2026. Volume 10, Number 1 *Pages 141-147*

UOT: 612.82
DOI: https://doi.org/10.30546/09081.2026.1.1048

NEUROEDUCATION: HOW BRAIN SCIENCE CAN IMPROVE TEACHING METHODS

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ARTICLE INFO

Article history:
Received:2025-03-06
Received in revised form:2025-03-22
Accepted:2026-04-28
Available online:2026-06-19

Açar sözlər:
Neuroeducation, social-emotional learning (SEL), spaced repetition, cognitive load, emotional regulation

ABSTRACT

Neuroeducation integrates neuroscience, psychology, and education to create teaching methods based on how the brain learns. This research examines key brain functions such as memory, attention, emotion, and neuroplasticity, and challenges myths like fixed learning styles. It highlights evidence-based strategies including retrieval practice, spaced repetition, and multisensory learning that improve retention and engagement. The study also explores how managing cognitive load and emotional regulation can enhance classroom learning. By applying these neuroscience insights, educators can design more effective, inclusive, and scientifically grounded teaching practices that better support student learning and development. Ultimately, this interdisciplinary approach empowers teachers to bridge the gap between brain research and classroom practice, fostering deeper learning and long-term academic success.

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NEVROTƏHSIL: BEYIN ELMI TƏDRIS METODLARINI NECƏ YAXŞILAŞDIRA BILƏR

XÜLASƏ

Nevrrotəhsil, beynin necə öyrəndiyini əsas götürərək tədris metodlarını yaratmaq üçün nevroelm, psixologiya və təhsili birləşdirir. Bu tədqiqat yaddaş, diqqət, emosiyalar və nevroplastiklik kimi əsas beyin funksiyalarını araşdırır və "sabit öyrənmə üslubları" kimi mifləri tənqid edir. Həmçinin məlumatın yadda saxlanmasını və iştirakçılığı artıran sübuta əsaslanan strategiyaları – məsələn, yaddaşdan çağırma, fasilələrlə təkrar və çoxhissiyyatlı öyrənmə – vurğulayır. Tədqiqat, həmçinin, kognitiv yüklənmənin idarə olunması və emosional tənzimləmənin sinifdə öyrənməni necə yaxşılaşdıracağını araşdırır. Bu nevroelmi bilikləri tətbiq etməklə müəllimlər daha effektiv, inkluziv və elmi əsaslı tədris metodları yarada bilər ki, bu da şagirdlərin öyrənmə və inkişaf prosesini daha yaxşı dəstəkləyir. Nəticə etibarilə, bu fənlərarası yanaşma müəllimlərə beyin araşdırmaları ilə sinif təcrübəsi arasındakı boşluğu aradan qaldırmağa kömək edir, daha dərin öyrənmə və uzunmüddətli akademik uğur qazandırır.

Açar sözlər: *Neyrotəhsil, sosial-emosional öyrənmə (SEL), fasilələrlə təkrar, kognitiv yüklənmə, emosional tənzimləmə*

In recent decades, the interdisciplinary field of neuroeducation—also known as educational neuroscience—has emerged at the intersection of neuroscience, psychology, and education. Neuroeducation seeks to bridge the gap between what we know about the human brain and how we apply that knowledge in educational settings. With rapid advances in brain imaging technologies and cognitive neuroscience, researchers now have unprecedented access to understanding how the brain processes information, retains memory, develops attention, and regulates emotion—all of which are foundational to effective learning.

Traditional educational theories have often been based on observation, intuition, and classroom experience rather than on biological evidence. Although such theories have provided important foundations for teaching practices, they sometimes lack empirical validation about how learning truly occurs at the neurological level. In contrast, neuroeducation—an interdisciplinary field that merges neuroscience, psychology, and education—aims to ground pedagogical strategies in scientific insights from the study of the brain. This approach provides a more evidence-based framework for understanding how students absorb, retain, and apply knowledge.

Research in neuroeducation has revealed critical factors that influence learning, such as the role of working memory limitations (Sweller, 1988), the impact of stress and emotion on cognition (McGaugh, 2000), [1] and the importance of sleep in memory consolidation (Walker & Stickgold, 2006).[2] For example, findings on the prefrontal cortex have highlighted how attention and executive functions develop over time, which has implications for designing age-appropriate learning tasks. Similarly, insights into neuroplasticity—the brain's ability to reorganize and form new connections—support the idea that intelligence is malleable and that all students can learn with the right kind of instruction and practice.[3]

Neuroeducation also encourages educators to move away from long-held myths, such as the belief in fixed "learning styles" (e.g., visual, auditory, or kinesthetic). Despite their popularity, studies have consistently shown that there is no strong evidence to support the idea that teaching according to a student's preferred learning style improves learning outcomes. For instance, a comprehensive review by Pashler et al. (2008) concluded that there is no credible scientific support for tailoring instruction to learning styles and that doing so could even mislead teaching efforts.[4]

Instead, neuroeducation promotes the adoption of strategies grounded in cognitive neuroscience—such as retrieval practice, spaced repetition, and multisensory learning—all of which have been shown to significantly enhance memory and understanding. Retrieval practice, or the act of recalling information from memory, has been shown to improve long-term retention more effectively than passive review. A study by Roediger and Karpicke (2006) demonstrated that students who engaged in retrieval practice retained 50% more information a week later compared to those who simply re-read the material. [5]

Spaced repetition, which involves reviewing information over increasingly longer intervals, strengthens neural pathways associated with memory. Research in this area, such as the work by Cepeda et al. (2006), has shown that spacing study sessions across time leads to better retention than massed practice (cramming), with improvements of up to 15% in long-term recall. [6]

Multisensory learning, which integrates visual, auditory, and kinesthetic input, aligns with how the brain naturally processes information. Studies using fMRI imaging (Shams & Seitz, 2008) have shown that when multiple senses are engaged, the brain forms stronger and more interconnected neural patterns, facilitating better comprehension and recall.[7]

By integrating these findings, neuroeducation not only informs curriculum design and instructional methods but also transforms classroom management practices. For instance, strategies that reduce cognitive overload, such as chunking information and minimizing distractions, help optimize the brain’s working memory capacity. John Sweller’s Cognitive Load Theory (1988) explains that when students are presented with too much information at once, learning efficiency decreases. Therefore, structuring lessons to avoid unnecessary complexity can enhance understanding.[1]

Finally, neuroeducation influences assessment strategies, advocating for formative assessments that reflect how students learn rather than simply measuring final outcomes. Tools such as concept maps, reflective journals, and low-stakes quizzes allow teachers to gauge ongoing understanding and adapt instruction accordingly, consistent with principles of formative feedback and metacognition.

Ultimately, neuroeducation holds the potential to revolutionize education by creating teaching environments that are more aligned with how the brain naturally learns—offering a path toward more effective, inclusive, and scientifically informed education systems.

Current research in neuroeducation has provided meaningful contributions to understanding how factors such as neuroplasticity, executive functions, emotional regulation, and sleep impact learning. For instance, the concept of neuroplasticity—the brain's ability to change and adapt as a result of experience—has significant implications for lifelong learning and remediation of learning difficulties. Similarly, understanding the neural basis of working memory and attention can help educators design more effective classroom activities that align with students' cognitive capacities.

Despite its promise, the integration of neuroscience into educational practice is not without challenges. Critics have warned against the misuse of neuroscientific findings in classrooms, often referred to as "neuromyths," and emphasized the need for better communication between neuroscientists and educators. Nonetheless, when applied responsibly, insights from brain science can serve as a valuable tool to enhance teaching practices and improve learning outcomes across diverse educational contexts.

Neuroscience can be translated into practical teaching methods, with the aim of improving educational effectiveness and student engagement. It investigates the key cognitive and neural principles that support learning, evaluates current neuroeducational strategies, and proposes a scientifically informed model for pedagogy grounded in brain-based evidence.

Many educators continue to rely on traditional teaching methods—such as lectures, rote memorization, and passive note-taking—without fully considering how the brain learns most effectively. These approaches often focus on content delivery rather than engaging cognitive processes like attention, emotion, and memory consolidation. However, decades of research in neuroscience and cognitive psychology suggest that active engagement, spaced repetition, and emotional relevance significantly enhance learning outcomes. For example, studies by Craik and Tulving (1975) demonstrated that deeper levels of processing—such as semantic analysis and making meaningful connections—lead to better memory retention compared to shallow processing like rote memorization. Similarly, Medina (2008) highlights in Brain Rules that the brain prioritizes information that is emotionally charged or personally relevant, as emotional arousal increases the likelihood of long-term memory formation via activation of the amygdala and hippocampus. Additionally, Roediger and Karpicke (2006) found that students who engaged in retrieval practice, rather than just re-reading notes, retained significantly more information over time. These findings suggest that teaching strategies grounded in how the brain naturally processes and stores information—such as active recall, spaced practice, and emotionally meaningful content—are more effective than passive, traditional methods. Therefore, educators should shift toward evidence-based practices that align with the brain's learning mechanisms to improve educational outcomes. However, neuroscientific research shows that the brain learns best through active engagement, emotional connection, repetition

spaced over time, and multisensory input. Traditional methods often neglect these principles, which can reduce long-term retention and student motivation. [9] [10] [11]

Neuroeducation, also known as educational neuroscience, integrates insights from cognitive science, psychology, and education to develop more effective and scientifically grounded teaching strategies. By examining how the brain processes, stores, and retrieves information, neuroeducation seeks to align instructional methods with the brain's natural learning mechanisms. For instance, cognitive science contributes understanding about attention, memory, and executive functions; psychology offers frameworks for motivation, behavior, and emotional regulation; and education translates these findings into practical classroom applications. This fusion enables educators to design learning environments that are not only pedagogically sound but also neurologically informed, thereby enhancing both teaching effectiveness and student learning outcomes.

Neuroplasticity, the brain's ability to change and reorganize itself by forming new neural connections, plays a central role in how students learn, adapt, and grow. Contrary to earlier beliefs that the brain's structure becomes fixed after a certain age, modern neuroscience has shown that learning continuously shapes the brain throughout life. This concept has profound implications for education, as it suggests that intelligence and academic ability are not static traits but can be developed through effective teaching and practice. One landmark study by Draganski et al. (2004) used MRI scans to show that participants who learned to juggle experienced measurable increases in gray matter in areas of the brain related to visual and motor skills. Similarly, research by Carnegie Mellon University (2009) demonstrated that targeted reading interventions for struggling children led to significant changes in brain activity, particularly in regions associated with language processing. These findings reinforce the idea that with the right learning environment and strategies—such as repetition, feedback, and active engagement—students can "rewire" their brains to acquire new skills and overcome learning difficulties. In the classroom, this understanding empowers educators to foster a growth mindset, encouraging students to see challenges as opportunities for neural development rather than as fixed limitations. [12]

Active learning significantly enhances knowledge retention because it engages multiple cognitive and neural systems involved in processing, storing, and retrieving information. Unlike passive learning methods—such as listening to lectures or reading notes—active learning requires students to participate mentally and physically through tasks like discussion, problem-solving, teaching others, and applying concepts in real-world contexts. Neuroscience supports this approach: when students actively manipulate and interact with information, they engage more sensory, motor, and prefrontal brain regions, strengthening the neural pathways responsible for long-term memory. For example, Freeman et al. (2014) conducted a meta-analysis of 225 studies and found that students in active learning environments had significantly better exam performance and lower failure rates compared to those in traditional lecture-based settings. Another study by Prince (2004) showed that students retain more when they engage in collaborative learning, especially when they have to explain concepts to peers, which activates retrieval practice—a key mechanism in memory consolidation. Active learning also increases emotional and attentional engagement, both of which are crucial for encoding information into long-term memory. These findings highlight that when students are cognitively, emotionally, and socially involved in the learning process, retention and understanding improve substantially.[13] [14]

Understanding the limits of student attention is essential for designing effective and brain-friendly teaching methods. Cognitive neuroscience suggests that the average student can maintain focused attention for approximately 10 to 20 minutes before mental fatigue begins to reduce concentration and retention. This range can vary depending on age, task difficulty, emotional state, and individual differences. Research by Hartley and Davies (1978) found that attention typically peaks in the first 10–15 minutes of a lecture, after which engagement declines unless there is a change in activity or stimulus. More recent studies using EEG and fMRI have shown that sustained attention activates the prefrontal cortex, which requires periodic rest or stimulation to maintain performance. Without cognitive resets—such as brief pauses, interactive discussions, or movement breaks—students are more likely to experience attention drift, reducing the effectiveness of instruction. Techniques such as the "brain break" (a 2–5 minute break involving stretching, movement, or a short unrelated activity) help restore mental energy and re-engage the brain's attentional systems. These findings emphasize the importance of segmenting lessons, varying teaching methods, and incorporating short resets to optimize attention and learning outcomes.[15]

Two of the most evidence-based techniques for enhancing long-term memory are spaced repetition and retrieval practice, both of which are strongly supported by cognitive neuroscience. Spaced repetition involves reviewing information at increasing intervals over time, rather than cramming in a single session. This technique aligns with the spacing effect, a phenomenon first identified by Ebbinghaus (1885), which demonstrates that information is retained more effectively when learning is distributed over time. Neuroscientific research shows that repeated activation of memory traces over spaced intervals strengthens synaptic connections in the hippocampus and neocortex, making memories more durable and less susceptible to forgetting. Retrieval practice, on the other hand, requires learners to actively recall information without cues, which enhances memory consolidation and strengthens neural pathways. Roediger and Karpicke (2006) demonstrated that students who practiced retrieving information performed significantly better on later tests than those who simply reviewed the material repeatedly. These techniques not only improve factual recall but also foster deep learning, as retrieval strengthens the brain's ability to organize and apply knowledge flexibly. Incorporating spaced repetition and retrieval practice into classroom instruction can significantly improve students' long-term retention and academic performance. [16] [17]

Dopamine, a neurotransmitter commonly associated with pleasure and reward, plays a crucial role in learning by influencing motivation, attention, and goal-directed behavior. In educational settings, dopamine acts as a neural signal for reward prediction—it is released when students anticipate or receive something positive, such as praise, achievement, or a sense of mastery. This release reinforces behaviors and encourages repetition of actions that lead to desirable outcomes. Neuroscientific studies, such as those by Schultz et al. (1997), have shown that dopamine is not only triggered by rewards themselves but also by cues that predict rewards, making it central to the brain's reward-based learning system. When students are engaged, curious, and challenged at an optimal level, their brains are more likely to release dopamine, which enhances attention and the encoding of new information into memory. Classroom strategies such as gamified learning, immediate feedback, and achievable goal setting can stimulate the dopamine system, increasing both motivation and retention. Understanding dopamine's role helps educators design lessons that are not only informative but also inherently rewarding, activating the brain's natural learning circuits. [18]

On the other hand, stress and anxiety can have profound negative effects on learning by disrupting cognitive processes essential for attention, memory, and problem-solving. When a student experiences stress, the brain's amygdala, responsible for processing emotions, becomes highly active, often triggering a "fight or flight" response. This heightened emotional state can inhibit the functioning of the prefrontal cortex, the region responsible for executive functions such as planning, reasoning, and working memory (Arnsten, 2009). As a result, learners may find it difficult to concentrate, retrieve information, or engage in complex thinking tasks. Chronic stress can also impair the consolidation of long-term memories by affecting the hippocampus, a brain area vital for learning. However, research shows that implementing strategies such as mindfulness meditation, deep breathing exercises, and creating a psychologically safe and supportive classroom environment can reduce anxiety and mitigate these adverse effects. Moreover, social-emotional learning (SEL) programs that teach coping skills and emotional regulation have been linked to improved academic performance and well-being (Durlak et al., 2011). By addressing stress and anxiety proactively, educators can help optimize brain function and create conditions more conducive to effective learning.[19] [20]

One landmark study investigating the impact of stress on learning was conducted by Cahill, Prins, Weber, and McGaugh (1994), which explored how stress hormones affect memory consolidation. In their experiment, participants were shown emotionally charged and neutral pictures and were later tested on their recall of these images. The researchers found that emotional arousal—associated with the release of stress hormones like cortisol and norepinephrine—enhanced memory for emotionally significant stimuli but impaired memory for neutral information. This selective effect illustrates how stress can prioritize certain types of information in the brain's memory systems, potentially disrupting balanced learning.[21]

Further, research using functional MRI by Dedovic et al. (2009) demonstrated that acute stress impairs activity in the prefrontal cortex, leading to reduced working memory performance. Participants subjected to a stress-inducing task (like public speaking or mental arithmetic under pressure) showed decreased activation in brain areas responsible for executive function, confirming that stress compromises cognitive abilities crucial for learning.[22]

These studies highlight the neurobiological mechanisms through which stress and anxiety influence learning and underscore the importance of interventions aimed at stress reduction to support optimal cognitive function in educational settings.

In conclusion, neuroeducation represents a transformative approach to teaching and learning by aligning educational practices with evidence-based insights from neuroscience and psychology. This interdisciplinary field bridges the long-standing gap between brain research and classroom application, offering a scientifically grounded understanding of how students learn, remember, and engage. By incorporating findings on neuroplasticity, attention, working memory, emotional regulation, and motivation, neuroeducation empowers educators to design instruction that is not only more effective but also more inclusive and responsive to diverse learning needs. While traditional teaching methods have long relied on intuition and routine, they often neglect the brain's natural learning mechanisms. In contrast, neuroeducation provides a framework for moving beyond outdated models—like learning styles and rote memorization—toward dynamic, student-centered approaches informed by the workings of the brain.

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