FORMATION OF ARTIFICIAL INTELLIGENCE COMPETENCIES IN FUTURE EDUCATORS IN THE CONTEXT OF DIGITAL EDUCATION

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Abstract: The integration of artificial intelligence (AI) into educational systems represents a fundamental shift in how educators must be prepared for twenty-first-century teaching. The growing presence of AI technologies in classrooms demands that future educators acquire competencies that blend technological understanding with sound pedagogical practice. This article outlines the conceptual foundations, challenges, and strategies for developing AI competencies among future educators within digital education contexts. It highlights key dimensions of competence formation and offers a structured framework for assessing the appropriateness of AI integration across diverse educational settings.

Keywords: AI, AIED, technologies in teaching, digital education, digital competencies.

AI competencies for educators encompass the knowledge, skills, and attitudes necessary to effectively integrate artificial intelligence technologies into teaching and learning processes. These competencies bridge technological understanding with pedagogical expertise to enhance educational outcomes (Muengsan & Chatwattana, 2024). AI competencies refer to the ability to understand, evaluate, and effectively utilize artificial intelligence technologies in educational contexts. This includes comprehension of AI principles, practical application skills, and the capacity to make informed decisions about AI integration in teaching practices (AlMahdawi, 2024).

A systematic approach to evaluating the suitability of AI integration requires comprehensive assessment criteria that consider contextual factors, pedagogical alignment, and technical feasibility. Key contextual dimensions include the educational level—ranging from age-appropriate tools for primary education to advanced applications in higher education and professional development—and the degree of institutional readiness, such as infrastructure capacity, faculty digital competence, administrative support, and budget allocation.

Pedagogical alignment demands that AI applications correspond to curriculum standards, enhance higher-order cognitive skills, and support differentiated instruction. They should integrate smoothly with established teaching methods, including constructivist approaches, collaborative and project-based learning, personalized learning, and authentic assessment practices. Technical feasibility involves ensuring adequate hardware and network resources, robust data security, compatibility with

existing learning management systems, and manageable implementation complexity. Training requirements, accessibility of user interfaces, and scalability across class sizes are also critical.

Ethical and social considerations form a parallel axis of evaluation. Privacy and data protection require compliance with educational regulations such as FERPA and GDPR, transparent AI decision-making processes, and clear consent mechanisms. Equity and accessibility demand attention to the digital divide, inclusive design for students with disabilities, cultural sensitivity in AI algorithm design, and equal access to AI-enhanced learning opportunities.

Assessment methodologies should combine quantitative metrics—such as improvements in learning outcomes, engagement rates, efficiency indicators, and cost-benefit analyses—with qualitative approaches, including stakeholder feedback, case studies, focus group discussions, and classroom observations. Decision-making frameworks benefit from multi-criteria decision analysis, weighted scoring systems, risk assessments, and pilot testing for iterative refinement. Implementation roadmaps can then be developed with phased rollouts, targeted professional development, and continuous monitoring to adapt to evolving educational needs.

AI competencies form an essential component of digital literacy in modern education. Digital literacy encompasses interrelated skills, including media, technology, information, visual, communication, and social literacies (Muengsan & Chatwattana, 2024). AI awareness and competency extend these foundational digital skills and represent a critical capacity for educators preparing students for a data-driven society (Bender, 2024).

Core Components of AI Competencies for Future Educators

The development of artificial intelligence (AI) competencies requires a multifaceted approach that unites technical knowledge, pedagogical expertise, and ethical awareness to prepare educators for effective and responsible use of AI in educational contexts. Future educators must acquire a solid understanding of AI principles, terminology, and practical applications, including knowledge of generative AI capabilities that produce text, images, sound, and synthetic data (Muengsan & Chatwattana, 2024). Appreciating how AI processing systems parallel human cognitive functions helps teachers recognize how these technologies can complement human teaching and learning. Comprehensive familiarity with key concepts such as machine learning, natural language processing, and generative AI is essential, yet research reveals persistent gaps in professional understanding of AI terminology and underlying principles, underscoring the need for targeted training (Rainey et al., 2021). Generative AI in particular offers powerful opportunities for education by enabling the creation of realistic virtual assistants, personalized learning services, and digital art that can transform instructional practices and enrich learning experiences (Muengsan

& Chatwattana, 2024). Equally critical is the capacity to integrate these technologies meaningfully into teaching practices while maintaining sound pedagogy. Educators must be able to design and manage AI-enhanced digital learning environments that foster student engagement and measurable achievement (Vilppola et al., 2022) and to implement AI-supported assessment methods such as formative evaluation tools and digital testing systems. Evidence from game-based platforms such as *Kahoot!* demonstrates how AI-enhanced tools can strengthen academic performance, motivation, and learner engagement (Mdlalose et al., 2021). Alongside technical and pedagogical expertise, the cultivation of strong ethical and critical thinking competencies is essential. Responsible use of AI requires awareness of issues of plagiarism, equity, access, and data privacy; educators must ensure that AI-driven practices meet established ethical and privacy standards (Bender, 2024). Finally, future educators need the ability to critically evaluate AI tools and applications, assessing their appropriateness, effectiveness, and potential impact on student learning, while recognizing both the opportunities and limitations inherent in AI technologies.

Current State of AI Competency Development

Research consistently highlights a substantial gap between the growing need for artificial intelligence (AI) competencies and the current level of preparation among educators. Understanding these shortcomings is crucial for designing effective training programs and long-term support systems. Studies show that educators generally display only medium levels of AI awareness, with faculty members scoring 3.05 on a five-point scale, indicating considerable room for improvement in both knowledge and understanding of AI technologies (AlMahdawi, 2024). Similar patterns of underpreparedness appear in other professional domains. For example, research among healthcare professionals reveals widespread deficiencies in knowledge of AI principles, understanding of terminology, and confidence in using AI technologies; many report feeling inadequately trained to implement AI in practice settings (Rainey et al., 2021). These findings suggest that educators are likely to face comparable challenges in integrating AI into teaching and learning.

Professional development opportunities currently available to educators have not kept pace with these needs. Many teachers express dissatisfaction with existing programs, describing them as insufficiently practical and poorly aligned with the specific competencies required for AI integration (, 2024). To address these shortcomings, strategies for AI competency development must be comprehensive and multifaceted, combining theoretical instruction with opportunities for authentic practice.

Promising approaches include game-based learning platforms integrated with generative AI, which create challenging and engaging environments that foster practical exploration and skill acquisition (Muengsan & Chatwattana, 2024). Such

platforms typically incorporate four essential elements: input factors—such as students, teachers, objectives, rules, learning media, and assessment; a game-based learning process enhanced by generative AI; measurable outputs, including learning achievement and digital literacy skills; and a feedback mechanism to guide iterative improvement (Muengsan & Chatwattana, 2024). The learning process itself can follow five key steps—exploring knowledge, explanation, playing games, presenting ideas, and engaging in discussions and conclusions—while applying five guiding principles: practice, learning by doing, learning from mistakes, goal-oriented learning, and the articulation of learning points (Muengsan & Chatwattana, 2024).

Work-based learning models also hold significant promise by enabling immediate experimentation with AI tools and the application of new ideas in authentic educational contexts (Vilppola et al., 2022). In addition, personalized training and sustained support are essential to ensure lasting competency development. Meaningful progress typically emerges through continuous interaction with mentors or advisors who balance confidence building with skill enhancement, providing ongoing feedback and targeted assistance (Ortiz-Laso et al., 2023).

Implementation Challenges and Solutions

Developing AI competencies in future educators faces numerous challenges that demand systematic approaches and targeted interventions. At the institutional level, common barriers include limited financial resources, inadequate technological infrastructure, and resistance to technological change. Without comprehensive support and careful strategic planning, such constraints hinder the effective integration of artificial intelligence into teacher preparation programs. Time and resource limitations also pose difficulties: many educators report persistent feelings of haste and a lack of time for professional development, while training programs that fail to acknowledge existing skills can discourage progress and reduce motivation (Vilppola et al., 2022). In addition, research highlights correlations between AI confidence and demographic variables such as gender, age, and highest qualification, indicating the need for differentiated approaches that address diverse learner needs and ensure equitable opportunities for skill development (Rainey et al., 2021).

The future of AI competency development carries profound implications for educational transformation and the preparation of digitally literate citizens. Integrating AI competencies as a core component of teacher education programs is essential rather than treating them as optional enrichment. Undergraduate curricula must include hands-on experiences with AI applications and digital technologies to ensure that future educators gain practical expertise (Hashish & Alnajjar, 2024). Achieving this vision requires robust technological infrastructure supported by high-performance computing resources—such as GPU-enabled workstations and cloud computing services—along with virtual and augmented reality equipment, interactive

whiteboards, and reliable high-speed internet connections. Secure data storage, redundant backup systems, and strong wireless networks are equally critical for sustained access to AI tools. Access to software and platforms, including professional AI development frameworks such as TensorFlow and PyTorch, no-code or low-code AI environments, AI-integrated learning management systems, and simulation software for educational scenarios, provides the necessary foundation for applied learning. Specialized educational software—such as AI-powered tutoring systems, data visualization tools, and assessment platforms with AI analytics—further supports authentic classroom practice.

Building AI competencies also depends on human expertise and carefully structured professional development. Universities must cultivate AI-literate faculty through advanced degree programs, ongoing professional development, sabbatical opportunities in industry, and collaborative teaching models that pair AI experts with education specialists. Intensive summer institutes, regular workshops on emerging AI technologies, and peer mentoring networks strengthen faculty skills, while access to online certification programs ensures continuous growth. Dedicated technical support teams—including IT specialists, instructional designers, and data analysts—are vital for assisting both faculty and students in the implementation of AI projects. Student-focused services such as AI tutoring centers, peer mentoring programs, career counseling, and academic advising reinforce individual progress and confidence.

Curriculum design must provide structured learning pathways that begin with foundational AI literacy courses and progress toward specialized tracks aligned with subject areas and grade levels. Capstone projects that integrate AI into teaching practice, micro-credentialing for specific competencies, and rigorous assessment tools—including standardized evaluations, peer reviews, and portfolio systems—enable systematic measurement of AI competency development. Comprehensive educational resources, from interactive online modules and case study libraries to open educational resources (OER) and practical lesson plan templates, support sustained learning and application.

Strategic partnerships and external collaborations strengthen the capacity of teacher education programs to develop AI competencies. Partnerships with technology companies can provide access to tools, training opportunities, internships, guest lectures, and joint research projects, while educational discounts, beta testing opportunities, and cloud computing credits expand technological access. University networks and professional organizations facilitate faculty exchanges, collaborative research grants, and the dissemination of best practices through conferences and professional societies. Long-term success also relies on financial and administrative commitment. Institutions must allocate sufficient funding for infrastructure, faculty hiring, software licensing, and the renovation of learning spaces while maintaining

ongoing budgets for training programs, technical maintenance, and student support services. Federal and state grants, private foundation funding, and alumni or donor contributions can help sustain these initiatives.

The relationship between lifelong learning tendencies and digital competencies highlights another important dimension of AI competency development. While studies show a significant correlation between these constructs (Keskin, 2023), assuming direct causality is methodologically and theoretically problematic. Correlation does not establish causal direction, and third variables—such as institutional support or socio-economic factors—may influence both lifelong learning and digital competence. Cross-sectional research designs cannot establish temporal precedence, while longitudinal studies face challenges such as participant attrition and rapidly changing technology landscapes. Furthermore, both lifelong learning and digital competence are multidimensional constructs that vary across cultural contexts and individual experiences. Recognizing this complexity, teacher education programs should avoid oversimplified causal assumptions and instead adopt conceptual frameworks that view the relationship as reciprocal and mediated. Reciprocal models acknowledge feedback loops in which lifelong learning and digital competence reinforce each other over time, while mediated approaches emphasize the role of self-efficacy, social support, and opportunity structures in shaping these relationships.

Ultimately, AI competencies have the potential to transform educational practice by enabling new forms of personalized learning, innovative assessment methods, and advanced pedagogical approaches. To realize this transformation, educators must acquire a comprehensive set of competencies that encompass technical literacy, pedagogical integration, ethical awareness, and practical implementation skills (Marzal & Vivarelli, 2024). Technical AI literacy includes an understanding of machine learning algorithms, natural language processing, computer vision, data analytics, and the ability to evaluate the effectiveness and limitations of AI tools. Pedagogical integration requires designing adaptive learning environments, creating curricula that respond to individual student needs, and employing AI-driven differentiated instruction. Educators must also use AI for formative assessment and real-time feedback while maintaining human oversight. Ethical implementation demands that teachers recognize and mitigate algorithmic bias, ensure privacy and data protection, and advocate for inclusive AI practices that respect cultural and socio-economic diversity. Finally, educators must cultivate collaborative and critical evaluation skills to balance automation with human judgment, share best practices within professional learning communities, and adapt AI strategies in response to emerging technologies and student feedback.

By addressing these challenges with a strategic, well-resourced, and ethically grounded approach, teacher education programs can prepare future educators to

harness the transformative potential of artificial intelligence while safeguarding educational quality and equity.

In the context of Uzbekistan, the development of AI competencies in future educators is closely tied to the country's ongoing national digital transformation strategies and educational reforms. The government's "Digital Uzbekistan 2030" program has established ambitious goals for integrating advanced technologies into key sectors, including education, thereby creating both opportunities and challenges for teacher preparation institutions. While significant investments have been made in expanding broadband infrastructure and modernizing higher education facilities, disparities remain between urban and rural regions in terms of technological access and skilled personnel. Teacher education programs are increasingly encouraged to incorporate AI-related content, yet there is still a pressing need for systematic faculty development, industry partnerships, and curriculum innovation to align with international standards. Furthermore, ensuring that AI integration respects cultural and linguistic diversity—particularly the use of Uzbek and other local languages in AI-powered educational tools—will be critical for equitable adoption. By leveraging state support, international collaborations, and targeted professional development initiatives, Uzbekistan can accelerate the formation of a new generation of educators equipped with the technical, pedagogical, and ethical AI competencies required to sustain the nation's digital education agenda and to prepare students for participation in the global knowledge economy.

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