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The Science of Learning: Connecting Neuroscience and Education

Zorana Vasiljevic

Department of English Language and Literature, Bunkyo University, Japan

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ABSTRACT

This paper explores how contemporary neuroscience offers valuable insights to transform educational practice. Challenging persistent neuromyths that obscure evidence-based understanding, it reveals the brain's remarkable ability to adapt and reorganize through experience and instruction. Emphasising the brain's social nature, the discussion highlights how supportive, emotionally safe learning environments foster both cognitive and emotional development. Drawing on recent research, the paper also presents strategies such as retrieval practice and metaphorical thinking that enhance attention, memory, and self-regulation, while addressing common barriers like procrastination and illusions of competence. Finally, the critical roles of sleep, stress management, and physical activity in maintaining brain health and optimising learning outcomes are examined. By integrating these insights, the paper advocates for educational approaches grounded in neuroscience that promote deeper learning, learner autonomy, and overall well-being.

1. Introduction

While interest in the brain can be traced back to ancient Greek philosophers and physicians such as Hippocrates, neuroscience, an interdisciplinary field that integrates insights from neurology, psychology, and biology, emerged as a distinct scientific discipline in the mid-20th century. Since the early 1990s, brain imaging technologies such as fMRI, PET, and MRI have enabled real-time observation of brain activity, deepening understanding of the brain's structure and functions, including language, reasoning, and learning. These advances have made neuroscience a valuable resource for informing educational practice and child development.

Within this context, educational neuroscience has emerged as a subfield dedicated to investigating how learning occurs in the brain. The concept of "brain-based learning" reflects efforts to apply these findings directly to education, highlighting the crucial role of teachers in shaping neural pathways through the learning experiences they provide. As Hart (1999) notes, teaching without knowledge of the brain is like designing a glove without knowing the hand. Neuroscientific findings, combined with evidence from empirical research and classroom practice, provide a solid framework for addressing diverse learning needs across educational contexts.

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[*] Corresponding author's E-mail address: zorana@bunkyo.ac.jp

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The primary objective of this paper is to summarise key neuroscientific findings relevant to education and learning, with the aim of informing classroom practice, dispelling persistent neuromyths, and highlighting evidence-based strategies for improving learning, attention, memory, and self-regulation. The review integrates insights from neuroscience, cognitive psychology, and pedagogy to provide a conceptual framework grounded in research yet applicable to educational contexts. As a narrative review, its purpose is thematic synthesis rather than exhaustive coverage, with a focus on clarifying misconceptions and translating scientific knowledge into meaningful implications for teaching and learning.

2. Methodology

This paper employs a narrative review methodology to synthesise current research at the intersection of neuroscience and education. Narrative reviews allow for thematic integration and critical interpretation rather than exhaustive or statistically aggregated coverage, making them suitable for addressing conceptual issues such as neuromyths and pedagogical implications. Data were collected between November 2024 and July 2025. Searches were conducted in the following academic databases: Scopus, ERIC, PsycINFO, and Google Scholar. Search terms included *educational neuroscience, neuroplasticity, brain-based learning, neuromyths, memory consolidation* and *retrieval practice.* Reference lists of key articles were also manually examined to identify additional relevant sources. Inclusion criteria were: (a) peer-reviewed articles, books, or systematic reviews published between 2000 and 2025; (b) empirical or conceptual relevance to learning, memory, teaching practice, or brain function; and (c) English-language publications.

Practitioner-oriented sources were identified primarily through targeted searches of widely used professional literature (including Amazon searches for books on brain-based learning) and were included to illustrate how neuroscientific ideas are translated, simplified, or sometimes distorted in educational practice, rather than to provide primary evidence. Claims drawn from these sources were retained only when they aligned with findings from peer-reviewed research. Sources excluded were opinion pieces without empirical support and purely commercial "brain-training" literature. Overall, the methodology reflects the paper's aim to bridge research and practice while maintaining evidential integrity, offering educators an accessible yet critically grounded synthesis of contemporary findings on learning and the brain.

3. Literature Review

3.1. Neuroscience and Neuromyths

Advancements in image-based technologies have increased interest in the brain and its functions among scientists, educators, and the general public. The popularisation of neuroscience through the media and the internet has made its findings more accessible. However, incomplete reporting and the misinterpretation of scientific results, partly due to field-specific terminology, have also contributed to the spread of misconceptions, commonly referred to as *neuromyths*. The OECD defines a neuromyth as "a misconception generated by a misunderstanding, a misreading or a misquoting of facts scientifically established (by brain research) to make a case for the use of brain research in education and other contexts" (OECD, 2002, p. 111). Some neuromyths are widespread and persistent despite substantial evidence that disproves them. Common examples include the 'Age of Three' myth, the '10% Brain Use' myth, the 'Learning Styles' myth, and the 'All Gas and No Brakes' myth about adolescents. These examples will be briefly reviewed in the sections that follow.

3.1.1 The “Age of Three” Myth

The “Age of Three” myth claims that brain development is nearly complete by the age of three, prompting many parents and educators to prioritise early stimulation and purchase brain-enhancing toys. Early childhood is indeed a period of rapid synaptic growth and plasticity (Shonkoff & Phillips, 2000), and early life experiences are certainly important. They influence the development of brain structures in ways that have lasting effects on the ability to form attachments, regulate emotions, and develop a sense of self-esteem. These capacities are essential for building social connections, managing stress, and feeling a sense of personal value (Cozolino, 2013). However, neuroscience shows that brain development continues throughout life. Synaptic pruning and myelination extend into adolescence and adulthood (Giedd, 2004), and cognitive and emotional capacities evolve over decades (Goswami, 2004; Kuhl, 2010). Sensitive periods do exist, but they do not equate to irreversible developmental windows. The brain has sensitive periods, not critical periods. Misinterpretation of early plasticity has led to premature instruction in infancy and underinvestment in education for older children (OECD, 2002). Recognising the lifelong nature of brain development has practical implications for education, including the design of age-appropriate curricula, the timing of interventions, and the equitable distribution of resources across early childhood and later stages of learning.

3.1.2 The “10% Brain Use” Myth

The popular myth that humans use only a small percentage of their brains has sparked a flood of brain improvement products and services claiming to help individuals unlock hidden mental powers – to “unleash their Superbrain”. However, neuroscience evidence strongly refutes this claim. Brain imaging techniques such as fMRI and PET scans show that all parts of the brain are active at different times, depending on the task. Each brain region has specific functions, and damage to any part can impair crucial abilities (Hammond, 2012). Importantly, the brain also consumes a significant portion of the body's energy, even during sleep (CERI & OECD, 2007). Although the adult human brain accounts for only 2% of total body mass, it consumes approximately 20% of the body's daily glucose (Attwell & Laughlin, 2001). During early development, these energy demands are even higher, reaching about 50% in children and up to 60% in infants (Steiner, 2019). From an evolutionary perspective, it would be highly inefficient for such a metabolically expensive organ to remain largely unused. Rather than lying dormant, the brain uses sparse coding to maximise efficiency.

Despite overwhelming disconfirming evidence, the 10% brain use myth has proved remarkably persistent. In a large-scale study involving over 2,000 respondents in Brazil, Herculano-Houzel (2002) found that the myth was widely accepted—particularly among university students, 59% of whom gave incorrect responses. Similarly, Howard-Jones et al. (2009) examined beliefs about brain development and function among 158 graduate trainee teachers and found that one in three agreed with the claim, while only 6.3% explicitly rejected it.

The enduring popularity of this myth is concerning because it highlights a significant gap between scientific knowledge and public understanding. Such misconceptions not only distort how people view their cognitive abilities but also make students and educators more vulnerable to pseudoscientific claims and commercial brain-training products with little proven benefit.

3.1.3 Learning Styles Myth

Learning styles theory suggests that aligning instruction with a learner's preferred modality (visual, auditory, or kinaesthetic) enhances learning outcomes. The concept remains influential in educational theory and practice and continues to feature prominently in teacher training programmes. A review of twenty widely used introductory textbooks in education and educational psychology found that approximately 80% introduced the concept of learning styles, with around 25% recommending that instruction be adapted to match students' individual preferences (Wininger et al., 2019). Similarly, Howard-Jones et al. (2009) reported that 82% of teacher trainees believed that learning is improved when information is presented in a learner's preferred style. Among in-service teachers, endorsement was even higher: 93% in the UK and 96% in the Netherlands supported the idea (Dekker et al., 2012).

Yet literature reviews find no empirical support, noting vague definitions, weak study designs, and confusion between correlation and causation (Fallace, 2023; Hattie & O'Leary, 2025; Pashler et al., 2008). Neuroscience shows that the brain processes multisensory input more effectively than single-modality information (Rousseau, 2024). Because visual, semantic, sensory, motor, and emotional neural networks each have distinct memory systems, engaging multiple channels enhances storage and recall (Cozolino, 2013). Restricting learning to one modality can therefore hinder understanding.

The continued popularity of learning styles may stem from confusion with learning strategies, the growing emphasis on personalised education, and commercial interests. Rather than focusing on matching instruction to presumed learning styles, teachers are encouraged to promote evidence-based learning strategies, critical thinking, and learner autonomy, ensuring that classroom practice reflects scientific understanding of how learning truly occurs.

3.1.4 The "All Gas and No Brakes" Myth

Neuroscience has contributed valuable insights to the design of educational interventions for adolescents by elucidating the relationship between brain development, behaviour, and learning. The ongoing maturation of brain regions associated with self-regulation and social cognition has implications for addressing antisocial behaviour in school settings (Blakemore, 2012). Adolescent risk-taking, in particular, is frequently interpreted through the dual systems model, which posits a developmental imbalance between a highly active reward system and a still-developing prefrontal cortex. This mismatch is often described using the metaphor of having "all gas and no brakes" (White, 2005), reflecting increased impulsivity driven by early dopaminergic activity and insufficient cognitive control.

While this metaphor has intuitive appeal and may help educators interpret adolescent behaviour, it risks oversimplifying the complex relationship between brain function and behaviour. Moreover, such simplifications can give rise to ethical concerns, particularly regarding assumptions about free will, personal responsibility, and behavioural malleability in educational contexts (Payne, 2012). Neuroscience-based narratives, when presented without adequate context, may inadvertently lead teachers to adopt deterministic views that underestimate students' capacity for change and growth.

To mitigate these risks, it is essential that neuroscientific findings be communicated in ways that are both accessible and appropriately contextualised. This necessitates collaboration between neuroscientists and education professionals to ensure that messages are grounded in evidence yet sensitive to pedagogical realities (Howard-Jones, 2014).

In sum, neuromyths—despite often stemming from well-meaning efforts to enhance teaching—are not without consequence. Teachers' beliefs significantly shape classroom practices and can either facilitate or hinder student development. Integrating neuroscience into teacher education programmes can play a crucial role in equipping educators to critically evaluate scientific claims, recognise neuromyths, and make informed, ethical decisions that promote positive outcomes for all learners.

3.2. Wired to Connect, Built to Change

Brain-based learning requires an understanding of two fundamental characteristics of the brain: its capacity for change and its social nature.

3.2.1 Neuroplasticity

The brain, long viewed as fixed, is now understood as highly dynamic and capable of lifelong adaptation. Advances in neuroimaging techniques, such as functional magnetic resonance imaging (fMRI), have revealed that the brain is continuously shaped by experience—a property known as *neuroplasticity*. The term combines *neuro*, referring to the nervous system, and *plastic*, from the Greek *plastos*, meaning "mouldable." Human brains have evolved to be highly adaptable, enabling individuals to adjust effectively to ever-changing environments.

The brain contains around 86 to 100 billion neurons, each capable of forming between 1,000 and 10,000 synaptic connections with other neurons. These connections generate trillions of potential neural pathways that support learning, memory, and cognitive development (Central Queensland University, n.d.). At its core, the brain is designed to learn from experience, encode information, and apply that knowledge in meaningful ways. Every thought, action, and memory is processed through highly individualised and complex neural networks.

Neuroplasticity drives all normal brain development and supports learning from basic motor skills to advanced academic content. New behaviours, experiences, and environmental demands continuously reshape the brain’s architecture, either strengthening or weakening neural pathways based on use. While much of this adaptation involves modifying existing synaptic connections, structural changes can also occur. For example, on average, 700–1,000 new brain cells are generated each day in the adult hippocampus (Spalding et al., 2013). When even a single presynaptic neuron among billions releases a neurotransmitter that binds to and activates receptors on a postsynaptic neuron, a synaptic connection is strengthened. With repeated activation through practice or exposure, this pathway becomes increasingly efficient, illustrating the well-established neuroscientific principle: “Neurons that fire together, wire together.” Conversely, pathways that are rarely activated weaken over time, reinforcing the principle of “use it or lose it.”

While much of this adaptation is beneficial, it is important to recognise that not all forms of neuroplastic change are advantageous. The *plastic paradox* refers to the brain’s capacity to adapt not only to productive behaviours but also to maladaptive ones with equal rigidity. Negative neuroplasticity can result from factors such as social isolation, physical inactivity, poor nutrition, inadequate sleep, and substance abuse. These conditions can reinforce detrimental neural patterns that impair cognitive and emotional functioning. However, such patterns are not necessarily permanent. Through the adoption of healthier behaviours, these maladaptive networks can be reshaped. One mechanism that supports this change is neurotransmitter switching, whereby certain neurons alter the type of neurotransmitter they release in response to new experiences. This process enables the replacement of unhelpful habits with more adaptive ones, reinforcing the idea that neuroplasticity allows the brain’s structure and function to be modified in response to behavioural and environmental changes.

The recognition of the brain’s malleability carries important implications for education. It challenges deterministic views of intelligence and provides a more hopeful framework for both educators and learners. Many students internalise beliefs that they are inherently “not smart enough" or "not talented," which can discourage persistence and risk-taking in learning. Psychological interventions that promote a growth mindset—emphasising the brain's ability to change—can help counter these limiting beliefs. When students understand that intellectual abilities can be developed through effort, the use of effective strategies, and seeking support, they are more likely to engage actively in learning (Oakley & Sejnowski, n.d.).

Empirical research supports the efficacy of such interventions. In a large-scale study led by Yeager et al. (2019), high school students participated in a 50-minute online course designed to promote a growth mindset. The results were notable: students' grade point averages (GPA) increased by an average of 0.10 points, and the proportion of students earning D or F grades dropped by more than 5% compared to a control group. The intervention also led to increased enrolment in higher-level mathematics courses. Gains were particularly significant among lower-achieving students, who benefited most from the encouragement to embrace academic challenges.

Neuroplasticity is thus a foundational concept for educators, as it affirms that learning experiences directly influence the physical structure and functional organisation of the brain. As an experience-dependent organ, the brain is shaped by environmental input, meaning that educators play a crucial role in students' cognitive and emotional development (Burns, 2019). While the mechanisms of neuroplasticity are biologically grounded, their translation into educational practice necessarily involves interpretation and adaptation within pedagogical contexts. Each learning experience—whether positive or negative—modifies neural circuits in ways that can either enhance or hinder future learning. Doidge (2010) argues that educators can act as "neuroplasticians," deliberately designing learning environments that promote healthy, adaptive brain development. Through informed, intentional pedagogy, teachers can foster robust neural networks that support both academic achievement and emotional well-being, while also helping to counteract the effects of negative cognitive or environmental predispositions. In this view, education is not merely the transmission of knowledge but an active, biologically consequential process that shapes the minds and lives of learners.

3.2.2 The Brain as a Social Organ

The second important point to consider is that the human brain has evolved as a fundamentally social organ. The need to relate to others and to be understood lies at the core of human experience. Our mental and emotional environment—comprising social relationships, conversations, cultural norms, and emotional bonds—shapes how the brain functions, develops, and survives. The brain requires stimulation and connection to thrive; without interaction with other brains, it eventually shrinks and deteriorates (Cozolino, 2013).

Empirical work provides evidence for the overlap between social and physical pain. In a study by DeWall et al. (2010), participants who experienced social exclusion reported reduced distress after taking acetaminophen. Neuroimaging data showed that acetaminophen reduced neural responses to distress caused by social rejection in brain regions associated with the affective component of physical pain, suggesting shared neural mechanisms underlying social and physical pain.

Matthew Lieberman, a neuroscientist and professor of psychology at the University of California, Los Angeles and one of the leading figures in social neuroscience, makes a similar point in his book *Social: Why Our Brains Are Wired to Connect.* He argues that social pain, such as rejection, activates the same brain regions as physical pain, demonstrating that the connection is more than metaphorical. In one of his studies, participants who were excluded from a virtual game displayed brain activity patterns resembling those caused by physical pain.

They reported feeling better after taking Tylenol, a physical painkiller, highlighting the effect of social pain on the brain (Lieberman, 2013).

Lieberman also challenges Maslow's traditional hierarchy of needs, suggesting that social connection is even more essential to human survival than basic needs such as food or shelter. From infancy, survival depends on the emotional connection others have to us, and our brains have evolved to prioritise social thinking. Lieberman explains that we possess a dedicated brain system for understanding others, which activates automatically when we are not focused on a task, indicating the centrality of social cognition in our daily lives. He concludes that cultivating social intuition can help unlock our full potential, and that "social superpowers," such as empathy and cooperation, can make us more intelligent, happier, and more productive (Lieberman, 2013).

In educational settings, fostering students' trust and confidence can increase serotonin levels in the brain, a neurotransmitter that plays a key role in modulating neuroplasticity (Burns, 2019). It is therefore essential that teachers create and maintain a positive classroom environment. This involves using interpersonal skills, creative methods, and engaging personalities to build enriched learning contexts through multisensory activities that support brain development and plasticity.

3.3. Brain-based Teaching

Brain-based teaching draws on neuroplasticity and recognises the brain as both a social and physical organ.

3.3.1 The Neuroscience of Learning and Memory

As discussed earlier, all learning experiences shape the brain's structure by altering the strength and organisation of neural connections. For learning to be effective, three cognitive processes must occur: attention, encoding, and retrieval. Attention, which is the selective focus of cognitive resources on relevant stimuli, enables the intake of new information. Encoding involves integrating new material with prior knowledge to support meaningful understanding and long-term storage. Retrieval refers to accessing stored information from long-term memory and bringing it into working memory for active use.

Memory is not a fixed entity or a single location in the brain but a complex, dynamic process emerging from the coordinated activity of multiple brain systems. Rather than functioning like a filing cabinet, memory operates through the reconstruction of past experiences, reactivating sensory, emotional, and conceptual elements distributed across different brain regions. Memory consolidation, which is the process of stabilising and strengthening learned information, depends on persistent, effortful engagement. Through consistent practice, synaptic connections are reinforced, supporting long-term retention and flexible application.

One of the most effective strategies for enhancing memory is active recall, which involves deliberately retrieving information rather than passively reviewing it. Research consistently shows that learners who engage in retrieval practice are more likely to retain and apply knowledge effectively (Central Queensland University, n.d.). Frequent retrieval strengthens memory traces, making future recall more efficient. Techniques such as quizzes, flashcards, and self-testing exercises facilitate this process. However, retrieval tasks should go beyond simple factual recall and promote higher-order thinking, encouraging students to apply, connect, and extend their knowledge in meaningful ways (Coe, 2018).

This emphasis on active, effortful learning aligns with Cozolino's (2013) argument that the human brain evolved to learn through trial-and-error exploration rather than passive absorption typical of industrial-style education. Cognitive research similarly shows that active engagement, including retrieval practice, fosters deeper understanding and more durable learning. To support this, Jensen and McConchie (2020) recommend brain-based lesson design that incorporates novelty, variety, and multisensory input. The brain responds strongly to dynamic and engaging stimuli, and when instruction is delivered in creative and enjoyable ways, students demonstrate greater motivation, engagement, and retention.

In addition to retrieval and engagement, the presentation and structure of information are critical for supporting learning. Educators must carefully consider the amount, order, and emphasis of information presented. Once established, techniques such as repetition, rehearsal, and guided practice reinforce encoding and long-term retention. The primacy–recency effect (Sousa, 2016) demonstrates that students are more likely to remember content presented at the beginning (primacy) and end (recency) of a session, while information in the middle is less well retained.

In sum, effective learning is a biologically grounded, highly individualised process that depends on attention, encoding, and retrieval. By designing instruction that reflects principles of brain functioning and memory formation, educators can foster inclusive, engaging, and enduring learning experiences, optimising both cognitive development and classroom outcomes.

3.3.2 Teaching Students How to Learn

Supporting students in becoming effective, independent learners requires more than the transmission of subject knowledge. It also involves explicit instruction in how to study, think critically, overcome challenges, and organise complex information. Many students continue to rely on familiar but ineffective approaches, such as rereading, highlighting, and last-minute cramming. Although rereading may increase familiarity with material, it does not reliably enhance long-term retention, and the fluency it generates is frequently mistaken for learning (Yang, Razo, & Persky, 2019). Similarly, highlighting is only beneficial when paired with active engagement and elaboration (Dunlosky, 2013).

In contrast, strategies that actively engage memory, attention, and metacognition demonstrate consistent learning benefits. Dunlosky (2013) identified practice testing, distributed practice, and interleaved practice as particularly effective. Practice testing strengthens memory because it requires learners to retrieve information rather than simply re-encounter it. Retrieval-based learning is effective even when the practice format differs from the final assessment (Yang, Razo, & Persky, 2019). When spaced over time and paired with timely, specific feedback, quizzes and low-stakes assessments enhance both content retention and metacognitive awareness (Agarwal, Bain, & Chamberlain, 2012). To maximise benefit, practice questions should extend beyond factual recall and require application, synthesis, and evaluation (Coe, 2018). Asking learners to explain why incorrect responses are wrong further reinforces conceptual understanding.

These strategies can be implemented through a range of formats, including in-class quizzes, self-testing at home, or student-generated questions. Encouraging students to prepare questions for each textbook section, for example, both deepens processing and provides materials for future revision. Distributed practice, in which learning is spaced over time, reduces forgetting and supports consolidation. Interleaved practice, which alternates between topics or types of problems within a study session, prompts learners to discriminate between concepts and select appropriate strategies. Although these approaches may feel more effortful than blocked or massed practice, they lead to superior long-term performance and more flexible knowledge use (Dunlosky, 2013; Yang, Razo, & Persky, 2019).

Ultimately, teaching students how to learn means equipping them to monitor their understanding, select and apply effective strategies, and persist through difficulty. By developing these evidence-based learning habits, students acquire skills that support success across subjects and extend well beyond formal education.

3.3.3 Supporting Deeper Understanding through Metaphors

In addition to employing effective study methods, learners benefit from strategies that make abstract or complex ideas more meaningful. Metaphors are among the most powerful tools for achieving this. By connecting unfamiliar concepts to familiar ones, they activate existing neural networks and facilitate initial comprehension. For example, comparing an electrical wave to an ocean wave can help learners visualise the invisible movement of energy. This reflects what neuroscientists refer to as *neural reuse*, a process in which prior knowledge is repurposed to make sense of new material, and it shows how insights from neuroscience can inform educational practice.

Although metaphors are simplifications, they provide valuable support in the early stages of learning. Using multiple metaphors to explain the same idea can further deepen understanding by presenting it from different perspectives. Even unconventional or humorous metaphors can enhance recall and make complex material more engaging. When used intentionally, metaphors reflect how the brain builds new knowledge on the foundation of existing networks, helping bridge the gap between knowing and understanding and making abstract concepts more accessible to learners. Ultimately, their power lies in transforming information into something that feels familiar and meaningful, enabling learners to construct deeper and more lasting understanding.

3.3.4 Thinking in Two Modes: Focused and Diffuse Thinking

Understanding and problem solving depend not only on effective study methods but also on how the brain processes information. Oakley and Sejnowski (n.d.), in their *Learning How to Learn* course, explain that learners use two complementary modes of thinking: focused and diffuse.

Focused thinking is structured, deliberate, and logical. It involves sustained attention and relies on well-established neural pathways, making it particularly effective for tasks that require step-by-step reasoning and detailed analysis. Diffuse thinking, by contrast, is more relaxed, subconscious, and associative. It takes place when the mind is not actively concentrating — for example, during a walk, a shower, or moments of daydreaming — and enables the formation of new and sometimes unexpected connections.

Effective learning emerges from the interaction between these two modes. A student might engage focused thinking to work through a challenging concept and then step away, allowing diffuse thinking to reorganise information and reveal new insights. Historical figures such as Salvador Dalí and Thomas Edison reportedly used this alternation deliberately, shifting between concentrated effort and mental rest to stimulate creativity.

Together, focused and diffuse thinking reflect the brain's dual approach to learning: one that builds precision and structure, and another that fosters flexibility and innovation. Recognising and intentionally engaging both modes can help learners deepen understanding, solve problems more effectively, and approach learning as a dynamic process rather than a purely linear one. For teachers, this means designing learning experiences that alternate between periods of intense, structured practice and opportunities for reflection or mental rest. Incorporating brief pauses, varied tasks, or activities that encourage students to step away from concentrated effort can support this balance and lead to more meaningful and creative learning outcomes.

3.3.5 Overcoming Procrastination

Even with strong strategies and mental models, many learners struggle with procrastination, a common and self-defeating habit. Procrastination offers temporary emotional relief but leads to long-term academic and psychological costs. Research estimates that 20 to 25% of adults and up to 50% of students are chronic procrastinators (Ferrari & Díaz-Morales, 2014; McLean Hospital, 2024).

The roots of procrastination vary. Some learners avoid tasks due to anxiety or perfectionism; others struggle with executive function issues linked to ADHD or depression. Procrastination activates the brain's insula, which processes emotional discomfort, making avoidance feel immediately rewarding. Over time, chronic procrastination has been linked to higher stress, poor mental health, and delayed decision-making in everyday life (McLean Hospital, 2024; Sirois, 2007).

The key to overcoming procrastination is simply getting started. Breaking tasks into manageable chunks and using time-management techniques can help reduce cognitive load. Procrastination is often triggered by focusing on the final product, such as a completed assignment or test result, which can elicit discomfort, anxiety or avoidance. Therefore, shifting attention to the process of learning can reduce these negative emotions and support sustained effort. A process-oriented approach involves establishing regular habits and allocating short, focused periods of time to work without fixating on immediate completion. One effective method is the *Pomodoro® Technique*, which involves working with full focus for 25 minutes (focused thinking), followed by a 5 to 10-minute break (diffuse thinking). This cycle supports motivation, prevents mental fatigue, and helps learners build momentum through small wins, supporting long-term engagement.

In conclusion, teaching students how to learn is just as important as teaching them what to learn. By replacing passive study habits with evidence-based strategies like retrieval practice, distributed learning, and interleaving, learners can build lasting understanding. Metaphors can help bridge the abstract and the familiar, while the ability to shift between focused and diffuse thinking promotes both clarity and creativity. Equally important is learning to manage procrastination and adopt practical techniques that support motivation and follow-through. When learners understand how their minds work and how to use that knowledge strategically, they become more confident, autonomous, and resilient in the face of academic challenges.

3.3.6 The Memory Paradox: Why Our Brains Need Knowledge in an Age of AI

This section examines why internalised knowledge remains essential in modern learning, even in an age of AI and abundant external information. It first explains how memory works, then discusses how cognitive offloading can undermine learning, and finally considers the implications for education and effective use of technology.

Drawing on research from neuroscience and cognitive psychology, Oakley et al. (2025) explore the role of memory in learning. Memory is not merely a passive storage system for information; it is an active cognitive architecture with two subsystems: declarative memory, which stores explicit facts, concepts, and personal experiences, and procedural memory, which supports skills and habits. Declarative knowledge is consciously accessible and flexible, allowing a person to apply facts in different situations and combine information in new ways—skills essential for complex reasoning and problem-solving. Procedural memory, in contrast, encodes routines and sequences that are accessed automatically and intuitively. Deep learning involves the transition of knowledge from the declarative system to the procedural system. Repeated retrieval, deliberate practice, and reflection strengthen neural connections and help form schemata—mental frameworks essential for interpreting new information and demonstrating expertise.

Oakley et al. (2025) argue that growing reliance on cognitive offloading tools and the devaluation of memorisation have undermined reasoning, learning, and problem-solving capacities. Schemata form through repeated encounters with related information and the integration of new material into existing knowledge. Over-dependence on external devices, such as computers, the internet, and AI, disrupts the brain's natural neural tagging processes, which are critical for memory consolidation. Simply knowing where to locate information is not the same as internalising it. Googling cannot replace remembering. The ability to recall the location of information may create the illusion of knowledge, while the underlying cognitive schema remains weak (Skulmowski, 2023). As Oakley and Sejnowski (n.d.) emphasise, one common illusion of competence occurs when learners glance at a solution and assume they understand it. Without actively working through the problem themselves, students fail to "knit those concepts into their own underlying neural circuitry." True mastery requires information to persist in long-term memory. Offloading often leads to shallow engagement, resulting in superficial encoding. Weak or unconsolidated memories cannot support higher-order thinking or problem solving.

This cognitive limitation is linked to one of the brain's core learning mechanisms: prediction error—the difference between expected and actual outcomes. When expectations are violated, the brain increases attention and updates its internal models. However, if schemata are weak and declarative knowledge is limited, learners cannot generate meaningful predictions. In such cases, errors and knowledge gaps go unnoticed because there are no internal benchmarks for evaluation. True expertise, Oakley et al. (2025) argue, arises not from external lookups but from internal cognitive structures developed through sustained mental effort.

Oakley et al. (2025) also critique contemporary "student-centred" educational approaches, which prioritise discovery learning over explicit instruction. Mid-20th-century education emphasised repetition, drills, and testing, later criticised as "drill and kill" and replaced by constructivist, learner-centred pedagogies. Memorisation was marginalised, while abstract skills such as analysing, evaluating, and synthesising were emphasised. In teacher training, instructors are often encouraged to be "guides on the side" rather than "sages on the stage." Oakley and colleagues argue that structured, explicit instruction and guided practice are essential for academic progress. Traditional "talk and chalk" methods support the development of declarative knowledge, and repeated practice strengthens neural networks, enabling robust schemata and deep conceptual understanding. They describe the widespread rejection of these techniques as a form of "pathological altruism"—well-intentioned ideas that backfire (Oakley et al., 2025, p. 30). Factual knowledge is indispensable for critical thinking, information evaluation, and acquiring new learning. When knowledge is not internalised, cognitive load increases, as learners spend time searching for information instead of retrieving it from memory, which slows task performance.

This leads to a central paradox of 21st-century learning: "in an age saturated with external information, genuine insight still depends on robust internal knowledge" (Oakley et al., 2025, p. 4). The human mind remains the foundation for the critical and effective use of technology. Oakley and her collaborators do not advocate eliminating digital tools or returning to passive, teacher-centred classrooms. Rather, they caution against cognitive laziness and emphasise the value of exercising memory and attention. Technology should enhance, not replace, human cognition. Memorisation plays a crucial role in storing information in long-term memory, and effective learning requires balancing the use of external tools with the development of deep internalised knowledge. Strong foundational knowledge is essential for using advanced technologies like AI critically and effectively. In practice, successful 21st-century learning depends on integrating human cognition with technology while maintaining a thoughtful balance between explicit instruction and exploratory learning, responsive to the learner's needs, context, and developmental stage.

3.4. A Healthy Brain, a Happy Brain

The mind, brain, and body function as an interconnected system. This section explores three key factors that contribute to brain health and cognitive functioning: stress regulation, physical activity, and sleep. Understanding how these elements interact with the brain can help improve learning outcomes and overall well-being.

3.4.1 Regulating Stress

Stress is the brain's natural evolutionary reaction. The fight, flight, and fright responses are automatic biological reactions activated when the body perceives a threat or danger (Vogel & Schwabe, 2016). This acute stress response is regulated by the autonomic nervous system, particularly the sympathetic nervous system. During threatening situations, the limbic system, especially the amygdala, overrides higher-order cognitive processes. This response redirects the body's energy to essential systems such as the cardiovascular, respiratory, and muscular systems to increase the chances of survival (Nagel & Scholes, 2016).

While essential for survival, stress in classrooms can disrupt learning circuits and neurotransmitter function. Overactivation of the amygdala blocks new sensory information from reaching memory and association circuits, making students unreceptive to new material (Jensen & McConchie, 2020). Stressful situations also cause the release of cortisol, a hormone that disrupts neural development. Prolonged stress can impair learning and negatively impact physical health (Cozolino, 2013). Chronic stress is associated with structural changes in the brain, including reduced dendritic branching and impaired neurogenesis (McEwen, 2017).

The cumulative pressures of exams, deadlines, and tightly synchronised curricula contribute significantly to students' anxiety. As a result, stress, boredom, and alienation have become common emotional states in classrooms worldwide. However, curriculum goals can still be met through lessons that are both stimulating and challenging without being intimidating.

Students' affective states play a critical role in how information is transmitted and stored in the brain. Although stress experienced shortly before or after the presentation of new information can enhance memory encoding and consolidation, stress occurring before memory retrieval often impairs recall, negatively affecting exam performance (Vogel & Schwabe, 2016). The retrieval of factual information depends on the functioning of the prefrontal cortex; however, exposure to stress activates the amygdala, which in turn suppresses prefrontal cortex activity, impairing the ability to recall facts. Stress also interferes with memory updating—the integration of new information into existing knowledge structures—thus influencing not only how much is learned (memory quantity) but also the nature and quality of what is encoded.

Importantly, stress affects not only students but also teachers. For teachers, appraising classroom events as stressful may lead to the formation of strong negative memories, potentially influencing professional attitudes and mental well-being. Stress may reduce flexibility and limit the ability to adapt to students' individual needs. In turn, this may lead to reliance on habitual and repetitive teaching practices, which can exacerbate classroom challenges.

Given the significant impact of stress on teaching and learning, Vogel and Schwabe (2016) emphasise the importance of educating both teachers and students about how stress affects memory and learning. They also advocate training in effective stress-coping strategies. Teachers should strive to create a supportive and emotionally safe learning environment. Motivating and engaging lessons can serve as a protective buffer against stress and have been shown to positively affect brain function. Such instruction can enhance brain metabolism, facilitate the transmission of electrical impulses in memory-related regions, and promote the release of neurotransmitters associated with executive functions, including planning, decision-making, self-regulation, and cognitive flexibility. These processes also contribute to sustained attention. Thus, effective teaching involves not only the transmission of knowledge but also the provision of emotional support. By fostering a positive classroom climate and reducing stress, teachers can help students build emotional resilience and improve learning outcomes (Jensen & McConchie, 2020).

3.4.2 Physical Activity

The health benefits of regular exercise are well recognised. Regular exercise boosts the immune system (Bermon et al., 2015) and helps prevent heart disease, cancer, diabetes, and dementia (Grazioli et al., 2017). Less well known is that physical activity also plays an important role in supporting and enhancing brain function. Research suggests that exercise can support both short-term cognitive performance and longer-term cognitive health. One of its most significant effects is on the hippocampus, a region critical for learning and memory. Exercise stimulates the formation of new neurons (neurogenesis) in the hippocampus and helps ensure their survival, thereby supporting memory consolidation and recall (Hueston, Cryan, & Nolan, 2017). It also increases cerebral blood flow, promoting capillary growth and supporting neural plasticity, with effects observed in several brain regions, including the frontal lobes, which are associated with planning, decision-making, and higher-order cognitive processes (Cozolino, 2013).

In addition to these structural effects, exercise has been associated with functional outcomes such as creativity and problem-solving. Many report gaining new insights and ideas while engaging in activities such as jogging, a phenomenon often attributed to shifts from focused to more diffuse modes of thinking, which may facilitate the emergence of novel associations (Oakley & Sejnowski, n.d.). Sejnowski even argues that exercise is more effective than any available pharmaceutical intervention for enhancing learning. Supporting the educational relevance of physical activity, Ratey and Hagerman (2008) describe a school-based intervention in which students participated in physical education classes scheduled before academically demanding subjects. As a result, their academic performance improved dramatically, placing the entire school in the top tier. Burns et al. (2016) examined the effect of a comprehensive school physical activity programme on classroom behaviour in low-income children. After six weeks of regular physical activity, the probability of a class reaching 80% on-task behaviour increased markedly, with further gains observed after twelve weeks. Improvements were reported across multiple grade levels. Additional studies have reported positive associations between physical activity and student attendance (D'Agostino et al., 2018; Michael et al., 2015).

The benefits of physical activity therefore extend beyond momentary cognitive activation to broader patterns of engagement, behaviour, and cognitive support that may contribute to long-term academic development. In this context, the growing trend of reducing physical education in schools to make room for additional instructional time raises concerns about potential unintended consequences for students' cognitive and educational development.

3.4.3 Sleep

Sleep is a regular, rhythmic activity regulated by both circadian rhythms in the brain and body as well as a homeostatic system of chemicals crucial for stable and balanced physiological functioning. While the precise relationship between these two systems remains a subject of ongoing research, current evidence suggests that the homeostatic system exerts greater influence over circadian rhythms than the reverse (Collins, 2023).

Sleep plays a critical role in maintaining physical and cognitive health. Research suggests that simply being awake leads to the accumulation of metabolic waste products in the brain. The brain removes these toxins primarily during sleep, when brain cells shrink and the space between them increases, facilitating the flow of cerebrospinal fluid that clears waste from neural tissue (Oakley & Sejnowski, n.d.). This cleansing function underscores the importance of sleep as a biological mechanism for preserving neural function and overall brain health.

Sleep also plays a vital role in the consolidation of memories and the support of learning processes. During sleep, particularly during slow-wave sleep (SWS), the hippocampus replays memory activity patterns, facilitating the gradual transfer of memories to distributed cortical networks. Systems consolidation may span days, months, or even years, depending on the memory system involved and the nature of the task (Dudai, Karni, & Born, 2015). When new information is acquired, small protrusions known as dendritic spines begin to form on neurons. These spines establish synaptic connections with other neurons but do not fully develop until sleep occurs. During sleep, the brain reactivates neural activity patterns from the preceding day, strengthening these emerging connections. This "night-time practice" enables dendritic spines to grow larger and synapses to become stronger, thereby enhancing the efficiency of neural pathways. Regular sleep is therefore essential for the stabilisation and retention of new learning.

Although considerable research has examined the effects of total sleep deprivation, partial sleep deprivation—which affects a significantly larger portion of the population—has received comparatively less attention. While individual sleep needs vary, research indicates that most people require approximately 7.5 to 8 hours of sleep per night (Collins, 2023). Sleep deprivation reduces physical and mental energy, attention, motivation, access to previously learned information, decision-making abilities, cognitive flexibility, and problem-solving skills (Collins, 2023; Walker, 2017). Prolonged sleep deprivation has been associated with a range of serious health consequences, including irreversible brain damage, headaches, depression, cardiovascular disease, diabetes, dementia, Alzheimer's disease, and an increased risk of mortality (Walker, 2017).

To support more effective learning, changes are needed at both the organisational and individual levels. Modern cultural norms, especially within education and the workplace, tend to favour early risers. However, neuroscientific findings indicate that adolescent circadian rhythms typically lag by several hours compared to those of adults. According to Dr Paul Kelley, a research associate at the University of Oxford, the optimal learning period for most adolescents is between 11:00 and 15:00. Adhering to a standard 9:00 a.m. to 5:00 p.m. schedule results in an average weekly sleep loss of approximately ten hours among teenagers. Experimental programmes involving later school start times have led to significant improvements of 12% in national examination scores and a reduction in absences due to illness by over 50% compared to the national average (Kelley et al., 2017). Although later start times demonstrate measurable cognitive and health benefits, changes depend on national policy, transportation logistics, family obligations, and institutional constraints.

Evidence also suggests that later start times would be beneficial for adults (Kelley, Kelley, & Evans, 2018). Circadian sociology analyses indicate that beginning work at 10:00 a.m. would align more closely with adult biological rhythms and enhance cognitive and occupational performance. Implementing flexible working hours could help reconcile the conflict between biological and social time, offering potential advantages for both organisations and their employees. Furthermore, young people would benefit from increased education regarding the importance of sleep, particularly the negative consequences of last-minute cramming before examinations. Like other habits, the development of consistent sleep routines requires time and conscious effort. Maintaining a regular bedtime and wake-up time is essential for the regulation of neurochemical balance. As Matthew Walker (2017) notes, alarm clocks should ideally serve not as waking devices but as prompts to begin one's nightly rest.

4. Conclusion

Understanding how the brain learns is fundamental to creating effective, engaging, and inclusive educational environments. The findings of this narrative review suggest that neuroscience offers meaningful guidance for educational practice when interpreted with caution and contextual awareness. Neuroscience provides valuable insights into cognitive processes such as memory, attention, and emotional regulation, all of which are central to learning. However, its integration into educational policy and practice must be approached critically and responsibly. Effective learning depends on biologically grounded mechanisms such as memory consolidation, attention, and emotional regulation, yet implementation varies across cultural, institutional, and socioeconomic settings.

While concepts such as neuroplasticity affirm the brain's adaptability and the potential for growth through experience, the persistence of neuromyths demonstrates the need for ongoing education and sustained collaboration between researchers and practitioners. Equally important is the development of metacognitive and memory-supporting strategies that empower learners to take control of their learning processes. Teaching students how to learn—through retrieval practice, reflection, and self-regulation—is as vital as teaching subject content. Moreover, the promotion of brain health through sufficient sleep, physical activity, and stress regulation should be regarded as an educational priority rather than an ancillary concern.

Finally, the rise of AI and digital tools has made access to information easier than ever, but as Oakley et al. (2025) argue, true understanding depends on internalised knowledge structures built through effortful mental engagement. Educators must therefore strive for a balanced approach—one that leverages technology while nurturing deep, durable learning. Future research should continue to examine how evidence-based strategies can be adapted equitably and sustainably across diverse educational systems and learning environments. As neuroscience continues to illuminate the biological foundations of learning, its careful, context-sensitive application can help shape a more responsive, compassionate, equitable, and scientifically grounded educational landscape.

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