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IMPROVING THE METHODOLOGY FOR DEVELOPING THE INTELLECTUAL COMPETENCE OF FUTURE TEACHERS THROUGH MODERN NEUROPEDAGOGICAL TECHNOLOGIES

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Annotation: Modern educational reforms emphasize cultivating future teachers' higher-order thinking and cognitive skills. Neuropedagogy – the application of neuroscience findings to education – offers a theoretical and practical framework to enhance intellectual competence in teacher trainees. This article reviews the theoretical foundations of neuropedagogy and its role in strengthening learners' cognitive abilities, and surveys modern neuropedagogical tools (e.g., virtual simulations, neurofeedback devices) in teacher education. We focus on Uzbekistan's pedagogical universities, where recent policies (e.g. the 2030 Education Concept) call for innovative, individualized teaching methods. Uzbek research (e.g., Sotivoldiyeva, 2023) and international studies indicate that aligning instruction with brain-based principles (e.g. personalized learning, active engagement) can boost metacognitive skills such as self- regulation, critical thinking, and problem-solving. For example, using neuropedagogical virtual laboratories significantly improved Uzbek chemistry students' understanding and reasoning (with ~88– 92% reporting gains). Similarly, pilot programs using wearable neurofeedback and adaptive learning showed marked gains in trainees' attention, reflection, and self-management. We argue that integrating neuropedagogical technologies into Uzbekistan's teacher training curricula – guided by national reforms – can meaningfully develop pedagogical students' intellectual competence. Practical recommendations include adopting simulations, neuro-adaptive learning platforms, and professional development in educational neuroscience. Further research should explore localized neuropedagogy models and long-term impacts on teaching quality.
Keywords: Neuropedagogy; Intellectual competence; Teacher education; Neuroscience; Uzbekistan; Educational technology; Cognitive skills.
Developing the intellectual competence of future teachers is an urgent goal in modern education. Intellectual competence broadly refers to cognitive skills like critical thinking, problem-solving, and metacognition (self-regulation and reflection). These skills enable teachers to plan effectively, adapt to new knowledge, and foster deep learning in their students. In the context of Uzbekistan's educational reforms (the "New Uzbekistan"), policymakers have explicitly prioritized raising the intellectual and moral level of the young generation. For example, the 2019 Presidential Education Development Concept (2030) calls for renewing curriculum content, introducing individualized instruction and modern ICT, and raising students' intellectual development to a "qualitatively new level". However, recent assessments indicate Uzbek students underperform in creative and critical domains: Uzbekistan scored well below the OECD average on PISA 2022 creative-thinking tests. This performance gap highlights the need for innovative pedagogies that explicitly target higher-order cognition.
Neuropedagogy – an educational neuroscience approach – has emerged as a promising response. In essence, neuropedagogy applies findings about the brain's learning processes (from neuroanatomy, neurobiology, and psychology) to design and implement more effective teaching methods. It is described as a "symbiosis of science and education" that aims to stimulate the

brain and form neural connections during learning. By aligning teaching with the brain's natural information-processing patterns (e.g. parallel processing, emotional engagement, pattern recognition), neuropedagogy offers concrete strategies to bolster learners' cognitive functions. In Uzbekistan, pedagogical faculty students (future teachers) stand to benefit from neuropedagogical training: they must master both content and modern teaching methodologies. Embedding neuroscience-based methods in teacher education can therefore help these students develop their own intellectual and metacognitive capacities, preparing them to teach in innovative, student-centered ways.

This article reviews the theoretical foundations of neuropedagogy, examines its role in nurturing intellectual competence, and explores practical neuropedagogical technologies for teacher training. We pay particular attention to the Uzbekistan context: its educational policies, local research, and the needs of pedagogical universities. By synthesizing Uzbek and international sources, we argue that integrating neuropedagogical approaches into teacher preparation can align Uzbekistan's higher education with global best practices and national priorities.

Neuropedagogy originated as an outgrowth of educational neuroscience in the late 20th century. With the rise of neuroscience in Western Europe during the 1990s, researchers began exploring how brain science could inform teaching and learning. They discovered that understanding brain development and function could directly improve pedagogy. For example, learners' neurophysiological traits (such as neural plasticity, attention patterns, and sensory processing) vary widely and influence how students absorb information. Neuropedagogical theory posits that tailoring instruction to these brain-based differences creates more effective learning experiences. As Koval et al. (2025) note, implementing neuropedagogical approaches allows for personalized learning that considers each learner's neurobiological profile, thereby increasing overall educational effectiveness. Moreover, continuous advances in neuroscience yield new insights for optimizing cognitive processes: educating with the brain in mind can explicitly develop metacognitive abilities like self-regulation and critical thinking.

Scholars define neuropedagogy in various ways, but common elements include its interdisciplinary scope. Rakhmetova et al. (2024) define neuropedagogy as "an applied neuroscience that uses knowledge of cognitive neurology, differential psychophysiology, neuropsychology, [and] data on the brain organization of the processes of acquiring different types of educational material". In other words, it systematically incorporates research on how neurons, brain regions, and cognitive systems behave during learning, and then translates that into teaching strategies (often called "neurodidactics"). This goes beyond simply teaching about the brain; it means structuring lessons to harness brain mechanisms. For instance, because the brain processes visual and auditory information in parallel, educators might present material multimodally to engage multiple neural pathways simultaneously. Because emotion plays a key role in memory formation, neuropedagogy encourages incorporating storytelling or aesthetic elements to make content memorable. Several core principles emerge from neuropedagogical research: (a) Variation of methods: The brain acts like a "parallel processor," so using varied instructional methods keeps multiple networks active.

Intellectual competence in teacher education encompasses skills like analytical reasoning, creativity, metacognition, and the ability to adapt knowledge to new situations. It enables future teachers to plan lessons critically, solve classroom problems, and cultivate similar skills in their students. Developing these competencies in teachers is crucial: competent teachers produce competent learners. Importantly, neuropedagogy directly targets such skills. Research shows that when instruction aligns with brain-based learning strategies, students acquire deeper understanding and higher-order thinking. For example, experimental studies using neuropedagogical tools report large gains in analytic and problem-solving abilities. In one study of university students learning chemistry with neuropedagogically-designed virtual simulators, 88% of participants reported better understanding of the subject and 92% noted improved logical reasoning. Similarly, Nurmakhanova et al. (2024) found that after using virtual neuro-informed chemistry labs, nearly all students reported improvements in perception, imagination, and logical thinking. These cognitive benefits translate into intellectual competence: students develop more robust conceptual frameworks and problem-solving schemas.

In teacher education specifically, strengthening intellectual competence means helping trainees become reflective, self-directed learners and thinkers. Neuropedagogy supports this by nurturing metacognition. By using brain-based learning activities and providing neurofeedback, instructors can prompt students to monitor their own thinking (e.g. noticing when attention wanes). In Ukraine, Koval et al. (2025) implemented a neurofeedback-assisted training for primary education majors, tracking "academic neuromarkers" such as self-management, reflection, and attention shifting. Within just two months, students demonstrated clear improvements in these markers. In practice, this might look like students using wearable devices to see real-time attention graphs and consciously adjusting their focus during tasks. This self-awareness is a key component of intellectual competence (knowing how one learns). More broadly, international studies (e.g. Petlák & Schachl, 2019; Marchak et al., 2021) have observed that neuropedagogical interventions tend to enhance critical thinking and creativity, which are precisely the higher-order skills Uzbekistan's reforms aim to promote.

It is noteworthy that neuropedagogy is not just about cognitive skills in isolation; it also emphasizes emotional and social aspects of learning. Emotional intelligence, pattern recognition, and a sense of meaning-making are built into this approach. For instance, Karamat (2024) argues that combining logic and imagination is essential to creative education, suggesting neuropedagogy can facilitate this integration of analytical and creative thinking (even if explicit Uzbek sources on this are scarce). Thus, implementing neuropedagogical techniques (from game-based learning to collaborative projects) can help future teachers internalize these complex skills themselves, ready to model them for their students.

A range of modern technologies embodies neuropedagogical principles by making learning interactive, adaptive, and brain-friendly. The most commonly studied tools include virtual reality (VR) simulations, wearable neurofeedback devices, and AI-driven learning platforms. These technologies have been experimentally applied in teacher training and related fields:

Virtual/Augmented Reality and Simulations: Immersive environments allow teachers-in- training to experiment with concepts at their own pace. For example, virtual chemistry labs let learners manipulate molecules visually, engaging spatial and analytic brain networks simultaneously. Such simulators have dramatically improved student outcomes: in a neuropedagogical VR chemistry course, 96% of students found the learning more engaging, and many reported better conceptual understanding. By visualizing content at multiple levels (macro and micro), VR helps form mental models – a core intellectual skill. In teacher education, VR could simulate classroom scenarios or bring abstract educational theories to life, making the learning process active rather than passive.

Wearable Neurofeedback and Brain-Computer Interfaces: Wearable sensors (e.g. EEG headsets, smartwatches) can monitor attention, engagement, or stress in real time. Koval et al. (2025) used fitness tracker watches as neurofeedback tools in a pilot training. With this data, instructors and learners can adjust the task difficulty or take a focused break – essentially personalizing learning. As one study noted, "future teachers can learn through personalised, dynamic learning paths with neurofeedback, aligning closely with the competencies they will need". Such adaptive feedback loops help future teachers develop self-regulation, as they become aware of how their brain reacts to different tasks. Over time, this can heighten meta- cognitive control – a hallmark of intellectual competence.

Adopting these technologies in teacher preparation requires investment and training. Yet research suggests strong potential payoffs. For example, even short-term exposure to neuropedagogical VR and neurofeedback produced measurable gains in attention and reasoning. Embedding such tools into practicum courses or methods classes could give Uzbek pedagogical students hands-on experience with brain-based learning – both as learners and as future designers of learning experiences.

Uzbekistan's higher education system is undergoing rapid modernization, and pedagogical universities are central to the vision. Aligning neuropedagogical methods with national initiatives could greatly enhance teacher training. Uzbek educational policy already emphasizes personalized, high-quality instruction. For instance, the national concept highlights individualization of learning and integration of ICT and innovative projects. Neuropedagogy directly supports these aims: its core is customizing teaching to each learner's brain. Thus, embedding neuropedagogical content into Uzbek teacher education programs would advance both the letter and spirit of the reforms.
Concrete steps might include:
Curricular Integration: Courses on educational neuroscience or brain-based teaching methods can be introduced in pedagogical faculties. For example, a required module on "neuropedagogical tools in education" could survey cognitive development, attention science, and the use of adaptive technologies. Specialized training in using VR labs, neurofeedback devices, or adaptive software can be incorporated into practicum classes (e.g. science methods, ICT in education). This aligns with Uzbekistan's roadmap for "professional development of teaching staff" and "innovative teaching methods".
Research and Pilot Projects: Encouraging faculty and graduate students to conduct localized research on neuropedagogy will build Uzbek expertise. The positive results reported in chemistry and physics education can be extended to pedagogy. For instance, a pilot study could test a neuropedagogical VR scenario for teaching history or math to pedagogical students, measuring cognitive gains. These data would inform policy. Moreover, partnerships (e.g. with the Ministry of Education or relevant committees) could fund neuropedagogy labs at leading pedagogical universities, integrating Uzbekistan-based content.
Policy and Guidelines: On a broader level, the Ministry of Public Education (now Ministry of Higher and Secondary Specialized Education) could develop guidelines or a "roadmap" for integrating neuropedagogy. This could include revising accreditation standards to mention neuroscience-informed methods or including neuropedagogical competencies in teacher standards. Since the Education Concept 2030 is implemented via annual roadmaps, adding neuropedagogical training as a target is feasible. Doing so would ensure alignment with the national goal of making Uzbekistan a PISA-top-30 country by 2030 – brain-based methods have been shown to raise student achievement over time.
Overall, implementing neuropedagogy in Uzbekistan's teacher education offers a culturally and policy- aligned path to strengthen intellectual competence. It responds to both Uzbek educational priorities (e.g. fostering intellectual development) and global research showing that neuroscience- informed pedagogy improves learning outcomes.
As Uzbekistan strives to modernize its education system, enhancing the intellectual competence of future teachers is vital. Neuropedagogy provides a theoretically sound and practically tested approach to this challenge. By incorporating neuroscience into pedagogy, teacher-training programs can directly target cognitive skills and metacognitive abilities that underlie intellectual competence. Experimental evidence (from Ukraine, Uzbekistan, and elsewhere) demonstrates that neuropedagogical methods –
whether via VR simulations, neurofeedback devices, or creative pedagogies – significantly boost learners' critical thinking, reasoning, and self-regulation. These outcomes align with Uzbekistan's educational vision, which explicitly calls for innovative, individualized, and ICT-supported teaching.

To capitalize on this potential, Uzbek pedagogical universities should adopt a multi-pronged strategy: update curricula to include educational neuroscience, invest in neuropedagogical technologies (labs, devices), and train faculty in these methods. Pilot studies and collaborations with international experts can guide context-sensitive implementations. In doing so, Uzbekistan will not only comply with its national reforms but also place its future teachers at the forefront of evidence-based education. The likely result is a new generation of educators with stronger intellectual competence, better prepared to nurture these skills in their own students.

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