NEUROTECHNOLOGIES AS AN ESSENTIAL COMPONENT OF EDUCATION

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Abstract. This study evaluates the impact of neurotechnologies on the educational process amidst emerging challenges in modern education driven by the integration of neuroscience into learning. Brain-based technologies offer significant potential to enhance educational efficiency and play a crucial role in personalizing learning to address pressing educational issues. The paper assesses both the opportunities and constraints of neurotechnologies in solving pedagogical challenges and examines their integration into diverse learning pathways. Modern neural network technologies can substantially improve the quality of the educational process by adapting it to the students' specific educational needs. Furthermore, the paper establishes the methodological foundations of neurodidactics by bridging natural sciences and humanities approaches. As an emerging interdisciplinary field combining neuroscience and pedagogy, neurodidactics focuses on uncovering the links between neural mechanisms and physiological processes, thereby facilitating the development of more effective instructional tools. Applying neuroscientific insights to practical teaching helps create a pedagogical environment tailored to the neurophysiological characteristics of learners. Despite these potential benefits, educators face several challenges when implementing neurotechnologies in education: limited accessibility for mainstream schools, the requirement for specialized expertise to ensure effective utilization, and the risk of reducing the personal meaning of learning actions due to over-reliance on technology. The core premise of this research is that neurotechnologies should be leveraged to cultivate optimal conditions for student self-actualization through the development of cross-disciplinary competencies.

Keywords: neurotechnologies, personalized learning, neural network technologies, neurodidactics, emerging educational technologies.

Introduction.

Modern individuals inhabit a world of neuro-reality: driven by neural network technologies, our lives are becoming increasingly diverse, inevitably presenting new challenges to the educational system that demand adequate responses. Today, various educational levels already incorporate technologies [20] based on brain research data, which promise remarkable outcomes. In alignment with the core logic of national educational initiatives, the primary objective is to cultivate opportunities for self-actualization, talent development, decent and effective labor, successful entrepreneurship, population preservation, and human health and well-being. A overarching trend among these targeted goals is the personalization of educational systems. Implementing this requires novel methods to capture the individual characteristics of educational process participants and subsequently organize instruction in accordance with these identified traits. This can be achieved through neurotechnologies, which possess the capacity to adaptively change to suit the learner—a feature of particular importance when working with children with special educational needs. Consequently, neurotechnologies can facilitate the construction of a personalized educational trajectory for every student.

Within the scientific community, a certain skepticism has emerged toward the numerous neologisms prefixed with "neuro-". To a large extent, this bias is driven by weak empirical evidence linking specific neural mechanisms to psychological processes. Nevertheless, one cannot ignore the scientific facts that bring us closer to understanding complex educational behavior. Regarding the adoption of emerging technologies in education, several distinct strategies can be observed: a leadership strategy, focused on identifying strengths and implementing them in practice; an integration strategy, aimed at discovering points of convergence with existing technologies and enhancing their capabilities with new tools; and a defensive strategy, centered on searching for the potential harms these new technologies might pose to the educational community. It is critical that educators resist professional inertia and avoid retreating into the defensive strategy, but rather actively discover opportunities within these emerging technologies to advance their professional practice.

Methods.

The contemporary educational landscape is witnessing the consolidation of a new paradigm of personalized learning [1]; [7]; [16]. Neurodidactics serves as the foundational framework for implementing this paradigm [9]. The concept of this emerging interdisciplinary field derives from two roots that reflect its methodological specificity, effectively bridging two distinct methodological strategies: the natural sciences and the humanities approaches.

The root "neuro" aligns the discipline with natural science inquiry, encompassing knowledge of the nervous system across various levels of organization. It drives the search for connections between pedagogical science and neurobiological processes, while enabling the application of neuroscientific methods to address core educational challenges related to personalized learning. Personalization, in this context, implies the personification of learners through the cultivation of cross-disciplinary competencies. When discussing personalization, we refer to the strategic structuring of individual educational trajectories within the instructional process. Personification, on the other hand, manifests in identifying the psychological and pedagogical capabilities of students, advancing their personal qualities, and fostering self-actualization.

One of the essential prerequisites for personal self-actualization in education is nurturing a sense of freedom and responsibility within learners. The pedagogy of free upbringing historically relied on the principles of both nature-conformity and culture-conformity. Today, numerous pedagogical methods and techniques can be substantially complemented and enhanced by insights derived from neuroscience.

For instance, by structuring instruction through play, an educator creates optimal conditions for activating a complex network of neural processes that heighten student engagement. Diverse gaming models can either amplify or diminish this effect depending on the degree of autonomy granted to the participants.

Reflecting on the mechanisms governing how the "program of freedom" unfolds within the human brain, I. P. Pavlov introduced the concept in his essay "The Reflex of Freedom" [14]. According to the scientist, learning can carry either a positive or a negative valence. If a student experiences constraints on their freedom, it elicits negative emotions, acting as negative reinforcement for the learning action. Conversely, when engaging in creative tasks, the student experiences a greater degree of autonomy due to the absence of rigidly defined procedural parameters; this generates a positive emotion against the backdrop of which academic performance can improve.

A foundational cornerstone for the evolution of neuropedagogy was laid by L. S. Vygotsky. In particular, he delineated the stages of interiorization (internalization) involved in the formation of voluntary action: "first: interpsychological—I command, you execute; then extrapsychological—I begin to speak to myself; then intrapsychological—the two points of the brain, which are excited from without, have a tendency to operate within a unified system and transform into an intracortical point" [6]. Thus, the emergence of a multicomponent structural and functional system is fundamentally driven by external social interaction. Another crucial regularity identified by Vygotsky is the principle of unity between the psychological and the physiological: "in the process of development... it is not so much the functions that change, as we used to study previously (which was our error), and not so much their structures... but rather it is the relations and connections between functions that change and modify; new groupings emerge that were unknown at the preceding stage" [6]. According to Vygotsky's cultural-historical framework, development is driven by the synergistic influence of society and an intrinsic property of the brain—neuroplasticity.

Furthermore, to fully grasp the expediency of incorporating neurotechnologies into education, it is essential to recognize the necessity of designing individual pathways for every student, rather than rushing to apply generalized typologies. First, one must truly know the learner: "If pedagogy wishes to educate a human being in all respects, it must first know them in all respects as well" [19]. Within this framework, the relationships between teacher and student, as well as between student and society, must fundamentally transform.

In his essay "We Live Because We Are Different," Yu. M. Lotman writes: "Human society is sustained by the differences between people, by the fact that no single person possesses even a fraction of the truth on their own, but all of us together constitute the path toward it. <...> We must learn to value the 'other' in another human being, and we must guarantee them this right—to be different" [11]. Embodying this mindset is a prerequisite for the personalized paradigm. For a teacher who merely strives to "fit" a student into averaged norms, there is no practical need to investigate children’s neuro-capabilities. Consequently, the traditional perception—focused solely on what is visible (observable) to the teacher—is being superseded by an awareness of the augmented reality within us. This shift inevitably alters pedagogical technologies.

Historically, the integration of technologies into education was driven by the need to objectify human action and minimize the subjective, personal component. While technology offers efficiency in solving specific tasks, it often does so at the cost of losing the personal meaning of the action. For this reason, the emergence of any novel technology triggers societal anxieties regarding the loss of "human" agency and its complete replacement by automation. However, technologies across different domains carry distinct purposes. In psycho-pedagogical technologies, the foundational purpose is to assist in overcoming educational difficulties. Curiously, the problem of learning difficulties has often come to be perceived merely as an inherent condition of the instructional process, supposedly requiring no new solution frameworks [18]. This stems from a conceptual conflation: confusing "difficulties as developmental milestones to be overcome" with "difficulties as partial deviations in the development of higher mental functions." Within the scope of this paper, we will address both interpretations while maintaining a clear distinction between them. Over the recent decades, insights from neurophysiology and neuropsychology have been utilized in education primarily to address the challenges faced by children with health impairments and special needs [2].

For neurotypical children, educators generally limited themselves to the insights of general psychology, paying attention to biological laws only within the context of implementing behaviorist theory. However, the nature of learning difficulties may stem not only from organic impairments but also from the individual characteristics of the child, which dynamically change throughout the instructional process. If an educator is well-informed about these characteristics, it becomes significantly easier and, more importantly, far more effective to structure the educational process. Consequently, contemporary pedagogy is adopting the concept of neurodidactics, which integrates advancements in neuroscience to refine and improve instructional technologies. Neurodidactics is thus emerging at the intersection of knowledge regarding the brain (its structure and function), behavior and mental processes, and learnability as a readiness for education.

Personification is operationalized through the deployment of neurotechnologies. Historically, experimental activities relied on invasive intervention technologies involving the implantation of an electrode (chip) to stimulate localized brain regions and enhance cognitive learning processes. Similarly, neurologists and psychiatrists supporting the educational process utilize pharmaceutical agents to correct aberrant forms of brain functioning. In the modern school environment, however, technologies that model non-contact interaction between learners and objects or processes within a virtual realm are being implemented—namely, immersive technologies [12].

These technologies make it possible to establish a feedback loop between the educational content and the psycho-emotional state of the student. Beyond augmented reality, neuropedagogy utilizes mind mapping technologies, gamification, and practice-oriented projects. These methodologies are specifically designed to activate the cognitive functions of the brain and the nervous system. Over the past five years, cognitive training platforms such as CogniFit and Wikium have expanded widely within education. These platforms focus on developing cognitive abilities through targeted exercises designed to train the brain's cognitive functions. This training becomes exceptionally effective when utilizing neuro-trainers equipped with a brain-computer interface (BCI)—a device that records the electrical activity of the brain (specifically alpha and beta rhythms). Concurrently, virtual excursions into various professional domains are also gaining widespread popularity.

The progression pathway is constructed by the learners themselves in alignment with their existential perceptions. These excursions are fundamentally educational, as they leverage neuro-devices to establish a zone of proximal development, thereby fostering the cultivation of universal learning actions. On one hand, neurobiological research demonstrates that educational material is best retained through sensory experience: the more extensive the educational practice, the more robust the internalization. Concurrently, schools and universities face structural constraints regarding practical, hands-on training. For instance, it is impossible to send students to complete an internship at a spaceport. However, utilizing a VR headset makes it feasible to learn how to fuel a rocket, repair an engine, and perform many other complex tasks. Furthermore, according to neuroscientists [8], effective instruction must account for the innate characteristics of the individual—such as their psychological profile—and teach in accordance with their interests and educational demands. This implies group discussions for some learners, and autonomous self-directed study for others.

Educators frequently highlight the operational difficulties of implementing individualized instruction in classrooms with more than thirty students. Nevertheless, the integration of neuro-tools enables the personalization of learning: tailor-making diverse assignments for specific pupils, establishing individualized grading criteria, or tracking progress without formal evaluation. One of the contributing factors to the decline in academic performance among modern schoolchildren is an educational system that is "unfriendly to the child's brain." The traditional paradigm relies exclusively on the non-selective perception, acquisition, and reproduction of information prescribed by the teacher. To construct a brain-friendly environment, a specialist is required who can bridge the gap and mediate interaction between the child, with their unique neurophysiological characteristics, and the educator, who shapes the learning environment. This specialist could be a school psychologist equipped with neuroscientific knowledge, or a dedicated neuropedagogue. The professional scope of a neuropedagogue encompasses several domains. First and foremost, they are distinguished by possessing both pedagogical expertise and a deep foundation in cognitive sciences, effectively acting as an intermediary for both schoolchildren and instructors by implementing best practices derived from cognitive research evidence.

In collaborative activities, the neuropedagogue helps coordinate the actions of students and educators in alignment with the neuropedagogical approach.

To assess current awareness, a survey was conducted among mainstream school educators, with 74 teachers participating. The majority of respondents (69%) merely had a superficial awareness of cognitive research, while 28.3% were informed about the achievements of cognitive science but did not know how to apply this knowledge in practice. Only two teachers (2.7%) knew how to translate scientific findings into pedagogical innovations and utilize them to improve instructional efficiency. Consequently, a neuropedagogue can act as a crucial intermediary between the advancements of neuroscience and educators addressing practical educational challenges.

Another defining characteristic of a neuropedagogue is transpotency (transpectivity) - the capacity to record the trajectory of realized expectations, mapping out the spaces where latent potential transforms into reality. Executing this documentation requires not only a proficiency in neurotechnologies but also the ability to establish a constructive dialogue with specialists who possess a broader array of diagnostic tools (such as neurophysiologists and neuropsychologists). Thus, an essential prerequisite for a neuropedagogue's effective performance is a state of open orientation: being open to the student's inner potential and to receiving reliable, evidence-based scientific information. Furthermore, it is critical that the outcome of the neuropedagogue's work - the individualized learning trajectory - remains transparent and accessible to both the student and the educators supporting the child.

Modern education is saturated with extraneous elements that disrupt immersion into the learning environment (most notably, digital gadgets). Therefore, one of the primary responsibilities of a neuropedagogue is the organization of immersive learning. To achieve this, an environment is modeled that allows students to fully engage in the learning process without distractions. The neuropedagogue mitigates these distracting factors and, utilizing the collected neuro-information about the student, selects appropriate stimulating visual modalities tailored to their needs.

Instructional efficiency is enhanced through greater student engagement. A neuropedagogue is fundamentally distinguished by several key competencies: a proficiency in technologies that ensure the actualization of higher mental functions for student self-development and self-actualization; the ability to organize the transpotivity of learning activities by designing an interactive educational trajectory; the capacity to navigate cognitive technologies to provide the visualization of models, signs, symbols, diagrams, and other instructional forms; a mastery of virtual reality technologies when implementing immersive learning; the mitigation of the destructive impacts of educational standardization by expanding the capabilities of neurodidactics; and the competent utilization of the learner's higher mental functions during the implementation of neuro-educational technologies.

Neuroethics, a branch of bioethics that has evolved over the past decade, investigates the potential consequences of applying neurocognitive insights within education. Researchers caution that the integration of neurotechnologies into education must not become a catalyst for widening educational inequality and social differentiation [5]. It is critical to avoid extremes. On one hand, to withstand stress in the modern world, it is absolutely necessary to account for the mechanisms of brain functioning. On the other hand, if the purpose of deploying neurotechnologies shifts toward "enhancing" human nature—for instance, through the use of neurotransmitters—we risk triggering a competitive biohacking race between pharmacologists and neurobiologists. In this regard, establishing a clear understanding of the boundaries of pedagogical intervention in collaboration with neurosciences remains paramount (Table 1).

Table 1. Levels and methods of intervention on human neurostructures

Problem-Solving Level in Neuroscience	Object of Intervention	Method of Intervention	Specialists Providing Assistance
Molecular	Mechanisms of signal transmission by neurons and axons, neuronal development; influence of hereditary mechanisms on acquired experience; influence of experience on neuronal functions and alterations in human behavior.	Neurostimulation, neurotransmitters	Neurophysiologist, pharmacologist, epigeneticist
Cellular	Physiological and electrochemical aspects of information processing and transmission by neurons and axons.	Neurostimulation	Neurophysiologist
Systemic	Anatomical and physiological foundations of reflexes, sensory integration, motor coordination, emotional responses, and cognitive abilities.	Neurorehabilitation, neuroprosthetics	Neurorehabilitator, neurophysiologist, psychologist
Cognitive	Interconnection between the nervous system and cognitive functions, the impact of experience on brain functioning and subsequent changes in human behavior.	Neuroimaging	Neurophysiologist, educational psychologist

There is no definitive concept of "good genes" that guarantee successful learning. Genes possess a conditional nature; their functionality is strictly determined by the external environment. Our observable academic achievements are driven by the intricate interplay between a combination of genes and the environment. Therefore, education must orient itself toward the insights of epigenetics - the science governing the mechanisms of gene expression. For individuals with health impairments and special needs, the pharmacological regulation of activity states stands as an essential prerequisite for learning.

Conversely, for neurotypical students, medicinal interventions can exert a destructive impact. Similarly, while neurosimulators can expand learning opportunities for individuals with health impairments, the proliferation of "neuro-centaurs"—which fuse human and machine intelligence - within mainstream education poses a significant risk of suppressing the natural functionality of a learner's healthy brain. One of the central contradictions of the neurotechnological trend is that the desire to maximize educational efficiency simultaneously drives a reduction in the influence of the human factor.

This stems from a striving for algorithmic rationality. We tend to favor technologies through which our own cognitive inertia (laziness) does not compromise performance. In doing so, we nullify proactivity and human agency in education. Yet, the more an individual relinquishes their agency, the less capable they become of learning effectively. Consequently, when integrating neurotechnologies, it remains vital to prioritize the student's readiness to assume personal responsibility.

Another distinct risk may manifest during the organization of an educational environment that is excessively calibrated by neurotechnologies. The experience of developing scientific thinking is inherently linked to spatial organization - namely, the ability to exert one's own will and be guided by it. Therefore, to avoid falling under the absolute dominance of technology, it is crucial to employ these tools strictly to serve one's own objectives. To optimize a learner's neurobiological status, one must align the child's surrounding environment with the brain's natural strategies and assist every student in discovering their unique pathway toward fulfillment. The contemporary school framework typically imposes a rigidly structured environment. In contrast, supplementary (non-formal) education features a less rigid structure, thereby fostering a genuine sense of personal autonomy. Under these conditions, it is vital to understand the available resources. When we make decisions autonomously, it inherently enhances our motivation. In this regard, the supplementary education system possesses a more personalized vector: it facilitates self-discovery and self-actualization by offering opportunities to identify an area of personal mastery and progressively expand it. This is largely because the environment of supplementary education adapts to and assimilates emerging trends much more rapidly.

Table 2. Opportunities for applying neuroscientific knowledge in education

	Discoveries and Achievements in Neuroscience	**Opportunities for Application: By Educators**	**By Parents**	**For Self-Education**
	Brain plasticity (neuroplasticity) and neurogenesis.	Prioritize teaching self-regulation before introducing core subject content.	Understand that it is always possible to initiate a successful academic and life career.	Cultivate the habit of viewing yourself as a lifelong learner.
	Mirror neurons.	Incorporate diverse collaborative and group work formats.	Demonstrate joy and optimism in the learning environment.	Work with an instructor individually to ensure deeper engagement.
	The brain is heterogeneous; it contains multiple regions that compete during decision-making.	Allow students to make mistakes and conduct detailed analyses of their underlying causes.	Refrain from reprimanding the child for daily domestic errors or misbehavior. In a calm setting, discuss how they actually intended to act.	Accumulate actions and emotional experiences that actively define you as an individual.
	Variation in brain electrical conductivity.	Implement alternative curricula and individual	When evaluating a child's achievements,	Segment and space out your learning

	Discoveries and Achievements in Neuroscience	Opportunities for Application: By Educators	By Parents	For Self-Education
		educational pathways.	avoid baseline external parameters; compare them strictly against their own progress.	process.
	Interconnection between emotions and cognitive processes.	Instruction must always integrate an element of novelty to shift the brain into a state of mindfulness (conscious awareness).	Shield the child from acute stressful situations during intensive learning periods.	Challenge yourself with tasks that are stimulating but not overly burdensome.
	Short-term memory efficiency depends on enhanced synaptic conductivity, whereas long-term memory requires structural changes in neurons.	Establish an effective cumulative grading system: consistent, evenly distributed learning physically transfers information into long-term memory by growing new neural connections.	Engagement yields better results if the parent acts as an active inquirer into the child's life rather than a supervisor over homework execution.	Segment and space out your learning process.
	The more brain structures are engaged during secondary learning, the more complex its application must be.	Implement cross-cutting, comprehensive reflective tasks.	Assist the child in integrating the studied material into the context of their daily life.	Leverage real-world life situations to deepen the comprehension of the subjects studied.
	Physical activity stimulates brain function.	Teach concentration techniques through structured physical defocusing (brain breaks).	Do not restrict the child's natural urge to move; help them identify their own rhythm and optimal physical load.	Incorporate daily physical exercises that elicit positive emotional valence.
	Quality sleep facilitates and enhances learnability.	Orient tasks toward the student's physical readiness for demanding morning instruction. Identify the optimal time of day for concentrated work and schedule the most complex tasks accordingly.	Establish necessary conditions for high-quality, restorative sleep hygiene.	Take frequent structured breaks and ensure sufficient sleep duration.

Knowledge of the mechanisms governing brain function substantially expands the capabilities of contemporary education [3], [4]. We have analyzed the discoveries and advancements in neuroscience from the perspective of their practical application by educators, parents, and learners (Table 2). The most widely discussed discovery in neuroscience is neuroplasticity—the brain's capacity to structurally and functionally reorganize itself throughout an individual's entire lifespan [21]. Furthermore, the long-standing myth that nerve cells cannot regenerate has been comprehensively debunked. New neurons and the synaptic connections between them are continually generated, provided they receive appropriate cognitive stimulation.

It is critical to recognize that these neural innovations emerge primarily in situations of mindful awareness. The mechanical, rote repetition of any action yields a remarkably low developmental effect. Consequently, it is imperative for educators to teach students how to formulate challenging yet attainable goals. Another vital implication, equally significant for both instructors and parents, is that past academic performance is not an absolute predictor of future success. It is never too late to begin studying more diligently through active effort and, in doing so, to upgrade and fortify new neural connections.

Mirror neurons represent specific cells that bridge the gap between "self" and "others" by internally simulating observed actions and emotional states. As Giacomo Rizzolatti demonstrated in his foundational research, "the mirror neuron system appears to be absolutely essential for the emergence of those forms of shared or co-experienced realities through which each of us is capable of acting not merely as an isolated individual, but as a member of society" [15]. It is upon the scaffolding of mirror neuron activity that complex intellectual mastery develops. Historically, both art and novel linguistic frameworks likely emerged driven by the fundamental need to anticipate the psychological states of others and inhabit a unified conceptual domain.

Pedagogs must strategically alternate between diverse instructional formats - namely, individual and collaborative work - since interaction with others activates the mirror neuron system, thereby cultivating social skills and empathy. Similarly, it is essential for parents to teach children how to express positive emotions. To achieve this, parents themselves must frequently demonstrate joy and optimism, thereby facilitating positive emotional contagion. Structurally, the brain is an immensely complex system wherein multiple anatomical regions compete during the decision-making process. For instance, the amygdala initiates the process by evaluating the potential drawbacks of a choice, while the nucleus accumbens aggregates the anticipated benefits. Upon accumulating sufficient evidence, each of these structures transmits its respective signals: the amygdala advocates for a negative (avoidance) decision, whereas the nucleus accumbens signals for acceptance. The frontal cortex then synthesizes these competing signals, weighs the alternatives, and executes the final decision based on the inputs received. Crucially, the frontal cortex also interrogates memory - drawing upon past decision-making experience - as well as the immediate context of the situation and the choices made by peers within the social environment. This specific decision-making mechanism explains the occurrence of optical illusions, which are fundamentally constructed upon the brain's prior experience of synthesizing visual images through the distribution of light and shadow. Resisting such illusions is possible either by temporarily "deactivating" the higher executive controlling regions of the brain or by supplementing one's experience with awareness of potential cognitive distortions (exceptions).

In everyday reality, this mechanism exerts an inhibitory effect on the execution of habitual actions. However, when navigating critical decision-making situations, one must learn to suppress this cognitive inertia. To ensure that students act consistently and logically, educators must teach them how to justify their decisions. Typically, we execute a decision first and only subsequently rationalize it. Therefore, during the initial phase of instruction, it is vital to allow students to make mistakes without fear, followed by a systematic analysis of these errors; this provides the cortex with the opportunity to access this corrective knowledge during future decision-making processes. Similarly, parents must allow their children to make mistakes. When analyzing a misstep, it is crucial for the parent to empathize with the action by drawing upon similar experiences from their own life. Under no circumstances should parents contrast their "ideal self" against a child who is merely accumulating life experience. It is essential to recognize that the decisions made are always a compromise among a multitude of constraints. One of these constraints is the behavioral model of the adult, which the child will internalize - provided that the educator and parent do not counterpose their own vision of the situation against the child's understanding.

A pivotal milestone in neurobiology was Eric Kandel's discovery regarding the alterations in brain electrical conductivity during the learning process [10]. This implies that individual differences in information perception are fundamentally driven by the neurobiological capacity to construct new synaptic connections. In this regard, the systemic striving toward uniform educational standards inherently blocks the development potential of individual students. If parents attempt to raise a child according to a rigid pedagogical framework oriented toward specific outcomes at a strict age baseline, their formulated expectations regarding learning outcomes will most likely not be achieved; if they are met, it is historically the exception rather than the rule.

In contemporary science, explaining the essence of stress and identifying methods for its management are determined by neurophysiological mechanisms of both a cognitive and emotional nature, which share bidirectional connections [13]. Consequently, one of the central tasks of neuropedagogy is to develop students' emotional regulation skills. It is crucial to teach students to consciously recognize and monitor their psycho-emotional state and, whenever possible, manage anxiety. Both parents and educators must understand that high stress levels severely impair learning capacity. Therefore, a supportive, favorable learning atmosphere stands as a prerequisite for a child’s productive performance. To enhance instructional efficiency, the teacher must also pay deliberate attention to curriculum content that is capable of eliciting diverse emotional responses from the student.

The enhancement of memory mechanisms is inherently linked to the consolidation of incoming information. It is only through repeated - and ideally, regular-activation of short-term memory that the chemical and physical processes within synapses alter, effectively transferring information into long-term memory. Minimal consolidation requires approximately one hour, whereas more robust retention demands up to a week. For an educator, this insight is valuable not as a justification for routine, rote repetition, but rather as a catalyst for reforming instructional organization toward prioritizing a cumulative grading system. For a parent, it is vital to become a supportive participant who can ask engaging questions, thereby stimulating the child's desire to recall previously learned material.

The human brain evolved over a protracted evolutionary process, enabling both primary and secondary learning [3], [4]. We are born with hereditary expectations of the world that align with our sensory structures responsible for perception (sound, color, scent), which allow us to construct an internal map of the surrounding environment. However, humans continuously enrich their environment, and through secondary learning - such as reading and writing - the child faces the task of integrating into social life. Nature alone cannot impart social skills; this achievement requires the systematic consolidation of multiple functional brain structures.

A prerequisite for secondary learning is a high degree of meaningfulness. Therefore, prior to initiating any developmental activity, the educator must establish conditions that heighten the conscious awareness (mindfulness) of every student. It is by no means a novel assertion that a child feels more comfortable in an environment where their physical activity is not constrained. Neurophysiologists note that bodily freedom directly determines the development of creative thought. Within an environment of free movement, students exhibit higher self-esteem and are less susceptible to anxiety. Furthermore, physical activity facilitates brain oxygenation, creating positive preconditions for efficient cognitive performance. If a child prefers to move while memorizing, they should be encouraged to do so. Operating within a personally comfortable mode allows the child to relax and internalize the material more effectively. Periods of intense concentration must alternate with strategic defocusing, which is actively supported by physical exertion.

Sleep exerts a profound physiological effect, not only in restoring the body's vital functions but also in shaping the neural systems involved in human learning. During daytime activity, beta-amyloid plaques accumulate within the brain, essentially acting as "waste" that disrupts cerebral functioning. It is vital to recognize that informational "clutter" physically transforms into molecular waste. These accumulated plaques are cleared away by the brain's glymphatic system. This process occurs most efficiently during sleep, when neurons and glial cells literally shrink in size, allowing the "waste removal" to proceed without obstruction. If students are assigned tasks on digital learning platforms, educators can monitor and regulate their execution times to prevent cognitive overload. For parents, it is crucial to establish high-quality sleep hygiene to facilitate the restoration and consolidation of newly acquired experiences.

For a child, it is not merely the duration of sleep (8–9 hours) that matters, but also its quality, which is determined by the conditions both preceding and during the sleep cycle. Students are inherently diverse. Some possess the capacity to independently discover or even design effective learning techniques for themselves. However, many require targeted guidance from educators and parents to transform their self-perception and cultivate a growth mindset. Ultimately, insights from neuroscience can serve as a powerful tool to help learners attain their desired achievements.

Conclusion.

Contemporary neuroscience is evolving into an indispensable domain of knowledge for education, serving as a foundational tool to personalize learning. A deep understanding of the mechanisms governing a student's brain function inherently elevates the educator's professional responsibility for the outcomes of their pedagogical practice. Most frequently, instructional errors committed by a teacher manifest visibly only after several years, and occasionally, after a decade. If an educator is fully conscious of the specific structural and functional changes occurring within the student's brain as a direct consequence of their pedagogical intervention, they will inevitably exercise greater care and stewardship over the learner.

Presently, the bridge connecting academic researchers and schoolteachers remains exceedingly fragile; they occasionally observe one another from a distance but rarely cross paths. To foster the systemic development of education, it is imperative to establish more efficient and robust collaborative mechanisms between teachers and scientists to facilitate the reciprocal exchange of evidence-based experiences. When educational institutions deliberately structure their activities around modern insights into brain capabilities, the school ceases to function merely as a passive transmitter of standardized knowledge. Instead, it transforms into an active learning laboratory where the brain dynamically interacts with diverse resources, extracting personal meanings from this engagement and synthesizing a profound understanding of the subject of study and research.

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