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RAQAMLI TRANSFORMATSIYALASHGAN OLIY TA'LIMDA TALABALARNING NEYRO-AI KOMPETENSIYALARINI RIVOJLANTIRISHNING KOGNITIV-PEDAGOGIK ASOSLARI

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Annotatsiya.

Sun'iy intellektning oliy ta'limga jadal integratsiyalashuvi akademik ta'limning mohiyati va talabalar kompetensiyalariga sezilarli ta'sir ko'rsatmoqda. Universitetlar oldida talabalarni nafaqat sun'iy intellekt vositalaridan foydalanishga, balki sun'iy intellekt vositasidagi ta'lim muhitida tanqidiy fikrlash, yaratilgan axborotni baholash, kognitiv faoliyatni boshqarish va akademik mas'uliyatni saqlashga tayyorlash vazifasi tobora dolzarb bo'lib bormoqda. Shu nuqtai nazardan, sun'iy intellekt savodxonligini kognitiv o'zini o'zi boshqarish, refleksiv mulohaza va axloqiy xabardorlik bilan birlashtiruvchi neyro-AI kompetensiyasi tushunchasi alohida ahamiyat kasb etmoqda. Mazkur maqolada raqamli transformatsiya sharoitida talabalarning neyro-AI kompetensiyalarini rivojlantirishning nazariy va pedagogik asoslari o'rganilgan. Tadqiqot xalqaro siyosiy-me'yoriy hujjatlar, ilmiy adabiyotlar va oliy ta'limga sun'iy intellektidan foydalanishga oid zamonaviy tadqiqotlarning narrativ-tahliliy sharhiga asoslangan. UNESCOning sun'iy intellekt kompetensiyalari doirasi, Yevropa Ittifoqining AI savodxonligiga doir yondashuvi, OECDning sun'iy intellekt yordamida o'qitishga oid qarashlari, shuningdek, kognitiv boshqaruv, o'zini o'zi boshqarib o'rganish va multimedia ta'limining zamonaviy nazariyalariga alohida e'tibor qaratilgan. Tahlil natijalari neyro-AI kompetensiyasini sun'iy intellekt yaratgan natijalarni tanqidiy tekshirish, prompt madaniyati, kognitiv yuklamani boshqarish, multimodal fikrlash, akademik halollik va refleksiv ta'limni qamrab oluvchi integrativ pedagogik konstrukt sifatida tushunish lozimligini ko'rsatadi. Shuningdek, sun'iy intellekt yordamidagi samarali ta'lim yaratilgan javoblarni passiv qabul qilishga emas, balki talabaning axborotni mustaqil tahlil qilish, tekshirish, qayta ko'rib chiqish va asoslash qobiliyatiga bog'liq ekanligi aniqlangan. Maqolada oliy ta'lim muassasalarida sun'iy intellektidan foydalanishni kognitiv mustaqillik va axloqiy mas'uliyat bilan uyg'unlashtirishga o'rgatuvchi jarayonga yo'naltirilgan pedagogik modelni joriy etish zarurligi xulosa qilinadi. Bunday yondashuv tahliliy fikrlashni mustahkamlash, refleksiv ta'limni takomillashtirish hamda raqamli transformatsiyalashgan ta'lim muhitida akademik mas'uliyatga ega bitiruvchilarni tayyorlashga xizmat qiladi.

Kalit so'zlar: raqamli transformatsiya, neyro-AI kompetensiyasi, AI savodxonligi, oliy ta'lim, kognitiv boshqaruv, prompt madaniyati, akademik halollik, o'zini o'zi boshqarib o'rganish, tanqidiy fikrlash, pedagogik model.

КОГНИТИВНО-ПЕДАГОГИЧЕСКИЕ ОСНОВЫ РАЗВИТИЯ НЕЙРО-ИИ-КОМПЕТЕНЦИЙ СТУДЕНТОВ В УСЛОВИЯХ ЦИФРОВОЙ ТРАНСФОРМАЦИИ ВЫСШЕГО ОБРАЗОВАНИЯ

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Аннотация.

Стремительная интеграция искусственного интеллекта в высшее образование существенно изменила характер академического обучения и требования к компетенциям студентов. Перед университетами всё более остро стоит задача подготовки студентов не только к использованию инструментов искусственного интеллекта, но и к критическому мышлению в образовательной среде, опосредованной ИИ, оценке сгенерированной информации, регулированию когнитивной деятельности и сохранению академической ответственности. В этом контексте особую значимость приобретает понятие нейро-ИИ-компетенции, объединяющее грамотность в области искусственного интеллекта с когнитивной саморегуляцией, рефлексивным суждением и

этической осознанностью.

В статье рассматриваются теоретические и педагогические основы развития нейро-ИИ-компетенций студентов в условиях цифровой трансформации. Исследование основано на нарративно-аналитическом обзоре международных нормативно-концептуальных документов, научной литературы и современных исследований в области применения искусственного интеллекта в высшем образовании. Особое внимание уделяется рамочной модели компетенций в области ИИ UNESCO, подходу Европейского союза к ИИ-грамотности, взглядам OECD на обучение с поддержкой искусственного интеллекта, а также современным теориям когнитивной регуляции, саморегулируемого обучения и мультимедийного обучения. Результаты анализа показывают, что нейро-ИИ-компетенцию следует рассматривать как интегративный педагогический конструкт, включающий критическую проверку результатов, сгенерированных искусственным интеллектом, культуру промптинга, управление когнитивной нагрузкой, мультимодальное мышление, академическую добросовестность и рефлексивное обучение. Установлено также, что эффективность обучения с использованием искусственного интеллекта зависит не от пассивного восприятия сгенерированных ответов, а от способности студента самостоятельно анализировать, проверять, пересматривать и обосновывать информацию. Сделан вывод о необходимости внедрения в учреждениях высшего образования процессно-ориентированной педагогической модели, предусматривающей обучение студентов сочетанию использования искусственного интеллекта с когнитивной самостоятельностью и этической ответственностью. Такой подход способствует развитию аналитического мышления, совершенствованию рефлексивного обучения и подготовке академически ответственных выпускников в условиях цифровой трансформации образовательной среды.

Ключевые слова: цифровая трансформация, нейро-ИИ-компетенция, ИИ-грамотность, высшее образование, когнитивная регуляция, культура промптинга, академическая добросовестность, саморегулируемое обучение, критическое мышление, педагогическая модель.

COGNITIVE AND PEDAGOGICAL FOUNDATIONS OF DEVELOPING STUDENTS' NEURO-AI COMPETENCIES IN DIGITALLY TRANSFORMED HIGHER EDUCATION

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Abstract.

The rapid integration of artificial intelligence into higher education has significantly transformed the nature of academic learning and the competencies required of students. Universities are increasingly faced with the challenge of preparing students not only to use AI tools but also to think critically in AI-mediated learning environments, evaluate generated information, regulate their cognitive activity, and maintain academic responsibility. In this context, the concept of neuro-AI competence is becoming increasingly important, as it combines AI literacy with cognitive self-regulation, reflective judgement, and ethical awareness. This article examines the theoretical and pedagogical foundations for developing students' neuro-AI competencies under conditions of digital transformation. The study is based on a narrative analytical review of international policy frameworks, scholarly literature, and current research on artificial intelligence in higher education. Particular attention is given to UNESCO's AI competency framework, the European Union's approach to AI literacy, OECD perspectives on AI-supported learning, and contemporary theories of cognitive regulation, self-regulated learning, and multimedia learning. The analysis demonstrates that neuro-AI competence should be understood as an integrated pedagogical construct encompassing the critical verification of AI-generated outputs, prompt culture, cognitive load management, multimodal reasoning, academic integrity, and reflective learning. The findings further indicate that

effective AI-supported learning depends not on the passive reception of generated answers but on students' ability to independently analyze, verify, revise, and justify information. The article concludes that higher education institutions need a process-based pedagogical model that teaches students to combine the use of AI with cognitive independence and ethical responsibility. Such an approach can strengthen analytical thinking, enhance reflective learning, and support the development of academically responsible graduates in digitally transformed educational environments.

Keywords: digital transformation, neuro-AI competence, AI literacy, higher education, cognitive regulation, prompt culture, academic integrity, self-regulated learning, critical thinking, pedagogical model.

Introduction. Digital transformation has changed the meaning of student competence in higher education. A graduate is no longer expected merely to reproduce disciplinary knowledge or operate digital platforms at a basic level. Contemporary academic and professional environments increasingly require the ability to work with data, evaluate automated outputs, recognise the limits of algorithmic systems, protect academic integrity, and make reasoned decisions in conditions of information overload [1; 5–7].

This shift is not abstract. The World Economic Forum's *Future of Jobs Report 2025* is based on the views of more than 1,000 global employers, representing over 14 million workers across 22 industry clusters and 55 economies, and identifies AI and Big Data as the fastest-growing skills for 2025–2030 [1; 3], [1; 35–38]. The same report also places technological literacy, creative thinking, resilience, flexibility, agility, curiosity, and lifelong learning among the skills whose importance will continue to rise [1; 38–40].

This evidence indicates that higher education faces a double challenge. On the one hand, students must learn to use artificial intelligence tools as part of academic and professional work. On the other hand, they must not become passive consumers of machine-generated answers. The 2025 Student Generative AI Survey reported that 92% of students were using AI in some form, compared with 66% in 2024; it also found that 88% had used generative AI for assessments, while 18% had included AI-generated text directly in their work [2; 3–4].

However, the normalisation of AI use does not automatically mean the formation of meaningful AI competence. Many students can ask a chatbot for an explanation, a summary, or a draft, yet still lack the ability to check the reliability of the answer, compare it with scholarly sources, identify bias, understand the cognitive effort required for learning, or distinguish assistance from academic dependency [6; 4–8]. This is the central pedagogical problem addressed in this article.

The term “neuro-AI competence” is used in this article to denote an integrated set of student abilities that combines understanding of AI tools with awareness of human cognitive processes such as attention, memory, perception, cognitive load, reflection, and decision-making. This competence includes the ability to formulate purposeful prompts, analyse AI-generated outputs, verify claims through reliable sources, manage information overload, maintain academic honesty, and transform external assistance into personally understood knowledge [3; 24–36], [8; 257–285].

International frameworks support this broader understanding. UNESCO's *AI Competency Framework for Students* defines AI learning not simply as technical training, but as preparation for safe, meaningful, and responsible engagement with AI. The framework outlines 12 competencies across four dimensions: a human-centred mindset, ethics of AI, AI techniques and applications, and AI system design [3; 24–31].

At the same time, current labour-market evidence shows that AI-supported work is becoming routine. Therefore, universities are preparing students for professional environments in which value will depend not only on technological access, but also on human judgement, problem framing, interpretation, and responsibility [1; 35–40].

Despite this rapid transformation, a clear methodological gap remains. Existing discussions often focus either on the technical use of AI tools or on the risks of plagiarism and academic misconduct. Less attention is given to the pedagogical mechanism through which students learn to combine AI use with cognitive independence, reflective judgement, and ethical responsibility [3; 32–36], [7; 65–70].

Accordingly, the purpose of this article is to substantiate the theoretical and methodological foundations for developing neuro-AI competencies among higher education students in the context of digital transformation. The article focuses on the structure of neuro-AI competence, its cognitive and ethical components, and the pedagogical mechanisms that can support its development, including critical verification of AI outputs, prompt culture, cognitive load management, multimodal learning tasks, reflective assessment, and academic integrity.

METHODOLOGY

The methodological purpose was to examine how students' neuro-AI competencies are understood in contemporary higher education and how international experience can be used to clarify their pedagogical structure.

The review was organised around three groups of sources. The first group included international policy and competency frameworks on artificial intelligence, digital education, and future skills, including the World Economic Forum's *Future of Jobs Report 2025*, UNESCO's *AI Competency Framework for Students*, the European Union's AI Act, and

OECD materials on media and artificial intelligence literacy [1; 3–38], [3; 24–36], [4; Article 4], [5; 1–2]. The second group included studies on student use of generative AI in higher education, especially the 2025 HEPI survey, which provides recent evidence on the scale of AI use among university students [2; 3–9]. The third group included theoretical literature on AI literacy, cognitive regulation, self-regulated learning, academic integrity, and multimodal learning [6; 1–8], [7; 65–70], [8; 257–285], [9; 34–55].

The sources were selected according to their relevance to three questions: how student AI competence is defined; what cognitive and ethical risks appear when students use generative AI; and what pedagogical mechanisms can support independent learning in AI-mediated environments.

Table 1. Analytical basis of the review

Analytical focus	Main sources	What was analysed	Relevance to neuro-AI competence
Future skills and labour-market demand	World Economic Forum, McKinsey	AI and Big Data skills, technological literacy, lifelong learning, workplace transformation	Shows why students need more than basic digital skills
Student AI use in higher education	HEPI Student Generative AI Survey	Scale of generative AI use, use in assessment, student dependency risks	Proves that AI use has become a normal part of academic practice
AI competency frameworks	UNESCO, European Union AI Act, OECD	Human-centred AI, ethics, AI literacy, media and AI literacy	Provides international policy basis for student AI readiness
Cognitive learning theories	Sweller, Mayer, Zimmerman	Cognitive load, multimedia learning, self-regulated learning	Explains the neurocognitive basis of AI-supported learning
Academic integrity and responsibility	ICMJE recommendations, academic integrity literature	Disclosure of AI use, authorship, originality, responsibility	Supports ethical and transparent use of AI in academic work

This made it possible to avoid a purely descriptive review and to connect international experience with the specific problem of neuro-AI competence development. The analytical procedure consisted of four stages. First, the key concepts were clarified: digital transformation, AI literacy, neurocognitive regulation, prompt culture, academic integrity, and neuro-AI competence. Second, international documents and studies were compared according to their treatment of student readiness for AI-supported learning. Third, recurring pedagogical mechanisms were identified, including critical verification, prompt formulation, cognitive load management, reflective assessment, and disclosure of AI use. Fourth, these mechanisms were synthesised into a conceptual interpretation of neuro-AI competence as a combination of AI literacy, cognitive independence, ethical responsibility, and academic judgement.

RESULTS

The analysis of international experience shows that the development of students' neuro-AI competencies cannot be limited to the technical use of digital tools. In current educational and policy frameworks, AI competence is increasingly interpreted as a combination of knowledge, judgement, responsibility, and cognitive control. UNESCO's framework, for example, defines student AI competence through four dimensions: a human-centred mindset, ethics of AI, AI techniques and applications, and AI system design [3; 24–31]. This approach demonstrates that the student is expected not only to use AI but also to understand its limits, ethical implications, and possible effects on learning.

The first important result is the transition from AI access to AI readiness. In the earlier stage of digital education, the main question was whether students had access to devices, online platforms, and electronic learning resources. In the current stage, the more important question is whether students are prepared to use AI critically, safely, and meaningfully. The European Union's AI Act reflects this shift by requiring providers and deployers of AI systems to ensure a sufficient level of AI literacy among those who use such systems, taking into account their education, experience, training, context of use, and the people affected by AI systems [4; Article 4]. This means that AI literacy is no longer only an individual skill; it is becoming an institutional responsibility.

The second result concerns the rapid normalisation of generative AI in student learning. The HEPI Student Generative AI Survey 2025 reported that 92% of students used AI in some form, compared with 66% in 2024; 88% had used generative AI for assessments, and 18% had included AI-generated text directly in their work [2; 3–4]. These figures show that AI use is already part of everyday academic practice. However, the decisive issue is not the percentage of students using AI, but the quality of that use. If students use AI mainly to obtain ready-made answers, independent thinking may weaken. If they use it to clarify concepts, compare arguments, identify gaps, and revise their own work after verification, AI can support deeper learning.

The third result is that international frameworks increasingly connect AI competence with critical and media literacy. OECD's work on PISA 2029 Media and Artificial Intelligence Literacy emphasises that students need to engage proactively and critically in environments where production, communication, and participation are mediated by digital and AI tools [5; 1–2]. This is directly related to neuro-AI competence because the ability to work with AI cannot be separated from attention, interpretation, judgement, and verification. A student may generate a fluent text quickly, but fluency alone does not prove understanding. Learning occurs when the student checks the logic of the generated answer, compares it with reliable sources, and links it with disciplinary knowledge.

The fourth result is that strong international models place ethics at the centre of AI-supported learning. UNESCO links AI competence with responsibility, safety, and meaningful participation in society [3; 32–36]. The EU AI Act also treats AI literacy in relation to context, training, and possible effects on individuals or groups [4; Article 4]. Therefore, ethical responsibility should not be treated as a separate final topic after technical instruction. It must be included in every AI-supported academic task. For example, if students use AI while preparing a literature review, they should explain which prompts were used, what information was rejected, which sources were checked, and what part of the final argument represents their own analysis.

The fifth result is the need to move towards process-based assessment. Traditional assessment often focuses on the final essay, presentation, or project. In the AI era, this is insufficient because a final product may appear coherent while the student's own understanding remains weak. Therefore, assessment should include the learning process: problem formulation, prompt design, source verification, revision, reflection, and explanation of personal contribution. This approach is especially relevant to neuro-AI competence because it evaluates not only whether the student used AI, but whether the student controlled the learning process.

The sixth result is that prompt culture should be understood as an academic and cognitive skill. A prompt is not merely a technical command. It reflects the student's ability to define a problem, set boundaries, provide context, and determine the expected quality of the answer. A weak prompt usually produces a broad and superficial response; a strong prompt shows that the student has already understood the academic task. In this sense, prompt culture develops metacognitive thinking: the student learns to ask what is needed, what must be checked, what kind of evidence is required, and what form of answer would be academically acceptable [6; 4–8].

The seventh result is that foreign experience points to the need for institutional policy, not only individual teacher initiative. If each teacher sets different rules for AI use, students receive mixed signals. In one course, AI may be prohibited; in another, it may be allowed without guidance; in a third, it may be expected but not assessed properly. For this reason, universities need coherent rules on AI literacy, disclosure, acceptable assistance, academic integrity, and assessment redesign. Neuro-AI competence should therefore be formed at three levels: student level, teacher level, and institutional level.

Overall, the analysis shows a conceptual transition in higher education: from digital literacy to AI literacy, and from AI literacy to neuro-AI competence.

Table 2. From digital literacy to neuro-AI competence: conceptual transition in higher education

Stage of competence	Main focus	Student role	Pedagogical mechanism	Expected academic outcome
Digital literacy	Access to digital tools, platforms and online resources	User of digital systems	Searching, operating platforms, submitting tasks online	Basic ability to function in a digital learning environment
AI literacy	Understanding AI tools, their limits and possible risks	Informed user of AI systems	Learning how AI works, identifying risks, using AI responsibly	Ability to use AI tools with awareness and basic responsibility
Critical AI use	Verification of generated content	Evaluator of AI outputs	Source checking, comparison, correction of weak arguments	Development of critical judgement and information reliability skills
Neuro-AI competence	Cognitive regulation, ethical responsibility and reflective independence	Active constructor of knowledge	Prompt culture, cognitive load management, reflection, disclosure of AI use	Independent academic thinking in AI-mediated learning
Institutional AI readiness	Curriculum, assessment and academic integrity policy	Member of a regulated academic environment	AI guidelines, teacher training, process-based assessment	Responsible and transparent AI-supported academic culture

Digital literacy mainly concerns access and operation. AI literacy concerns understanding and responsible use. Neuro-AI competence adds cognitive regulation, academic judgement, reflective independence, and ethical transparency. This transition provides a stronger basis for designing teaching methods in digitally transformed universities.

DISCUSSION

The results suggest that neuro-AI competence should be understood as a pedagogical construct rather than a separate technical skill. Its significance lies in the fact that AI-supported learning changes the usual order of academic work. In traditional learning, students usually move from reading and searching to comparison, interpretation, and writing. In AI-supported learning, a polished answer may appear before the student has fully understood the question. This creates a serious pedagogical risk: the external product may look complete while the internal process of understanding remains shallow.

For this reason, universities should not focus only on detecting AI use. Detection may show whether a text was probably produced with technological assistance, but it does not teach students how to think better. A more productive approach is to redesign learning tasks so that students must demonstrate the process behind the final product. They should show how the problem was formulated, how AI was used, what was checked, what was corrected, and what conclusion was reached independently.

The discussion also shows that critical verification is the central mechanism of neuro-AI competence. Generative AI can produce convincing explanations, but such explanations may contain unsupported claims, fabricated references, or simplified interpretations. Therefore, students must learn to treat AI output as a draft for examination, not as final knowledge. This habit can be developed through tasks requiring comparison with scholarly sources, identification of weak arguments, and justification of accepted or rejected information.

Prompt culture also needs to be interpreted more deeply. It is not a fashionable technical skill, but a form of academic thinking. A precise prompt requires the student to understand the task, define the context, and determine the criteria for a useful answer. In this way, prompt formulation becomes a method for developing analytical language, conceptual clarity, and self-regulated learning.

Another important issue is cognitive load. Digital transformation has increased access to information, but access itself does not guarantee understanding. Students often face large volumes of fragmented information. AI may help them organise this information, but it may also create confusion if outputs are long, unverified, or conceptually unclear. Therefore, neuro-AI competence should include the ability to divide complex tasks into smaller parts, distinguish key concepts from secondary details, organise arguments visually, and connect new knowledge with previous understanding [8; 257–285].

Ethical responsibility is equally important. The ICMJE recommendations state that AI-assisted technologies should be disclosed when used and that such technologies cannot be listed as authors because responsibility for accuracy, integrity, and originality remains with humans. This principle is important for student learning as well: even when AI is used for support, the student remains responsible for the final academic product.

At the institutional level, the findings indicate that neuro-AI competence cannot be formed through isolated lectures about AI. It requires a consistent educational environment. Universities need AI literacy modules, clear academic integrity policies, teacher training, assessment rubrics, and transparent rules for acceptable and unacceptable AI assistance. Only then can AI become part of academic culture rather than an uncontrolled shortcut.

Thus, the development of neuro-AI competence requires a balanced model. AI should not be presented as a threat that must be completely prohibited, nor as a universal solution that can replace learning. Its educational value depends on how it is integrated into academic tasks. When guided properly, AI can help students organise information, test ideas, compare perspectives, and improve argumentation. When used without guidance, it may weaken independence, reduce reading effort, and blur the boundaries of authorship.

CONCLUSION

The article concludes that the development of students' neuro-AI competencies is a necessary direction for higher education under conditions of digital transformation. This competence goes beyond ordinary digital literacy and includes the ability to use AI tools critically, ethically, and cognitively productively.

The analysis of international experience shows a clear movement from simple digital access towards AI readiness. Modern higher education must prepare students not only to use AI systems, but also to understand their limitations, verify their outputs, disclose their use, and preserve personal academic responsibility.

Neuro-AI competence includes several interconnected components: AI literacy, critical verification, prompt culture, cognitive load management, academic integrity, multimodal reasoning, and self-regulated learning. These components should not be taught as isolated topics. They should be embedded into academic tasks that require students to move from AI-generated output to independent judgement.

The most appropriate pedagogical mechanism is a process-based learning cycle: problem identification, purposeful prompting, analysis of AI output, verification through reliable sources, revision, explanation of personal contribution, and reflection. This cycle helps prevent mechanical dependence on AI and strengthens independent academic thinking.

In practical terms, higher education institutions should revise assessment tasks, introduce AI literacy guidelines, support teachers in AI-related pedagogy, and develop clear rules for responsible AI use. Under such conditions, AI may become not a replacement for student thinking, but a tool for strengthening analysis, reflection, and academic responsibility.

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