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PEDAGOGICAL FOUNDATIONS OF CRITICAL THINKING DEVELOPMENT IN THE CONTEXT OF ARTIFICIAL INTELLIGENCE INTEGRATION IN EDUCATION

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Abstract. This article explores the pedagogical foundations of critical thinking development in the context of the rapid integration of artificial intelligence (AI) into the educational process. The current digital transformation of education highlights the need to rethink traditional pedagogical models for shaping students' thinking, as AI is becoming not only a learning support tool but also a factor influencing cognitive strategies, analytical practices, and decision-making processes. The paper analyzes the theoretical foundations of critical thinking in classical and contemporary pedagogy, beginning with ideas of John Dewey, Jean Piaget, Leonid Vygotsky, and Benjamin Bloom and concluding with the contemporary concepts of Peter Facchione, Robert Paul, and Lauren Elder. Particular attention is paid to the transformation of the educational environment under the influence of intelligent technologies, including adaptive learning systems, intelligent tutoring systems, and generative AI models. The article examines the pedagogical conditions for developing critical thinking in a digital environment, as well as the risks associated with algorithmic dependence, decreased cognitive autonomy, and issues of academic integrity. The conclusion is drawn about the need to integrate AI into education based on pedagogically meaningful models aimed at developing reflection, metacognition, and independent thinking of students.

Key words. Critical thinking, artificial intelligence, pedagogy, digital transformation of education, metacognition, constructivism, adaptive learning, educational technologies.

1. Introduction. Relevance of the Study.

The development of the critical thinking is traditionally considered one of the key goals of modern education. John Dewey emphasized the importance of reflective thinking as the foundation of meaningful learning and decision-making. In the 21st century, this issue takes on a new dimension with the rapid digitalization of education and the introduction of artificial intelligence technologies. AI is no longer solely a technical tool and is becoming a facilitator of students' cognitive activity. Generative AI systems, intelligent assistants, and adaptive educational platforms influence the way information is analyzed, argumentation id formed, and the process of solving educational problems.

Problem Statement. Despite the significant potential of AI in education, how exactly these technologies influence the development of critical thinking remains understudied. While AI can develop analytical skills, it can also pose risks of cognitive dependence and decreased independent thinking.

Purpose of the Study. To identify the pedagogical foundations for developing critical thinking in the context of integration artificial intelligence into education.

Research Objectives:

1) To analyze the theoretical foundations of critical thinking;
2) To examine the historical evolution of this concept in pedagogy;
3) To explore the impact of AI on educational processes;
4) To identify the pedagogical conditions for developing critical thinking in a digital environment;
5) To identify the risks and limitations of using AI.

2. Literature Review. The Concept of Critical Thinking. In the scientific tradition, critical thinking is viewed as a multi-component process, including analysis, evaluation, interpretation, and argumentation. According to P. Facione (1990), critical thinking is a purposeful, self-regulated judgment based on the interpretation, analysis, and evaluation of information. R. Paul and L. Elder (2006) view critical thinking as a disciplined process of actively and skillfully analyzing one's thinking with the goal of improving it.

Key Pedagogical Approaches. Modern concepts of critical thinking are based on: J. Dewey's pragmatism, J. Piaget's cognitive development, L. Vygotsky's sociocultural theory, B. Bloom's taxonomy, P. Freire's critical pedagogy.

Contemporary Research on AI in Education. Recent UNESCO research (2021-2023) emphasized that AI has the potential to transform educational systems, ensuring adaptability and accessibility of learning. OECD (2022) notes that digital technologies are changing the role of teachers from knowledge transmitters to facilitators of learning. However, research also points to the risks of students' overreliance on digital systems and a reduction in the depth of cognitive processing.

3. Theoretical Foundations of Critical Thinking Development Classical Approaches.

J. Dewey viewed thinking as a problem-solving process based on reflection. J. Piaget linked the development of thinking with the cognitive stages of a child's development, and L. Vygotsky emphasized the social nature of cognition and the role of the zone of proximal development.

Constructivism and the Sociocultural Approach. The constructivist paradigm assumes that knowledge is not transmitted, but rather constructed by the student through active interaction with the environment. In this context, critical thinking is developed through dialogue, discussion, and collaborative problem-solving.

Critical Pedagogy. P. Freire emphasized the need to develop students' ability to critically understand social reality. Education is viewed as a practice of freedom, not as a mechanical acquisition of knowledge.

4. Artificial Intelligence and the Transformation of Education AI Technologies in Education. Modern educational systems include: adaptive learning platforms, intelligent tutoring systems, generative models (e.g., Chat GPT), analytical learning systems.

Adaptive learning. Adaptive systems analyze learners' behavior and tailor content to their level of knowledge. This enhances individualization but can limit cognitive independence.

Intelligent Tutoring Systems. IST model teacher behavior, providing real-time feedback.

Generative AI. Generative models generate texts, solutions, and explanations, radically changing the process of completing learning tasks.

At the beginning of the 21st century, the development of artificial intelligence technologies became a key factor in the transformation of educational systems worldwide. While in the early stages of digitalization, technologies primarily served a supportive function, providing access to

educational materials and automating certain administrative processes, modern artificial intelligence systems are having a direct impact on the content, organization, and outcomes of learning. In the educational space, AI is gradually becoming an active participant in pedagogical interaction, capable of analyzing data on students learning activities, adaptive educational content, and providing personalized support during the learning process. According to UNESCO experts (2023), the introduction of artificial intelligence marks a transition to a new educational paradigm, one in which learning flexibility, individualization of educational trajectories, and the development of skills necessary for life in a digital society are particularly important.

Adaptive learning systems, based on machine learning algorithms and big data analysis, are having a significant impact on modern education. These systems can take into account the individual characteristics of students, their level of preparation, the pace of learning, and the nature of their errors. This makes the educational process more personalized and tailored to the real needs of each student. However, researchers note that the effectiveness of adaptive learning is determined not only by the technical capabilities of the platforms but also by the quality of the pedagogical design of the learning environment. Otherwise, there is a risk of reducing learning to the mechanical completion of algorithmically selected tasks without developing a deep understanding of the material being studied or independent thinking.

Intelligent tutoring systems and generative artificial intelligence models occupy a special place in modern educational practice. The emergence of tools such as ChatGPT, Gemini, and other generative platforms has significantly expanded the possibilities for obtaining information, creating educational materials, and organizing independent student work. Generative AI can act as a virtual consultant, explaining complex concepts, offering example problem solutions, and providing prompt feedback. However, this also raises a number of pedagogical issues related to the reliability of generated information, the potential for cognitive addiction, and a decrease in motivation for independent knowledge discovery. Under these conditions, the need to develop students' ability to critically evaluate the answers provided by intelligent systems, compare different points of view, and verify the accuracy of the information received is growing.

The transformation of education under the influence of artificial intelligence affects not only learning technologies but also traditional notions of the roles of teacher and student. While teachers were once the primary source of knowledge, in today's educational environment, their functions are increasingly focused on organizing cognitive activity, developing critical thinking, and guiding students' individual educational journeys. Students, in turn, become active participants in the educational process, interacting with both the teacher and intelligent digital systems. Therefore, finding the optimal balance between leveraging the capabilities of artificial intelligence and preserving the leading role of human thought, reflection, and conscious learning is a key challenge for pedagogy. The quality of training future specialists in the context of society's digital transformation largely depends on how effectively educational systems integrate intelligent technologies into humanistic teaching practices.

5. Pedagogical Foundations for Developing Critical Thinking in an AI Environment.

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Pedagogical Principles. Effective development of critical thinking in an AI environment requires:

1) Problem-based learning;
2) A dialogic educational process;
3) Reflective practice;

4) Integration of metacognitive strategies.

The Role of the Teacher. The teacher is transformed from a source of knowledge into a moderator of cognitive processes. Their function is to pose problematic tasks, stimulate argumentation, and evaluate the quality of thinking.

Learner Autonomy. AI should not replace thinking, but rather serve as a tool for its expansion. Developing the ability to independently verify information is key.

Metacognition and Reflection. Metacognition allows learners to become aware of their own cognitive processes, which is critical in the context of automated response generation.

Digital and AI Literacy. Critical thinking cannot be developed without developing the ability to analyze algorithmic systems and understand the limitations of AI.

Developing critical thinking in the context of the active integration of artificial intelligence into the educational process requires a rethinking of traditional pedagogical approaches to organizing learning. The modern educational environment is characterized by an unprecedented volume of accessible information, its rapid updating, and the widespread use of intelligent digital tools capable of generating texts, analyzing data, and proposing ready-made solutions. In this context, the goal of education is not so much to impart knowledge as to develop students' ability to meaningfully process information, evaluate its validity, identify logical contradictions, and make informed decisions. This is why the development of critical thinking is becoming a key focus of teaching in the era of digital transformation.

The theoretical foundations for developing critical thinking rely heavily on the ideas of the constructivist approach, according to which knowledge is not transmitted in a ready-made form, but is constructed by the learner through active interaction with the environment. In the context of the use of artificial intelligence, this principle is particularly relevant. Despite the ability of intelligent systems to provide quick answers and perform complex analytical operations, the process of meaningful knowledge acquisition remains impossible without the learner's active cognitive activity. The use of AI should not be viewed as a substitute for human thought, but as a means of creating additional opportunities for analysis, research, and problem solving.

One of the most important pedagogical principles for developing critical thinking in a digital educational environment is problem-based learning. According to this principle, the educational process should be built around problematic situations that require students to independently seek solutions, analyze alternative points of view, and provide reasoned justification for their own conclusions. Artificial intelligence can serve as an effective tool for supporting such learning by providing various problem-solving options, generating alternative hypotheses, or simulating complex situations. However, the pedagogical value of such tools is only realized if students go beyond accepting ready-made answers and instead subject them to critical analysis and evaluation.

Equally important is the principle of reflexivity, which requires students to be aware of their own cognitive processes. Reflection is considered one of the central mechanisms for developing critical thinking, as it allows individuals to analyze their own reasoning, identify errors, and adjust their cognitive strategies. In the context of artificial intelligence, developing reflexive abilities is particularly relevant. When receiving responses from intelligent systems, students must not only evaluate the quality of the information provided but also understand the basis for their own judgments, understand the reasons for agreeing or disagreeing with the proposed conclusions, and evaluate the validity of those conclusions.

The development of metacognitive skills plays a special role in developing critical thinking. Modern research shows that successful analytical work is directly related to a person's ability to control their own thinking, plan problem-solving processes, and evaluate the results of their

intellectual activity. The use of artificial intelligence creates additional conditions for the development of metacognition through the ability to receive instant feedback, compare different problem-solving methods, and analyze one's own mistakes. However, there is a risk of developing a passive attitude in the student, in which intellectual effort is replaced by resorting to ready-made algorithmic solutions. Therefore, one of the most important tasks for educators is organizing the educational process in such a way that AI serves as a means of supporting thinking, rather than a substitute for it.

In today's world, the role of the teacher is also significantly transforming. While the traditional educational model primarily involved the transfer of knowledge from teacher to student, the digital educational environment requires a shift to a model of pedagogical support and facilitation of learning. The teacher becomes the organizer of cognitive activities aimed at developing students' ability to independently analyze information, formulate reasoned conclusions, and critically evaluate various sources of knowledge. The teacher's ability to design learning assignments focused on analysis, comparison, evaluation, and solving non-standard problems is particularly important, as these types of activities foster the development of critical thinking to a greater extent than the simple reproduction of information.

A key prerequisite for developing critical thinking in an educational environment based on artificial intelligence is developing students' digital and AI literacy. Modern students must understand the principles of algorithms, recognize the limitations of intelligent systems, and be able to assess the validity of AI-based results. A critical approach to digital technologies requires the ability to identify algorithmic errors, recognize potential biases in artificial intelligence, and consider the context of digital content creation. Therefore, the development of critical thinking is closely linked to fostering a responsible attitude toward the use of technology and an awareness of the ethical aspects of interactions between humans and intelligent systems.

Thus, developing critical thinking in the context of integrating artificial intelligence requires the creation of a pedagogically sound educational environment in which digital technologies are used not to simplify thought processes, but to enrich and deepen them. Effective use of AI is only possible if humans retain a leading role in analysis, evaluation, and decision-making. In this regard, key pedagogical conditions include problem-based learning, the development of reflection and metacognition, the development of digital literacy, and the creation of educational practices that stimulate independent and responsible thinking in students. These conditions allow us to view artificial intelligence not as a threat to the development of critical thinking, but as a means of expanding the possibilities of individual cognitive activity in the modern educational environment.

6. Problems and Ethical Aspects. Academic Integrity. The use of AI increases the risk of plagiarism and uncritical copying of information. Algorithmic Bias. AI systems can reproduce social and cultural biases, influencing educational content.

Cognitive Addiction. Excessive use of AI can reduce the ability to independently analyze.

Data Protection. The collection of educational data requires strict adherence to ethical standards and confidentiality.

Despite the significant potential of artificial intelligence to improve the effectiveness of the educational process, its integration into the educational environment is accompanied by a number of pedagogical, ethical, and social challenges. Modern research demonstrates that the introduction of intelligent technologies impacts not only the organization of learning but also the nature of students' cognitive activity, transforming the ways they receive, process, and interpret information.

Therefore, the ethical and pedagogical support for the use of artificial intelligence is becoming one of the most pressing areas of modern educational science.

One of the most discussed issues is ensuring academic integrity in the context of the widespread use of generative artificial intelligence systems. Modern digital tools are capable of creating texts, solving problems, generating code, and performing other intellectual activities traditionally viewed as the result of independent student work. This has led to the emergence of new forms of academic misconduct, associated not so much with outright plagiarism as with the uncritical use of automatically generated content. The problem stems not only from the use of AI but also from the risk of reducing students' cognitive activity when the process of understanding material is replaced by receiving a ready-made answer. In such a context, the development of new approaches to assessing learning outcomes, focused not only on the final product but also on analyzing the student's thought process, reasoning, and reflection, is particularly important.

The problem of cognitive dependence on intelligent systems is a serious concern for researchers. Throughout the history of technological development, educational tools have been viewed as means of expanding human capabilities. However, modern generative models are capable of performing complex analytical operations, formulating conclusions, and proposing solutions, which creates the risk of a gradual transfer of some cognitive functions from humans to algorithms. If the use of artificial intelligence becomes a permanent substitute for independent analysis, there is a risk of weakening skills in critical evaluation of information, reasoning, and decision-making. This problem is especially pressing for students at the stage of developing cognitive strategies and intellectual independence. Therefore, pedagogy faces the challenge of finding the optimal balance between leveraging the advantages of AI and maintaining the learner's active cognitive stance.

An equally important aspect is the issue of the reliability of information generated by artificial intelligence. Despite the high efficiency of modern language models, their results are not always accurate and scientifically valid. Generative systems can produce convincingly formulated but factually erroneous answers, which in scientific literature is often referred to as "AI hallucinations." For educational practice, this means developing students' skills in verifying information, comparing various sources, and critically evaluating the data obtained. Thus, the use of AI does not diminish the importance of critical thinking; on the contrary, it makes it even more essential for successful learning.

The problem of algorithmic bias is receiving particular attention in modern research. Artificial intelligence is trained on large data sets that reflect the existing social, cultural, and linguistic characteristics of society. As a result, algorithms can reproduce or even reinforce existing stereotypes and prejudices. In educational settings, such biases can influence the content of information provided, recommendations to students, and decision-making processes. For this reason, critical analysis of the results of intelligent systems should be considered a mandatory element of digital literacy for modern students. Students must understand that artificial intelligence is not a neutral and completely objective tool, and its responses are formed based on specific data and algorithms, each with its own limitations.

The issue of privacy and personal data protection requires special consideration. The effectiveness of many intelligent educational systems relies on the continuous collection and analysis of information about students' learning activities. This data may include learning outcomes, digital behavior patterns, individual educational trajectories, and other personal information. On the one hand, using such data significantly increases the level of personalization of learning. On the other hand, it raises questions about ensuring information security, respecting students' rights, and

preventing the unauthorized use of personal information. Therefore, the development of transparent mechanisms for managing educational data is becoming a prerequisite for the ethical implementation of artificial intelligence in the educational process.

The changing nature of interactions between participants in the educational process is also significant. Traditionally, education was based on direct pedagogical communication, which served not only informational but also educational, social, and cultural functions. The active implementation of intelligent technologies may lead to a reduction in the volume of interpersonal interactions and an increased intermediary role for digital systems. Although artificial intelligence can effectively perform many organizational and informational functions, it cannot fully replace human interaction, empathy, moral support, and the educational influence of a teacher. Therefore, the use of AI should be viewed as a means of complementing pedagogical activity, not as a complete alternative.

Thus, an analysis of existing research suggests that the integration of artificial intelligence into education presents a complex set of pedagogical and ethical challenges. Among the most significant are ensuring academic integrity, preventing cognitive addiction, critically assessing the reliability of information, overcoming algorithmic bias, and protecting students' personal data. Addressing these issues requires not only technological advancements but also the development of new pedagogical approaches focused on preserving autonomous thought, fostering a critical attitude toward digital tools, and fostering a responsible culture of using artificial intelligence in the educational environment.

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