cognitive approach—grounded in cognitive psychology, schema theory, and metacognition research—provides a methodologically superior foundation for AI literacy education in pre-service teacher training.

The purpose of this study is to articulate the conceptual foundations of the cognitive approach to AI literacy education for future teachers, identify its constitutive components, and present empirical evidence of its effectiveness compared to instrumental approaches.

2. Literature review

The cognitive approach in educational psychology was developed in the works of J.S.Bruner, J.R.Anderson, and R.E.Mayer. Bruner's cognitive theory of learning emphasized the active role of the learner in constructing knowledge through hypothesis formation and schema development. Anderson's ACT-R cognitive architecture provided a comprehensive framework for understanding how knowledge is acquired, organized, and retrieved. Mayer's cognitive theory of multimedia learning extended cognitive principles to digital learning environments.

AI literacy as an emerging field has been conceptualized by D.Long and B.Magerko (2020), D.T.K.Ng and colleagues (2021), and the AI4K12 Initiative (Touretzky et al., 2019). UNESCO's AI Competency Framework for Teachers (2024) identifies five core competency areas: human-centred mindset, AI ethics, AI foundations and applications, AI pedagogy, and professional learning through AI. However, these frameworks predominantly focus on competencies rather than pedagogical approaches for developing them.

Critical thinking in the context of AI use has been examined by W.Holmes, M.Bialik, C.Fadel, and N.Selwyn. Their analyses highlight the importance of moving beyond instrumental approaches toward deeper cognitive engagement with AI technologies. However, the systematic integration of cognitive theory with AI literacy education remains an underexplored research area, particularly in pre-service teacher education contexts.

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3. Methodology

This study employs a mixed-methods design combining theoretical-conceptual analysis with empirical diagnostics. The theoretical phase involved comprehensive analysis of cognitive learning theories, AI literacy frameworks, and pre-service teacher education research, drawing on publications indexed in Scopus, Web of Science, and ERIC databases from 2019 to 2024.

The empirical phase involved 156 pre-service teachers from four pedagogical universities in Andijon, Tashkent, and Namangan regions of Uzbekistan. Participants were divided into experimental (n = 78) and control (n = 78) groups. The experimental group received AI literacy training based on the cognitive approach over one academic semester, while the control group received traditional instrumental-technical training. Assessment was conducted using a validated 28-item instrument measuring five dimensions of AI literacy (Cronbach's $\alpha = 0.87$). Statistical analysis employed Pearson's χ^2 test and independent samples t-test.

4. Results and discussion

The conceptual analysis substantiates that the cognitive approach to AI literacy education for future teachers comprises five interconnected components. The first component—cognitive understanding of AI concepts and systems—encompasses conceptual knowledge of how AI works, its capabilities and limitations, machine learning fundamentals, and the architecture of generative AI systems. The second component—critical analysis of AI-generated content—involves systematic evaluation of AI outputs for accuracy, relevance, bias, and reliability. The third component—metacognitive regulation of AI-mediated learning—addresses future teachers' capacity to plan, monitor, and evaluate their own learning processes when using AI tools.

The fourth component—schema-based knowledge construction—relates to how future teachers integrate new AI-related knowledge into their existing cognitive structures and develop expert-level mental models of AI in education. The fifth component—reflective evaluation of AI practices—involves systematic reflection on one's own AI use, its pedagogical implications, and its ethical dimensions. These five components work synergistically: deficiencies in one component undermine the effectiveness of others, while their integrated development produces robust AI literacy.

Table 1. Comparative AI literacy outcomes: cognitive vs instrumental approach (N = 156)

AI Literacy components	Cognitive group (M)	Control group (M)	Effect size (Cohen d)
Cognitive understanding	4.12	3.24	0.82 (large)
Critical analysis	3.94	2.87	0.94 (large)

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AI Literacy components	Cognitive group (M)	Control group (M)	Effect size (Cohen d)
Metacognitive regulation	3.78	2.61	1.02 (very large)
Schema construction	3.65	2.48	0.97 (large)
Reflective evaluation	3.83	2.73	0.91 (large)

The empirical findings demonstrate substantial advantages of the cognitive approach over traditional instrumental training. The experimental group showed significantly higher mean scores across all five AI literacy components, with effect sizes ranging from 0.82 to 1.02 (Cohen's d). The largest effects were observed for metacognitive regulation ($d = 1.02$) and schema construction ($d = 0.97$), components that are inherently aligned with cognitive psychology principles. Pearson's χ^2 test ($\chi^2 = 32.4$; $p < 0.001$) confirmed the statistical significance of the differences between groups. These results provide robust empirical evidence that the cognitive approach produces deeper and more transferable AI literacy outcomes than instrumental approaches.

The pedagogical implications of these findings are substantial. Pre-service teacher education programmes should be restructured to integrate cognitive approach principles into their AI literacy curricula. This involves moving beyond skills-based training toward concept-rich instruction that develops future teachers' mental models, metacognitive awareness, and critical reflective capacity. Specific didactic strategies include case-based learning with cognitive scaffolding, structured reflection journals, peer dialogue protocols, and authentic problem-solving tasks that require deep cognitive engagement with AI systems.

5. Conclusion

This study has substantiated the cognitive approach as a methodologically superior foundation for AI literacy education in pre-service teacher training. The approach's five constitutive components—cognitive understanding, critical analysis, metacognitive regulation, schema construction, and reflective evaluation—operate synergistically to produce robust AI literacy outcomes. Empirical evidence from 156 pre-service teachers demonstrates that the cognitive approach yields significantly better learning outcomes than traditional instrumental approaches, with large to very large effect sizes across all measured dimensions.

The findings have important implications for teacher education policy and curriculum design. National and institutional curricula should be revised to incorporate cognitive approach principles in AI literacy education, aligning with international standards articulated in UNESCO's AI Competency Framework for Teachers. Future research should examine the long-term sustainability of AI literacy developed through the cognitive approach and its transferability to professional teaching practice.

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