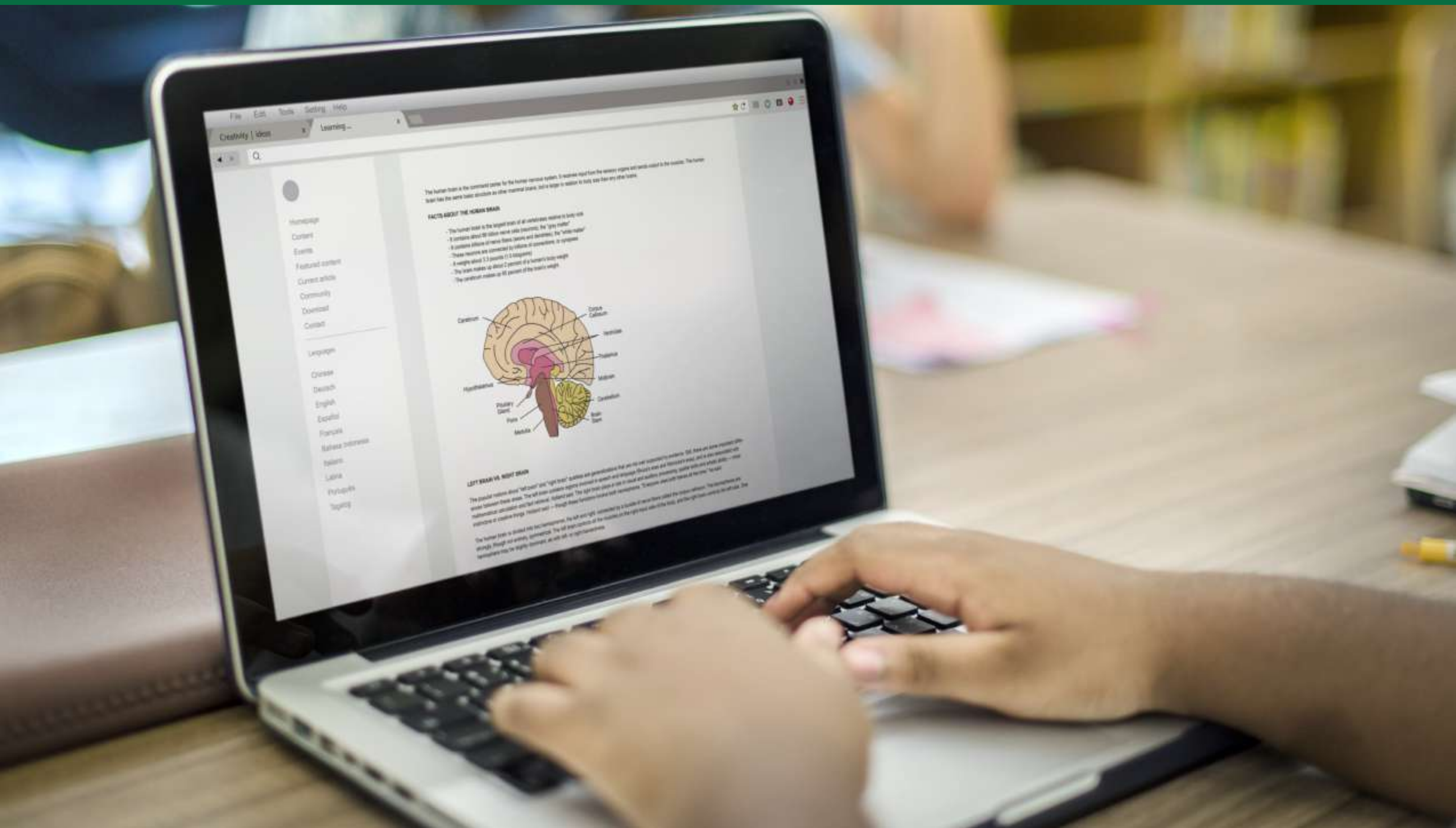
TeachME PROFESSIONAL DEVELOPMENT

CEUs for Teachers and Educators

Exploring Neuroeducation



Introduction

Neuroeducation is an interdisciplinary field, uniting experts from the fields of neuroscience, psychology, and education (namely pedagogy), to explore how children learn and how to apply brain-based teaching and best practices to the classroom. There is growing interest in the field of neuroeducation with the hope that applying neuroscientific research in the classroom will promote better learning, social-emotional experiences, and as a result, improved outcomes for students.

Section 1: What is Neuroeducation?

Neuroeducation, also referred to as "*educational neuroscience (EN)*," "*Mind, Brain, and Education (MBE)*," and "*Brain-Based Learning (BBL)*," is an interdisciplinary field of "inquiry [that] looks at how what we are learning about the human brain can affect the curricular, instructional, and assessment decisions that teachers make every day" (Sousa, 2022, p. 5). Neuroeducation brings together the disciplines of neuroscience, education, and psychology, to "figure out the links between education and brain processes," and ultimately improve learning and teaching practices (Le Cunff, 2022).

History of Neuroeducation

The connection between neurobiology and education was first publicly discussed in the first half of the 1900s by Educational Psychologist E.L. Thorndike, who "attempted to show how the science of learning and instruction could be informed by neuroscience" (Mayer, 2017). Thorndike published a three-volume series called *Educational Psychology*, and devoted the entire first volume to "the physical basis of learning," to show "the physiologic changes in synapses that correspond to learning" (Mayer). Thorndike attempted to explain neuronal connections and how they are strengthened or weakened by a person's experience. While Thorndike planted the seed for what would eventually become neuroeducation, and other researchers attempted to elaborate on it throughout the 20th century, it did not gain much momentum until the 1990s.

Moving into the 21st century, "important advances in the technology underlying cognitive neuroscience -- particularly, the widespread use of fMRI and EEG methodology -- have yielded an explosion in research aimed at connecting neuroscience and education" (Mayer, 2017). Throughout the 2000s and 2010s, Interest in the field of neuroeducation has only continued to grow exponentially. New groups and societies have formed, such as the International Mind, Brain, and Education Society (IMBES) in 2004 and the European Association for Research on Learning and Instruction's (EARLI) 'Neuroscience and Education' group, which has been holding biannual meetings on the subject since 2010 (Thomas et al., 2018). There are now thousands of articles, dozens of books, and entire scientific journals dedicated to this research. Likewise, there "has been a growth in postgraduate courses in educational neuroscience at leading international universities such as Harvard and the Universities of London and Bristol" (Thomas et al.).

Disciplines in Neuroeducation

Neuroeducation combines neuroscience, pedagogy, and psychology to bring "the current research from how the brain learns, behaves, and relates to instructional practices in the classroom" (Marian University [MU], 2022). Most educators on the frontline (teachers, paraprofessionals, related service providers (RSP), and even administrators) receive little formal training in how the brain learns best. In fact, learning about the brain can seem downright intimidating for people that are not specifically trained in neuroscience; however, neuroeducation creates a bridge between neuroscience, education, and psychology that allows individuals that are not neuroscientists to gain insight into how the brain functions. "Understanding how the brain processes information into learning and knowing more about what it takes for students' brains to be engaged, responsive, and alert are fundamental to the teaching and learning process" (MU).

Neuroscience

Neuroscience is the study of the brain's "development, structure, and function" (MU, 2022). If the goal of educators is to promote learning and success for students, understanding the basic functions of the brain and learning process is critical. The learning process actually changes the brain, both structurally and functionally. Teachers can use more effective instructional practices and design optimal lesson plans by "understanding how the brain responds and through applying principles from the neuroscience research in the classrooms" (MU).

Education (Pedagogy)

"Pedagogy is the study of the art and science of the teaching and learning process" (MU, 2022). Educators need to have a solid understanding of how factors, including but not limited to, "the environment, poverty, boredom, support systems, substance abuse, and all emotional, social, and cognitive facets," affect the brain and how it learns (MU). As such, educators are urged to use principles from the field of neuroeducation to inform their pedagogical practices. The hope is that if educators use pedagogy that is informed by actual brain science, it will result in improved academic and social-emotional outcomes for students.

Psychology

Educational psychology "is the study of developmental mental processes responsible for cognition and behavior" (MU, 2022). To work with students effectively, teachers need to have a basic understanding of brain development and how factors such as the environment, genetics, and personal experiences affect learning and behavior. Likewise, the educational psychology component informs teachers of "how stress affects the brain's ability to process information," to aid in designing instruction to address "the critical emotional, social, and cognitive developmental stages in every classroom" (MU).

Goals

"The implicit goal of all education is to change students' brains, by improving both their knowledge base and their understanding of information they acquire" (MU, 2022). Neuroeducation "is the active engagement of purposeful strategies based on principles derived from research" in the areas of neuroscience, pedagogy, and educational psychology (MU). Thus, the goal of neuroeducation is to bridge the gap between neuroscience, pedagogy, and educational psychology, to inform classroom practices and teaching strategies, and ultimately optimize student learning.

Challenges

Despite widespread research on the brain and learning, "a considerable gap continues to separate research on how people learn from classroom practice" (Conyers, 2017). The reasons for this disconnect include lack of training in teacher prep programs, ineffective translation of information, and the question of whether or not neuroscience has any place in the classroom.

Teacher Preparation Programs

Teacher preparation programs focus mainly on teaching methods and content areas, with some possible dabbling in an educational psychology course. Conyers cites a study by the American National Council for Accreditation of Teacher Education "finding a dearth of content in teacher education programmes about how children learn and little application of that research in practice." Further, most teacher preparation programs do not have courses dedicated specifically to cognition and learning, let alone neuroeducation. In a report by Welcome Trust, out of 1,000 teachers who were surveyed, over 90% "said their understanding of neuroscience is affecting them and 80% of teachers said they would cooperate with neuroscientists on educational research" (Cui & Zhang, 2021). In other words, the desire to learn about neuroeducation and allow it to inform teaching practice is present but the training options are limited.

Lost in Translation

Much of the information related to neuroeducation gets lost in translation, and never makes it into policy or practice. There is a need for "improvement of scientific dialogue and creation of a more widely shared language in educational and neuroscientific circles" (Elouafi et al., 2021). Essentially, there is a great demand for professionals who are proficient across the disciplines to translate information, and help with getting research into practice. Further, it is not a straightforward process to take laboratory research and turn it into teaching practices. "The real challenge, then, is to translate laboratory results into strategies to improve learning when establishing links between research and practice is not always easy" (Elouafi et al.).

Since policymakers and educators are eager to bring neuroeducation concepts into the classroom, researchers fear that this will be done prematurely. "The complexity of learning in the brain and the state of current scientific knowledge mean that there is a risk of premature translation before the foundation is established. The risk is heightened by the legitimate desire of policymakers to use scientific evidence to inform their education policies" (Thomas et al., 2018). Not only are educators eager to bring neuro-based practices into the classroom but commercial companies are also eager to sell products based on neuroscience findings, which can be problematic if the information is not translated correctly. When information about the brain is incorrectly translated or not entirely grounded in research, neuromyths are born.

Neuroscience is Irrelevant in Education

Although it is generally believed that neuroeducation is beneficial for educators, some argue that it is irrelevant. One famous conclusion made in 1977 by Bruer is that the "distance between neuroscience laboratory and classroom is a 'bridge too far,'" (as cited in Cui & Zhang, 2021). Other skeptics believe that "only evidence from psychological experiments that examine behavior is relevant to education," or that "social problems require social solutions, not reduction to neural mechanisms" (as cited in Jolles & Jolles, 2021). As a result, neuroeducation topics do not yet have a home in teacher prep programs.

Principles of Neuroeducation

Author, educational researcher, and professor of Harvard's Neuroscience for Learning program, Tracey Tokuhama-Espinosa (2018), led a Delphi Panel in 2006, with experts in psychology, neuroscience, and education, to determine "what, if anything, was worthy of making it out of the brain lab and into our classrooms" (p. 1). The Delphi Panel methodology is a "a process used to generate group decisions that genuinely represent the opinions of a panel. In order to reach a decision, a panel of experts undergoes several rounds of questions," and they are allowed to adjust their answers after reading the aggregated results of each round (Indeed, 2022). Tokuhama-Espinosa's panel consisted of experts from 11 different countries, who "provided studies and peer-reviewed articles to support their viewpoints as they argued for the inclusion or exclusion of ideas" (p. 1). The goal of Tokuhama-Espinosa's panel was to establish principles for neuroeducation, that is truths that "without exception, all human brains, independent of age, subject matter, or culture" adhere to (p.1). Tokuhama-Espinosa conducted a 10-year follow up of this study, which ended in 2017, and established only six neuroeducation principles that the experts agreed upon:

1. Human brains are as unique as human faces
2. Each person's brain is differently prepared to learn different tasks
3. New learning is influenced by prior experiences
4. The brain changes constantly with experience
5. The brain is plastic
6. There is no new learning without some form of memory and attention (p. 2).

The panel also identified 21 concepts about the brain that are also true, but vary greatly between individuals. Some of these concepts will be discussed in more detail below.

Principle 1: Human brains are as unique as human faces

Brains are like fingerprints, with no two people having the exact same one. While the basic structure (e.g. parts, and regions) is the same in most humans, no two are ever identical. The reason for this is that people's genetic makeup, as well as their personal experiences and freewill, "shape neural pathways" (Tokuhama-Espinosa, 2018, p. 2). In other words, each person's individual experiences in the world change the anatomy of the brain. For example, "Professional musicians, golfers or chess players . . . have particular characteristics in the regions of the brain which they use the most for their skilled activity" (University of Zurich, 2018). Short-term experiences affect the brain as well. If someone does not use a certain body part for multiple weeks, the part of the brain responsible for moving that body part will decrease in size (University of Zurich). Essentially, the concept of "use it or lose it" is true, as areas of the brain that are used more frequently have stronger neural pathways than those that go unused. Professor of neuropsychology, Lutz Jäncke, explains, "We suspected that those experiences having an effect on the brain interact with the genetic make-up so that over the course of years every person develops a completely individual brain anatomy" (as cited in University of Zurich).

Principle 2: Each person's brain is differently prepared to learn different tasks

The ITSI team (2018) puts it simply: "All brains are not equal because context and ability influence learning." A child's environment and interpersonal relationships have a great effect on brain development. "Brain architecture is developed by the presence of warm, consistent, attuned relationships; positive experiences; and positive perceptions of these experiences" (Darling-Hammond, et al., 2019). Tokuhama-Espinosa (2018) explains, "Learning capacities are shaped by the context of the learning, prior learning experiences, personal choice, an individual's biology and genetic makeup, pre-and perinatal events, and environmental exposures (p. 2). Therefore, a child with average intelligence learning in an enriched, nurturing environment will often excel more than a very bright child that is in an impoverished, unsupportive environment.

Principle 3: New learning is influenced by prior experiences

“Our mind learns and makes sense of experiences by finding old patterns to relate to before creating new ones” (ITSI, 2018). ITSI further explains, “By connecting the new information with the old information, new neural connections will appear that will anchor the new concepts to the already existing ones.” Students connect new information to old information in order to build a solid understanding of a concept. “New information that relies on old information cannot be absorbed if the old information is missing, or not completely understood” (ITSI). The quantity of what individuals learn, as well as the quality, will depend greatly on their past experiences and what they already know about a topic.

The Cognitive Load Theory (CLT) states that “the less familiar” a task is, the more an individual relies on working memory to “help juggle the relevant information,” while an individual with prior knowledge or expertise is able to focus more on learning engagement (Jarrett, 2020). “Students with low prior knowledge need more assistance to decrease cognitive load, while those with high prior knowledge more easily form new schema and perceive a lower cognitive load” (Dong et al., 2020). Schemas are “categories of information stored in long-term memory,” containing “linked memories, concepts, or words” (Loveless, 2022). Schemas can be compared to mental graphic organizers, grouping concepts in long-term memory to solidify understanding, and make it more retrievable. When students have prior knowledge, they are able to take new learning experiences and add to their existing schema, as well as build new ones around the new learning experiences. Essentially, CLT supports that “because short-term memory is limited, learning experiences should be designed to reduce working memory ‘load’ in order to promote schema acquisition” (Heick, 2022).

Principle 4 & 5: The brain changes constantly with experience / The brain is plastic

Neuroplasticity or brain plasticity refers to “brain’s ability to modify, change, and adapt both structure and function throughout life and in response to experience” (Voss et al., 2017). The brain is constantly changing as a result of individual experiences, and this happens throughout a person’s life. “These changes occur at a molecular level, whether simultaneously, in parallel, or even before they are visible in behavior” (Tokuhama-Espinosa, 2018, p. 2). The physical changes are not seen but the effects of such changes are visible. When an individual experiences something new, the brain reacts to it. “When you learn something new, the neurons involved in the learning episode grow new projections and form new connections. Your brain may even produce new neurons" (eLife Sciences Publication Ltd., 2020).

While neuroplasticity occurs at all stages of development, there are critical periods (CP) during early development, in which "brain plasticity is maximal . . . during which sensory experience is necessary to establish optimal cortical representations of the surrounding environment" (Cisneros-Franco et al., 2020). In simple terms, CPs refer to a time when the brain is in an optimal state to acquire new information or develop new skills. It doesn't mean that it is impossible to acquire such skills after the CP ends but it is much more difficult. Once the CP is over, "a range of functional and structural elements prevent passive experience from eliciting significant plastic changes in the brain" (Cisneros-Franco, et al.). As such, "young brains tend to be more sensitive and responsive to experiences than much older brains. But this does not mean that adult brains are not capable of adaptation" (Cherry, 2022). Neuroplasticity will be discussed in greater detail in Section 2.

Principle 6: There is no new learning without some form of memory and attention

"Attention is the process that allows us to take information in. It also helps us select useful information" (Rosen, 2022). Rosen identifies four key parts of paying attention: alertness, selection, sustaining, and shifting. Alertness is straightforward and refers to an individual's readiness to pay attention. Selection means that "kids must be able to identify what deserves attention," such as focusing on the teacher versus focusing on sounds from the hallway (Rosen). Sustaining refers to one's attention span and being able to pay attention for a duration of time, whether for a 3-minute video or a 40-minute lecture. Shifting attention refers to the ability to redirect attention when necessary; for example, students must shift their attention when an announcement is made over the intercom, and then back to their teacher for the lesson.

After new information is learned, the "attention funnel feeds" it into the brain's working memory (Rosen, 2020). Also referred to as encoding, the working memory process "manipulates new information so it's useful," allowing "us to use new and learned information while we are in the middle of an activity" (Rosen). While a student's attention brings in the information, it is their memory that makes the information meaningful and relevant. With consistent practice and exposure to a topic or skill, it ideally goes into long-term memory to be retrieved at a later time. However, there are a number of outside elements that might impact both attention and memory: disabilities (learning, or attention), social-emotional issues, and physiological issues, to name a few. Because there are so many elements that can affect attention and memory, and attention and memory are critical for learning, it is important to ensure that a classroom is set up for optimal learning conditions.

Section 1 Key Terms

Attention - The process that allows us to take information in. It also helps us select useful information (Rosen, 2022)

Cognitive Load Theory (CLT) - Theory that states because short-term memory is limited, learning experiences should be designed to reduce working memory 'load' in order to promote schema acquisition

Delphi Panel Method - A process used to generate group decisions that genuinely represent the opinions of a panel. In order to reach a decision, a panel of experts undergoes several rounds of questions

Neuroeducation - An interdisciplinary field of "inquiry [that] looks at how what we are learning about the human brain can affect the curricular, instructional, and assessment decisions that teachers make every day

Neuroplasticity - Brain's ability to modify, change, and adapt both structure and function throughout life and in response to experience

Pedagogy - The study of the art and science of the teaching and learning process

Working Memory - The capacity to store information for short periods of time while engaging in cognitively demanding activities

Section 1 Reflection Questions

1. What is your opinion on the role of neuroscience in the classroom? Do you think it can be helpful, or do you think it's "a bridge too far"?
2. Do you feel that your teacher preparation program gave you enough insight into the learning process? Were there specific courses dedicated to this?
3. If you could take a professional development course about neuroeducation, what would you want to learn and why?

4. What do you think is the biggest challenge of getting neuroeducation practices into policy and practice?

Section 1 Activities

1. Define neuroeducation in your own words and then write an explanation for each of the principles in your own words.

2. Conduct an action research project (*a method of systematic enquiry that teachers undertake as researchers of their own practice*) surrounding one of the principles of neuroeducation. Follow these steps:

    a. Select the research question

    b. Collect data

    c. Analyze data

    d. Share data

    e. Try new practice

Example research question: *How does the chunking of material affect a student's retention?* This can be measured by a short quiz. (Sousa, 2022, p. 12)

Section 2: The Brain and Learning

Brain Development

Early brain development - discussed here as birth to roughly age eight - is a hot topic in education because of the critical impacts it has on future health, learning, and life outcomes. One of the reasons why this period of development is so important is because the brain makes exponential growth at a rapid pace (Centers for Disease Control and Prevention [CDC], 2022). Specifically, "from birth to age 5, a child's brain develops more than at any other time in life," with 90% of brain growth happening before kindergarten (First Things First, 2022). A child's early experiences, positive or negative, actually change the architecture and function of their brains, which has lifelong implications. While the brain is especially susceptible to change in early years, which is the focus in this section, <u>it is important to note that it will continue to change with</u>

learning experiences throughout a person's life. Children are not "stuck with" the brain that they are born with and can improve their academic and executive function skills through learning. Learning, very literally, changes the brain!

In the Womb

Brain development begins in the womb, with both genetics and factors like proper nutrition during pregnancy, stress, prenatal care, and exposure to toxins and infections playing a role in healthy development (CDC, 2022). The brain begins to develop during the first trimester and does so throughout gestation. "In the first trimester, nerve connections are built that enable your baby to move around in the womb, while in the second trimester, more nerve connections and brain tissue are formed" (Pregnancy, Birth & Baby, 2019). By the last trimester of pregnancy, a fetus' brain "increases in size, folding of the brain's outer layer (cortex), and the development of connections between neurons" (Psychology Today, 2022).

Early Years

During infancy, relationships and experiences lay the foundation for future brain function (Lally & Mangione, 2017). As such, healthy brain development is largely dependent on positive, nurturing relationships with caregivers. "Infants come into the world with a set of neural reflexes that serve as primitive entry-points for regulating themselves in their environment (such as breathing, eating, and maintaining a steady body temperature) and for interacting with physical objects and other people" (Immordino-Yang et al., 2018). Engaging with caregivers allows infants to "notice patterns of actions, language use, and emotional expression," which form neural connections in their brain (Immordino-Yang et al.). As such, responsive relationships build neural connections that support a sense of safety and self-regulation, which is foundational for later learning.

Rather than looking at development from a nature versus nurture standpoint, development is more appropriately looked at through the lens of nature via nurture. While "genes provide essential information for establishing basic patterns of neuronal growth and connectivity, our individual experiences can affect gene expression and the trajectory of brain development" (Bick & Nelson, 2017). As such, caring, responsive, and stimulating environments are optimal for healthy brain development. On the other hand, "in less ideal environmental conditions, the foundational structure of the brain can be compromised, causing abnormalities in systems sub-serving healthy physical, cognitive, and social development" (Bick & Nelson).

Why are early experiences so critical for later development? As mentioned above, during the first few years of life, the brain grows more than it will during any other period of life, with at least "one million new neural connections (synapses) made every second," and developmental plasticity, or the brain's ability to change and adapt, at its highest (First Things First, 2022; Moore et al., 2017). Thus, a young child's brain is literally primed to respond to everyday experiences and interactions, and the brain's architecture is built accordingly.

Brain Connections. "The early years of a child's life are the best opportunity for their brain to develop the connections they need to be healthy, capable, successful adults" (First Things First, 2022). Research shows that the brain connections needed for critical skills, such as motivation, self-regulation, problem solving, communication, and self esteem, are formed, or not, during the first few years of life, and it is much more difficult to form these "essential" connections later in life (First Things First). For babies and toddlers, these connections are mostly built through positive experiences with caregivers. "Each new experience, each piece of information releases chemicals called hormones that create a new connection, or synapse, in the brain," and later on, "connections that are not used as frequently will be pruned, or removed, to allow for more useful connections to grow stronger" (Head Start, 2022). For example, when a baby cries and a caregiver provides comfort, "the synapses in the brain that respond to and expect caring behavior from others will grow strong," leading the baby to feel safe, secure, and open to positive learning experiences (Head Start). On the other hand, if a baby's needs are not met, then they experience stress and their brain builds stronger connections in areas wired for survival, closing them off to learning experiences.

Caring Relationships. "A baby's early experiences in relationships, whether at home or in an early education environment, set the stage for future brain functioning" (Lally & Mangione, 2017). Babies are entirely dependent on their caregivers for survival, protection, comfort, and happiness. As such, when their needs are fulfilled, their brains signal happiness. "These pleasurable early interactions stimulate the brain, motivating the baby to relate to those who care for them with confidence and ease" (Lally & Mangione). On the other hand, if a baby's needs are not met, "emotional and social development suffer, and, because babies' emotional base is the foundation for all other learning, so do intellectual and language development" (Lally & Mangione). Infancy is a critical time for building secure attachments with caregivers, including parents, guardians, and teachers. Secure attachment is "when children know they can depend on adults to respond sensitively to their needs" (Pahigiannis, Rosanbalm, & Murray, 2019). Secure attachment promotes feelings of safety, security, and confidence in babies, which are foundational for self-regulation, relationships, and future learning. When babies do not experience secure attachment, but rather insecure attachment, "the body's stress response is activated, flooding the developing brain with potentially harmful stress hormones" (Center on the Developing Child).

Experiences. One of the reasons why the human brain is as unique as a fingerprint is because much of the structure and function is based on individual experiences. "Brain development mainly involves the generation, pruning, and reorganization of neural connections to form brain networks that reflect a person's experiences and help him or her adapt to the world in which they live" (Immordino-Yang et al., 2018). As an individual engages with the world, including encountering challenges, relationships, formal education, et cetera, their experiences "influence patterns of brain structure and function that undergird a person's changing skills and inclinations over time" (Immordino-Yang et al.).

Adverse Experiences & Toxic Stress. Persistent, prolonged adversity and toxic stress can disrupt healthy brain development in children. Toxic stress is "when the stress children feel is strong, frequent, or prolonged, and it can disrupt healthy brain development and impact the way they think, feel, and grow well into adulthood" (Resilient Wisconsin, 2022). The human body has a stress response, often called "fight-or-flight," which evolved as a survival mechanism. The stress response triggers physiological changes, including a quickened pulse, a burst of adrenaline, "redirection of blood away from extremities and instead to major organs," and the release of cortisol (Scott, 2020). The stress response is meant to help people survive in life-threatening situations, which was necessary for ancestors. However, when children experience toxic stress, their bodies are constantly experiencing the stress response, which alters architecture and chemical makeup of the brain. Likewise, when a particular part of the developing brain is consistently used - in this case, the stress response - the synaptic connections in that area grow stronger; for example, if children are threatened by gang violence, their brains form stronger connections in the "fight or flight" area of the brain, causing them to be in a constant state of hyperarousal. "The brains of children and adolescents who experience persistent adversity respond by strengthening circuits that promote aggressive and anxious tendencies at the expense of circuits for cognition, reasoning, and memory" (Immordino-Yang et al., 2018). In addition to disrupting healthy development, frequent toxic stress makes "individuals more likely to develop health problems, including mental health disorders such as addiction, anxiety, and depression, and physical health problems, such as heart disease, obesity, and cancer" (Immordino-Yang et al.).

For the brain to be ready to learn, children need to feel safe and calm. When feelings of safety and security are disrupted by toxic stress, "the child's brain places an emphasis on developing neuronal pathways that are associated with survival, before those that are essential to future learning and growth" (Moore et al., 2017). When the brain perceives a threat or elicits the stress response, the parts of the brain associated with learning and memory are basically unavailable.

Critical & Sensitive Periods. Critical periods refer to brief times throughout a person's development in "which a system or organ has to mature" (Moore et al., 2017). Critical periods occur at different times for different systems of the body, and most of these happen during gestation. When referring to the brain and central nervous system, experts usually refer to "sensitive periods," which are "time windows during which the effect of experiences on brain development is unusually profound and can strongly shape the neural circuits" (Moore et al.). During sensitive periods, sensory experiences will have a greater impact on brain and behavioral development, but the door doesn't entirely "close" once the sensitive period is over, like it does during critical periods. Sensitive periods occur in childhood because a child's brain has "neuroplasticity responses that are not evident in adults, and which allow the young brain to develop appropriately and adapt constantly to environmental experiences and exposures" (Moore et al.). While neuroplasticity exists throughout the lifespan, it is less apparent in later years. As the brain matures, the connections become more permanent. "The brain's transitions from a more plastic to a more fixed state advantageously allows it to retain new and complex processes, such as perceptual, motor, and cognitive functions," but on the other hand, is less adept to change (Nickerson, 2021). As such, the brain's versatility during sensitive periods creates both opportunity and vulnerability for young children. This presents educators with the critical responsibility to create rich educational experiences for children, as these experiences can alter the brain's development and impact future learning, health, and overall life outcomes

The Brain's Mental Processes

In the past, researchers were interested in which individual parts of the brain were responsible for specific mental processes. More recently, there has been a shift to "focus on the networks of connectivity between regions that facilitate different activity modes important for thinking and learning" (Immordino-Yang et al., 2018). In other words, rather than individual parts, researchers have identified networks - that is, different parts of the brain working together - that are responsible for important mental processes. There are three major brain networks: Executive Control Network, Default Mode Network, and Salience Network (Immordino-Yang). "Through their co-regulation and coordination, each of these networks contributes to social, emotional, and cognitive functioning, allowing a person to operate well in the world and to take advantage of learning opportunities" (Immordino-Yang).

Executive Control Network

The Executive Control Network (ECN), unsurprisingly, deals with executive function (EF) skills and is activated during engaging, goal-directed activities. EF skills, sometimes referred to as "the management system of the brain," is a "set of mental skills that include working memory, flexible thinking, and self-control" (Belsky, 2022). EF skills include paying attention, organization and planning, starting tasks and staying focused, taking different perspectives, regulating emotions, and self-monitoring (Belsky). As such, the ECN "facilitates attention, allowing people to hold information in mind, shift strategies or approaches as necessary, and focus on the completion of goal directed tasks" (Immordino-Yang et al., 2018). Being able to focus, stay on task, and self-regulate are essential skills for school, work, and life success. Anatomically, much of this network is located in the prefrontal cortex, which is not fully developed until individuals are in their mid twenties. Thus, while EF skills begin to develop in early childhood, they continue to evolve all the way into early adulthood. This is why children often need support in developing executive function skills.

Working Memory. Working memory refers to "the capacity to store information for short periods of time while engaging in cognitively demanding activities" (Peng et al., 2018). Essentially, working memory is the ability to keep information in mind while using it to complete a task. Bensky (2022) compares working memory to a temporary sticky note in the brain, as "it holds new information in place so the brain can work with it briefly and connect it with other information." For example, children use working memory when they recall the steps of long division while working on a long division problem, or while reading a story to find answers to comprehension questions. Working memory has limited capacity, and this capacity increases with age. In general, researchers believe that "preschool infants can deal with about two items of information at once. Preadolescents can handle three or more. Through adolescence, further cognitive expansion occurs, and the capacity increases to five or more" (Sousa, 2022, p.

44). However, Sousa notes that “variables such as interest, mental time delays, and distractions may undermine and invalidate experimental attempts to find a reliable capacity limit” (p. 44). Similarly, the exact amount of time that something stays in working memory will depend on age, as well as interest, motivation, and distraction.

Working memory then uses certain criteria to determine if information should be encoded into long-term storage for future recall. While information pertaining to survival (e.g. don’t walk into oncoming traffic) and strong emotional experiences have a higher likelihood of being stored, learning experiences in the classroom are less straightforward (Sousa, 2022, p. 46). Working memory “connects with the learner’s past experiences and asks just two questions to determine whether an item is saved or rejected: ‘Does this make sense?’ and ‘Does this have meaning?’ (Sousa, p. 46). The first question refers to whether the learner understands the information, which is based entirely on past personal experiences. The second question refers to the relevance of the information for the learner, which is also very personal. “Whenever the learner’s working memory perceives that an item does not make sense or have meaning, the probability of it being stored is extremely low,” whereas the addition of sense, meaning, or ideally, both, increases the likelihood of retention (Sousa, 2022, p. 46). Sousa explains the reason for this, “Brain scans and other studies have shown that when new learning is readily comprehensible (sense) and can be connected to past experiences (meaning), there is substantially more cerebral activity followed by dramatically improved retention” (p. 47). Between sense and meaning, meaning has a higher likelihood for remembering than sense; this is probably due to the emotional impact of something meaningful.

<u>Implications for Teachers:</u> Kids are not born with EF skills, but are born with the tools to develop such skills. Teachers should find opportunities to help students develop these skills. “Teachers can offer explicit opportunities to learn executive functions by providing tools and modeling to help students learn to organize themselves, think ahead, plan their actions, and decide on what behaviors they will pursue, rather than reacting impulsively” (Darling-Hammond et al., 2022). Teachers can model EF skills through think alouds, sharing their own mental process as they go. The idea is to scaffold these skills through modeling, gradually allowing students to complete the activities independently.

Knowing that working memory capacity is limited for all age groups, and keeping age-specific capacities in mind, teachers should limit learning objectives in their lessons. For example, expecting elementary students to remember four different types of sentence structures and how to use them, in one lesson, is unreasonable. Less is more when it comes to key takeaways of a lesson; teachers should plan learning activities that will emphasize a couple of the key elements, rather than trying to make children remember more than their mental capacity can handle.

When working memory opts to not store information, relearning it is basically like learning brand new information, which is frustrating for both students and teachers. While teachers almost always plan with the goal of student understanding, sometimes the goal of making meaning is on the backburner. "To convince a learner's brain to persist with that objective, teachers need to be more mindful of helping students establish meaning" (Sousa, 2022, p. 48). Principle 3 tells us that new learning is influenced by prior experiences, which means that teachers must use lessons and curriculum that students can connect with their own past experiences, thus making meaning.

Closure. Closure in this case does not refer to an ending, or a "closing" in its traditional sense. Closure "describes the covert process whereby the learner's working memory summarizes for itself its perception of what has been learned" (Sousa, 2022, p. 64). Closure is important because it is during this time that a student "often completes the rehearsal process and attaches sense and meaning to the new learning, thereby increasing the probability that it will be retained in long-term storage" (Sousa, p. 64). Rehearsal "refers to the learner's reprocessing of new information in an attempt to determine sense and meaning" (Sousa, p. 107). Rehearsal aids in retention. Teachers initiate the closure process, which can occur at any point in a lesson, but they don't do the work like they would during review; students do "most of the work by mentally rehearsing and summarizing those concepts and deciding whether they make sense and have meaning" (Sousa, p. 64). Teachers can initiate closure in the following way:

- Give specific directions that focus on the new learning: "You will have two minutes to think about the three causes of global warming that we discussed today. Be prepared to turn and talk to your partner after the two-minutes is up."

These directions indicate "much quiet time they have for the cerebral summarizing to occur and identifies the overt activity (discussion) that will be used for student accountability" (Sousa, p. 64). During the discussions, teachers can gauge the accuracy of the students' closure processes, and correct any major errors.

Primacy-Recency Effect: When learning new information, "the amount of information retained depends, among other things, on when it is presented during the learning episode" (Sousa, 2022, p. 81). In this case, a learning episode refers to a class period, or a specific lesson within the class period. At certain points within the lesson, students will remember more than they will at other points in the lesson. The primacy-recency effect states, "We tend to remember best that which comes first and remember second best that which comes last" (Sousa, p. 82). We remember the least about what comes in the middle of a lesson. The reason for this is because the first items that we learn are within the working memory's "functional capacity," so "they command our attention and are likely to be retained in semantic memory" (Sousa, p. 82). Later information, in the middle of the lesson, typically exceeds working memory capacity, and is often lost. Near the end, "items in working memory are sorted or chunked to allow for additional processing of the arriving final items, which are likely held in working memory and will decay unless further rehearsed" (Sousa, p. 82). As such, there are prime times during a class period where new learning will occur more easily, and times where it will be more difficult. Thus, lessons should be planned accordingly.

Primacy-Recency Use in the Classroom

- **Timing:** Sousa (2022) approximates prime time 1 and prime time 2 (the times where optimal learning and retention take place) in a 40-minute lesson. Prime time 1 builds up from 0-5 minutes, peaks from 5-15 minutes, and then trends down from 15-20 minutes. There is "down-time" from 20-25 minutes, and then it begins rising from 25-35 minutes, and peaks to the 2nd highest point at 35-40 minutes (p. 82). These are approximations of a 40-minute period and are not exact but can be used for reference.

- **Teach new material first:** New information should be taught during prime time 1. New information or skills should be taught at this time because it is most likely to be remembered. *It is important to remember that <u>only correct information should be taught during this time</u>; in other words, asking students what they know about a new topic is NOT effective during prime time, as wrong answers could be mentioned and remembered.*

- **Practice or Review:** Practice/review should come after the new material is taught. "At this point, the information is no longer new, and the practice helps the learner organize it for further processing" (Sousa, p. 82). Likewise, this normally leads into a "downtime" where retention is more difficult, so new information should not be taught during this time.

- **Closure:** Closure should take place during the 2nd prime time because this is when retention is at the second highest in a lesson. This is an "important opportunity for the learner to determine sense and meaning" (Sousa, p. 83).

Many teachers are unfamiliar with the primacy-recency effect and lose out on prime learning time with things like attendance, collecting homework, discussing objectives, or reading announcements. By the time teachers actually introduce the new material, students are in their down time, and retention is much more difficult.

Default Mode Network

The Default Mode Network (DMN) is activated during resting-awake states (think opposite of engaging, goal-directed states), including "tasks that involve internally directed, interpretive, and reflective thought, for example when remembering past experiences, imagining hypothetical or future scenarios, or deliberating on inferred, abstract, or morally relevant information" (Immordino-Yang et al., 2018). Immordino-Yang et al. explains that the DMN is important for "conceptual understanding, reading comprehension, creativity, nonlinear and 'out-of-the-box' thinking, feelings of inspiration, social emotions like admiration and compassion." It also seems that the DMN is activated during "assigned tasks such as future planning involving the self, autobiographical memory, and interpreting social interactions," all of which have a reflective element to them (Anderson & Davidson, 2019). The DMN is not useless, or only activated during non-cognitive tasks. Instead, it is "activated in situations that require broad situational awareness over time and is deactivated during task situations requiring focused attention" (Anderson & Davidson, 2019). Anderson and Davidson explain, "The DMN is strongly implicated in the processing, comprehension and memory of narrative receptive media including aural, audiovisual, and text media." In terms of a classroom setting, it is likely that the DMN is activated during lectures as well, as students are receiving information but not actively engaging in an activity.

Salience Network

Salience is a term used to describe "the quality of being noticeable, or standing out," where salient elements, "are described as such because they attract attention and are meaningful or behaviorally relevant" (Uddin, 2017). As such, the Salience Network "weighs emotional relevance and perceived importance and urgency of information to facilitate switching between mindsets" (Immordino-Yang at al., 2018). This network helps the brain to focus on what is important in a given moment. The Salience Network switches modes using “external signals from the environment and internal bodily signals, such as from hunger and anxiety” (Immordino-Yang). This network is “critical for detecting behaviorally relevant stimuli and for coordinating the brain’s neural resources in response to these stimuli'' (Uddin). In other words, the salience network detects and analyzes stimuli, and then determines what the brain’s response should be, which is then translated to actions and behavior. Dysfunction in the salience network can lead to neuropsychiatric disorders like autism spectrum disorder (ASD), psychosis, and dementia (Uddin).

The Role of Emotions

How a person ‘feels’ about a teaching or learning situation determines the amount of attention devoted to it” (Sousa, 2022, p. 42). As such, emotions can either inhibit or support the learning experience. “Positive learning emotions include interest, curiosity, wonder, passion, creativity, engagement and joy. These activate the reward system of the brain, make the experience desirable, and aid in focus and attention” (Osiko et al., 2022). When students feel positive emotions during a learning experience, they are better able to overcome challenges, broaden their perspectives, and fully engage in the learning. Likewise, positive emotions promote motivation. On the other hand, “negative emotional states such as anxiety, stress, sadness, disinterest, disengagement, worry and fear can impede learning processes and the motivation to learn” (Osiko et al.).

Implications for Teachers: Teachers can make their classrooms conducive learning environments by making the classroom a safe space through a positive classroom climate, positive relationships, and attention to student emotions (discussed in greater detail in section 3). Also, to promote positive learning emotions, teachers can always utilize humor. “Research shows that humor has many benefits when used frequently and appropriately in the classroom and other school settings” (Sousa, 2022, p. 58). There are physiological benefits to humor, including increased oxygen in the blood, a result of laughing, as well as the release of endorphins (Sousa, p. 58). In addition to the physical benefits, using humor and laughter also get students’ attention, creates a positive climate, and increases retention. The reason for increased retention is because strong emotions enhance retention, so “the positive feelings that result from laughter increase the probability that students will remember what they learned and be able to recall it later” (Sousa, p. 58). While humor can be used as an opening joke or an “attention-getter” it can also be used within a lesson. This could be using humorous examples, videos, or pictures to relay an idea from the lesson. When using humor, be careful not to use sarcasm, which can end up negatively affecting students. Sarcasm, which comes from the Greek "to bite flesh . . . is one of the factors that can undermine that support and turn students against their peers, the teacher, and the school" (Sousa, p. 59).

Section 2 Key Terms

Closure - Describes the covert process whereby the learner's working memory summarizes for itself its perception of what has been learned

Rehearsal - This continuing reprocessing of information (Sousa, p. 79)

Scaffolding - A method where teachers offer support to students as they learn and develop a new concept or skill

Toxic Stress - When the stress children feel is strong, frequent, or prolonged, and it can disrupt healthy brain development and impact the way they think, feel, and grow well into adulthood

Long-Term Memory - Storage of information over an extended period of time

Section 2 Reflection Questions

1. What are some examples of ways that you already use closure in your classroom?
2. What strategies do you use in the classroom to promote positive emotions during lessons?
3. Think about a time that one of your students really struggled to focus and engage with the lesson. What negative emotions do you think this student was dealing with that interrupted his/her cognitive functioning?
4. What are some activities that you think would be effective during the "down time" of primacy-recency effect?
5. What specific difficulties might students have if they have working memory deficits?

Section 2 Activities

1. Take an existing lesson plan (or create a new one), and design it with the primacy-recency effect in mind. Organize it by times, noting prime time 1, prime time 2, and down time, and indicate the activities for each portion of the class.

2. Create a Slides presentation to teach students how their brains change with learning. This should promote a growth mindset, while explaining how learning and experiences change the brain. (Note: Create something that you would really share with your students; believe it or not, students love learning about how their brains work)
3. Create a diagram or picture that represents how working memory functions.
4. Design a closure activity for one of your lessons. This activity can take place at any point in the lesson but most promote rehearsal of concepts.

Section 3: Neuroeducation in the Classroom

Why it's Important

Neuroeducation is an emerging research field in which cognitive scientists, educators, and neuroscientists "collaborate to apply neuroscience research to change education . . . and [neuroeducation] also better reflects a knowledge field centered on education, characterized by neuroscience and technology, and based on experiential, social, and biological evidence" (Cui & Zhang, 2021). Neuroeducation encompasses all of the factors that influence learning, starting with how the brain typically develops, and how factors such as genetics, environment, social-emotional state, and personal experiences impact development and learning. The demand for neuroeducation and its subsequent growth in the last decade comes from two directions: "neuroscientists emphasize that their work has the potential to improve education, and educators are keen to understand what neuroscience can provide for their practice" (Cui & Zhang). "The establishment of the field . . . marks the arrival of an era that focuses on human brain learning models and mechanisms, which gives researchers, leaders, and teachers specific opportunities to reexamine educational practice and research," opening the door for better experiences for all students, as well as improved educational outcomes (Cui & Zhang). As of now, neuroeducation does not translate directly into policy or practice in the field of education; however, "educational policies and practices that are consistent with how the brain develops are more likely to promote learning and development than those that undermine or are inconsistent with brain science" (Immordino-Yang et al., 2018).

Improved Teaching, Improved Learning. If teachers understand how the brain learns and how various factors affect learning, then they can plan for optimal classroom conditions. Neuroeducation "can help teachers understand the brain operating mechanism, promote teachers to change teaching strategies, and optimize teaching design, to implement better teaching activities" (Cui & Zhang, 2021). Equally important is understanding barriers that get in the way of learning, including "physiological data . . . such as heart rate, respiration, and pupil, [which] can be used to judge learners' physical discomfort, fear, or reluctance to help better understand learning and teaching" (Cui & Zhang). Understanding barriers to learning, including but not limited to anxiety, depression, and distractibility, and having strategies to work through such barriers, are major focus areas of neuroeducation, and are key in improving learning experiences.

Neuroeducation also aims to improve the quality of learning experiences to increase retention. Neuroeducation research presents important principles to follow, and suggests that "correctly dealing with obstacles and correcting mistakes in the learning process will help to connect nerves and promote the transformation of knowledge, and retrieving information with consistent patterns leads to stronger neural connections" (Cui & Zhang, 2022). Understanding these concepts, as well as establishing classroom routines that utilize them, will improve learning experiences. Teachers can also use neuroeducation research in their "curriculum design and learning process and they can try to avoid asking mechanical, trivial, and non-challenging questions but put forward multi-dimensional methods to consider a concept or idea, and the neural pathways and learning results will also be strengthened in return" (Cui & Zhang). As a result, students will also feel more motivated and engaged in their learning.

Neuroeducation practices can also help teachers to better understand students with disabilities, such as dyslexia, attention deficit hyperactivity disorder (ADHD), and Autism Spectrum Disorder (ASD). For example, brain imaging technology (e.g. fMRI, MRI, EEG), "help find the differences in the brain structure of dyslexia children, such as reduced brain functional plasticity, and insufficient neural network activation," which can provide "good educational guidance and teaching intervention to alleviate children's dyslexia and improve their attention" (Cui & Zhang, 2022). Through brain imaging, researchers know that readers with dyslexia use different neural pathways while reading compared to strong readers, and have determined the need for explicit phonics instruction as a result. Neuroeducation aims to provide teachers with detailed information on the brain to help struggling learners.

Ideal Learning Conditions

“The factors that influence a child's learning outcomes, which operate at vastly different degrees of proximity to the learning process, should be seen as an interactive, interconnected system” (Thomas et al., 2018). Neuroeducation tells us that while the brain is doing the actual learning, there are several factors that influence what, and how much, the brain will learn. It is important for teachers to use what is known about the brain and learning to create an environment that is more conducive to learning.

Physiological

For individuals to engage in meaningful learning opportunities, certain physiological needs must be met. Some of these needs include sleep/rest, nutrition and low exposure to toxins, and physical activity and green space (Immordino-Yang et al., 2018).

Adequate Sleep. “Both physical and mental health, and the ability to think well, depend on getting an adequate amount of quality sleep” (Immordino-Yang et al.). In addition to feeling better overall, sleep is actually fundamental for long-term memory consolidation. “The encoding of information and motor learning into the long-term memory sites occurs during sleep—more specifically, during the rapid-eye-movement (REM) stage” (Sousa, 2022, p. 92). This means that when kids and adolescents aren’t sleeping enough, or aren’t reaching their REM cycles, their learning is not being consolidated into long-term memory. As such, they will have trouble remembering what they learned and using that information for new learning.

Studies also show that students that get less sleep often have lower grades than students that get more sleep; this is probably due in some part to the changes in circadian rhythms that affect focus, which is discussed in more detail below. However, lower grades due to lack of sleep can also happen because drowsiness makes it difficult to focus, and difficult to complete complex tasks. Sleep deprivation can also cause depressed moods and other unpleasant feelings. Furthermore, the “performance of complex and abstract tasks that involve higher-order brain functions declines more strongly after sleep deprivation than their performance of simple memory tasks” (Sousa, p. 94). This means that while students might be able to “function” on a very basic level with a lack of sleep, they will not be able to fully engage in learning tasks. Long-term sleep deprivation can cause more serious issues. Immordino-Yang et al. (2018) explains, “Over time, chronic sleep deprivation leads to impairments in mood, emotion regulation, memory, cognition, creative thinking, and situational awareness," as well as the development of new neuronal growth.

Circadian Rhythms. "The daily pattern of body functions" including breathing, digestion, "hormone concentration," "the sleep–wake cycle, and body temperature" are referred to as circadian rhythms (Sousa, 2022, p. 289). Sousa explains that the timing of these cycles is determined by the brain's exposure to daylight, which means that they are controlled largely by the sleep-wake cycle (p. 90). One circadian rhythm, referred to as the psychological-cognitive cycle, "regulates our ability to focus on incoming information with intent to learn" (Sousa, p. 91). Research shows that this circadian rhythm is about the same for preadolescents and adults, but starts later for adolescents due to the onset of puberty. For pre- and post-adolescents, the focus cycle peaks from about 7 AM until noon, and then starts to dip from noon to 1 PM, before escalating again. For adolescents, the cycle peaks about an hour later at 8 AM until 1 PM and then starts to dip until its low point at 3 PM. During these low points of focus, while learning technically can occur, it will take a lot more effort (Sousa, p. 91). It is also important to note that for adolescents, their "second wind" for focus peaks again around 4 PM and stays relatively high until 10 PM, which is why adolescents are often more tired in the morning and more awake at night.

<ins>**Implications for Teachers:**</ins> Taking these biological factors into account at the district level could result in later start times for middle and high schools, as this could be beneficial for adolescent learners. During a normal sleep time of eight to nine hours, it is believed that five REM cycles occur. Sousa (2022) explains, "Adolescents getting just five to six hours of sleep lose out on the last two REM cycles, thereby reducing the amount of time the brain has to consolidate information and skills for long-term storage" (p. 93). Sleep deprivation can cause additional problems, such as irritability, tiredness during the day, a lack of focus, and even anxiety and depression (Sousa).

Later start times is a more macro solution to this problem, <ins>but teachers can make little changes in their classroom settings</ins> to accommodate these changes as well. For example, teachers can schedule important tests or projects during times when students are at their peaks for focus, rather than during dips. Likewise, particularly middle and high school teachers, can be cognizant that their own dips will occur when their students are still at their peaks, and plan classroom activities accordingly. Teachers should also discuss the importance of sleep with their students, explaining how it directly affects memory, focus, and mood. While it might not seem intuitive in nature, students actually enjoy learning how their brains work.

Nutrition and Low Exposure to Toxins. Adequate nutrition is critical for healthy brain development, particularly for young children. Likewise, nutrition directly affects "mental processes" for school-aged children (Just, 2019). For example, deficiencies in nutrients, such as iron, "can decrease dopamine transmission, thus negatively impacting cognition" (Just). Decreased dopamine can also negatively impact a child's mood. Also, Just explains, "Amino acid and carbohydrate supplementation can improve perception, intuition, and reasoning." While specific vitamins and nutrients are important for various brain functions, a balanced diet is crucial for overall health. Because a balanced diet directly affects health, "students are likely to have fewer absences and attend class more frequently," thus having fewer interruptions to their learning (Just). "Studies show that malnutrition leads to behavior problems, and that sugar has a negative impact on child behavior," while hunger inhibits focus (Just).

Exposure to environmental toxins, drugs, and alcohol, can have a permanent, negative effect on brain development (Immordino-Yang et al., 2018). It's also important to note that "children's diets contain increasing amounts of substances that can affect brain and body functions," including caffeine (Sousa, 2022, p. 28). Caffeine is found in many snacks and drinks that teenagers, adolescents, and shockingly, some pre-adolescents, eat and drink regularly. Too much caffeine can cause nausea, anxiety, and insomnia, in both children and adults (Sousa, p. 28). In addition, the body can become dependent on caffeine, meaning that students experience withdrawal symptoms when they don't have it. Withdrawal symptoms include headaches, trouble concentrating, fatigue, and increased irritability (Gavin, 2022). It is no surprise that "eliminating the sale of soft drinks in vending machines in schools and replacing them with other drinks had a positive effect on behavioral outcomes such as tardiness and disciplinary referrals" (Just, 2019).

Implications for Teachers: Unfortunately, teachers cannot control what their students eat, or don't eat, when they are at home. Teachers can educate students and parents on the importance of a healthy diet, including sending home newsletters with healthy snack suggestions, recipes, or "easy" healthy foods, but obviously control here is limited. Within the classroom, teachers can offer healthy snacks to their students; this isn't to say that students should be snacking the entire time, but if students are hungry, learning doesn't occur. Hunger impedes a child's ability to focus, and also causes physical discomfort, such as stomachaches, headaches, and nausea. This is an example of Maslow > Bloom's, in that if children feel the physiological effects of hunger, they won't be able to concentrate on learning. "Roaring stomachs cause children to be cranky, hyperactive, and aggressive. These behavioral issues can distract kids from their school work," leading children to fall behind in school (Waite & Thoelke, 2021).

Hunger is a bigger issue than a student simply needing a snack. There are approximately 13 million American children who live with or are at high risk of hunger, meaning that they aren't sure when or where their next meal will be (Snack Pak 4 Kids, 2022). Imagine coming into school, not only hungry, but also not knowing the next time that food will even be available. It is not only physically debilitating but it is a root cause of anxiety. Likewise, without adequate vitamins and nutrients, concentration issues aside, the brain will not develop normally. As educators, and sometimes the only consistent adult in a child's life, ensuring that children have food available to them throughout the school day is a responsibility that may not be in the job description, but is extremely important. As such, teachers should be familiar with common signs that a child is facing hunger:

- Constantly asking about food
- Suddenly losing or gaining weight with no major changes (activity level, medications, etc.)
- Hoarding food
- Bullying
- Poor attention span, memory, or trouble concentrating
- Hyperactive or impulsive
- Aggressive or antisocial (Schoen, 2018)

It is important to remember not to single out any children if they exhibit one or more of these signs, as this can be embarrassing. Instead, it is best to discuss concerns with the school social worker or counsleor, who can help connect students and families with resources for the issue. Program Manager of Children and Families at Feeding America, Christina Martinez, said, "Children need nutrients so that they can grow, develop and focus on learning instead of thinking about the food they need . . . Ultimately, they need to be able to concentrate in the classroom, so they can succeed and reach their full potential" (Schoen).

Social-Emotional Factors

Relationships. Neuroeducation research shows that "warm, caring, supportive student-teacher relationships, as well as other child–adult relationships, are linked to better school performance and engagement, greater emotional regulation, social competence, and willingness to take on challenges" (Darling-Hammond et al., 2019). Positive relationships actually affect the architecture and function of the brain, particularly during early childhood. Brain architecture is developed through the "presence of warm, consistent, attuned relationships; positive experiences; and positive perceptions of these experiences," and these relationships "help develop the emotional, social, behavioral and cognitive competencies foundational to learning" (Darling-Hammond et al.). As such, these same relationships aid in learning in the classroom setting.

Physical & Emotional Safety. In order for learning to occur, students need to feel safe, both physically and emotionally. Stress and anxiety disrupt cognitive functioning because the brain enters survival mode. The brain has a hierarchy of response to sensory input; this means that higher priority input overrides data of lower priority (Sousa, 2022, p. 42). At the top of the hierarchy is sensory input that threatens survival. The brain is primed to keep its vessel alive, so "it will process immediately any data that past experience interprets as posing a threat to the survival of the individual, such as a burning odor, a snarling dog, or someone threatening bodily injury" (Sousa, p. 42). Once the brain perceives a threat, it releases adrenaline (i.e. the stress response) and essentially shuts off any activity that is not pertinent to survival. Because the brain is designed to keep us alive, survival is at the top of the hierarchy, and new learning is at the bottom; this means that survival input will always override new learning input. To put this information into classroom practice, when a student feels threatened or unsafe, the primitive parts of the brain take over and completely override the parts of the brain available for learning. As Sousa puts it, "Before students will turn their attention to cognitive learning (the curriculum), they must feel physically safe and emotionally secure in the school environment" (p. 42).

Emotions Impact Learning. Emotions can be defined as "an embodied response to a stimulus (whether real or perceived, external or internal) and are experienced along a continuum from positive to negative" (Osiko et al., 2022). Learning and emotion are not separate entities, but rather very much connected. At the top of the brain's sensory input hierarchy is data threatening survival, followed by emotional data, and lastly, data for new learning (Sousa, p. 43). Therefore, how individuals feel emotionally will affect the quality and the quantity of their learning. Sousa explains, "When an individual responds emotionally to a situation, the older limbic system (stimulated by the amygdala) takes a major role, and the complex cognitive processes are suspended" (p. 42). Most people have experienced this brain response when fear, sadness, anger, or joy took precedence over any rational thought. As such, if children are experiencing emotions like sadness or anxiety, their brains are not ready to learn new information. Even if they are able to sit through the class, they are unlikely to retain the information because their "learning brain" is turned off. "When learners generate positive emotions, their scope of attention broadens and their critical thinking skills are enhanced. Neutral and negative emotions, on the other hand, narrow the scope of attention and thinking" (Sousa, p. 241). As such, activities that challenge students and increase engagement are more likely to stick with them.

Implications for Teachers: "How the student feels about being in that classroom and about the lesson content itself can make all the difference between mental withdrawal or active participation and achievement" (Sousa, 2022, p. 78). Teachers must make social and emotional needs a priority in their classrooms. This means that "teachers create classroom communities grounded in respect, in which all students are affirmed for their value, with shared norms and responsibilities for all members" (Immordino-Yang at al., 2018). A safe and positive classroom climate will:

1. promote positive relationships between students, "so they are kind to each other, listen to each other, and respect different viewpoints,"
2. build positive relationships between teachers and students, so students know "feel you not only care about their academic success but also care about them as individuals," and
3. develop and implement classroom "norms" and "rules" that "are simple, clear, and provide a physically and emotionally safe learning environment" (Sousa, p. 105).

Keeping a positive classroom climate is an ongoing task and teachers should make changes as they see fit. "Teachers' abilities to maintain a supportive, culturally responsive environment with consistent routines support student learning by reducing hyper-vigilence, anxiety, and extraneous cognitive load" (Darling-Hammond et al., 2022).

Content knowledge and teaching skills matter, but relationships must come first. It's important that teachers let students know that they are on the same team, and that they are there for support. Creating positive rapport and building relationships with students, from day one, is key in providing a supportive environment. Building relationships takes time and effort but some ways to start include correctly pronouncing students' names and using correct pronouns. "You might be the only adult in school in that student's day to use their name in a positive way, so there's great power in learning names quickly," and correctly (Hager & Arenz, 2022). One way to ensure that names are being pronounced correctly and correct pronouns are being used is to give students a survey (Google Forms works great) at the beginning of the year, explicitly asking for preferred pronouns and names, if these should be used in class (and if not, what do they prefer in class), and how to phonetically pronounce names. This gesture lets students know that they are accepted for who they are and that the classroom is a safe space to be themselves. Using this same type of survey, teachers can also ask students about their interests, favorites, what makes them tick, and how they learn successfully. Not only does this show that teachers are taking interest in their students, but it creates a safe space for students to express themselves.

In addition to creating a safe space and building relationships, teachers need to be cognizant of their students' emotional states, and to have tools to de-escalate problematic internalized or externalized behavior. One way to simply see how students are doing is to do daily check-ins, ideally at the beginning of class. "Check-ins at the beginning of class honor experiences that students bring into the room before we ask them to think about something else" (Porosoff, 2021). Check-ins can and should be done at all ages but they will obviously not look the same.

- **Elementary Level Check-ins:** Feelings Chart, Students put their clip on the chart to indicate how they're feeling; Color Chart, Similar to the feelings chart but colors indicate feelings (red=mad, blue=sad, green=happy, yellow=anxious, etc.); Morning Meetings, Verbally discuss how students are feeling and/or if anyone needs supports.

- **Middle/High School Level Check-ins:** Google Forms, Students fill out a form when they get to class indicating their moods/feelings; Post-Its, Designate colored post-its for students to indicate if they need support, or if they just need understanding for that day (e.g. Red= I need support, Yellow= I have something going on or am disengaged), follow up with students as needed.

It's also important that teachers are able to recognize when there is a more serious emotional issue going on. This means that teachers need to be aware of warning signs that a student is in need of emotional support:

1. Acting sad or withdrawn for 2+ weeks

2. Overwhelming fear or anxiety for no apparent reason (including physiological symptoms)

3. Difficulty concentrating or sitting still

4. Severe mood swings (Zimmerman-Leizerov & Jerome, 2022)

If a teacher sees one or more of these signs, it is appropriate to not only talk to the students themselves (if they have a good relationship), but also to seek help from a school social worker or guidance counselor.

Teaching Practices

Not all teaching practices are created equal. There are some teaching practices that will aid in better retention, increase higher quality learning experiences, and enhance overall enjoyment by students, and we know this through research in neuroeducation. "Productive learning environments and teaching practices "support age-appropriate exploration and discovery, followed by reflection and discussion for deeper understanding" (Immordino-Yang et al., 2018). Best teaching practices will challenge students, while taking into account their zone of proximal development (ZPD). ZPD is defined as "the space between what a learner can do without assistance and what a learner can do with adult guidance or in collaboration with more capable peers" (Billings & Walqui, N.D.). Effective teaching practices "attend to the trade-off between plasticity and efficiency in brain development, offering activities that encourage both flexible thinking and mastery of necessary building-block skills and knowledge" (Immordino-Yang et al.).

Teaching to Multiple Senses Increases Retention. There is a long-standing neuromyth that if students are taught in their preferred "learning style" then they will learn better and achieve better outcomes; however, there is no scientific research indicating that teaching to a specific learning style will improve outcomes. Rather, it is through multisensory teaching and multisensory learning (MSL), or teaching/learning information through more than one sense, that improves retention. There is strong research on "the effectiveness of simultaneous use of visual, auditory, tactile-kinesthetic, and articulatory motor strategies during instruction," particularly for students with disabilities (Colorado Department of Education, 2020). Additionally, research shows that when an "activity engages multiple areas of the brain, it can help students develop stronger memories around how to do it," which aids in retention and future retrieval of the information (Waterford.org, 2019). When information is learned through more than one sense, the brain is more likely to encode it in long-term memory. MSL allows students to engage with the content in more than one way, which also increases engagement.

The left and right hemispheres process information differently but people learn best when both hemispheres are engaged. Sousa (2022) explains, "Just as we would catch more balls with both hands, we catch more information with both hemispheres processing and integrating the learning" (p. 170). Further, research indicates more connections are made in the brain when multiple senses are activated. "If more brain stimulation promotes growth of synapses and dendrites and more areas of the brain are stimulated when information is presented through MSL, then multisensory lessons can stimulate the growth of more brain connections" (McIver, 2017).

<u>Implications for Teachers:</u> When possible, it is beneficial to engage multiple senses in lessons. When teaching new ideas, aim to present information both visually and auditorily. "Write key words on the board that represent the critical attributes of the concept, then use a simple diagram to show relationships among the key ideas within and between concepts" (Sousa, 2022, p. 170). Doing this attaches both "auditory and visual cues" to the information, which helps students to create sense and meaning, and ultimately aid in later retrieval of the information (Sousa, p. 170). Concept mapping is another way to implement a visual representation of information that was previously taught verbally. "Concept mapping consists of extracting ideas and terms from curriculum content and plotting them visually to show and name the relationships among them" (Sousa, p.174). Concept mapping is especially helpful for students with disabilities.

While the combination of visual and auditory teaching is often the most simple to implement, the multisensory teaching options are endless. In math class, students can use base ten blocks to represent numbers, and even to solve math problems. Likewise, using manipulatives, like beads or buttons, to count or solve problems is beneficial. "By moving these items around and seeing how the quantities change, kids have a concrete way of understanding how these math operations work" (Hodnett, 2022). For struggling readers, multisensory approaches like writing words in sand or shaving cream have been shown to be effective as well. Science labs use MSL naturally, as students observe phenomena, conduct experiments, write down results, and make reports.

Physical Activity. Movement and physical activity improve brain performance. "Movement throughout the day helps students to re-energize their bodies and their brains, helping them to focus and concentrate better . . . [Additionally,] movement during the school day benefits academic performance and improves behavior" (Ferlazzo, 2020). Improvement of behavior makes sense, as sitting behind a desk all day gets boring, and students grow restless. Movement increases engagement, which decreases unwanted behaviors. When students are engaged, they are more excited to learn, and more motivated as a result.

The benefits of physical activity for learning do not stop at increased motivation and engagement. Studies consistently show that kids that are able to be active have "faster cognitive processing, and more successful memory retention than kids who spend the day sitting still," as well as more mental clarity, due to increased blood flow to the brain (Abdelbary, 2017). In addition, exercise "strengthens both the prefrontal cortex (which is involved in executive functioning) and the hippocampus (which plays a key role in memory and learning)," while also promoting creative thinking, focus, and retrieval of information (Kris, 2019). Physical activity also improves mental health. The reason for this is because physical activity increases levels of serotonin, norepinephrine, dopamine and endorphins, which support motivation, response to stress, and well-being (Kris, 2019). Movement does not have to be a hardcore workout in order to be beneficial. Adding components of movement within the academic classroom, PE class, or outside at recess, can all be beneficial for students.

<u>Implications for Teachers:</u> Despite knowing the benefits of physical activity, schools seem to be cutting back on physical education time, as well as recess. Likewise, despite the research behind physical activity and the brain, most classrooms still have students spending the majority of the time sitting at their desks and listening. Sometimes teachers prefer this method because they fear that movement will cause chaos in the classroom. However, "effective classroom movement is not chaotic nor is it necessarily unstructured . . . Effective classroom movement simply acknowledges that there is a direct connection between physical movement and things like attention, memory, and learning" (Ferlazzo, 2020).

Recess. At most schools, recess is considered a privilege, and might be withheld as punishment for bad behavior, or for falling behind academically. Sometimes it is eliminated to make more time for academics or practice for standardized tests. Withholding recess for any reason, especially as a form of punishment, is ultimately ignoring what we know about physical activity and the brain. The Center for Disease Control (CDC) says, "Exclusion from recess for bad behavior in a classroom deprives students of physical activity that can contribute toward improved behavior in the classroom" (Dendy, 2022). Physical activity leads to improved behavior of all students, but this is especially important for students with disabilities such as Attention Deficit Hyperactivity Disorder (ADHD). A study in School Psychology Quarterly emphasized the importance of physical activity and recess, explaining, "Results showed that levels of inappropriate behavior were consistently higher on days when participants [with ADHD] did not have recess, compared to days when they did have it" (As cited in Dendy).

It is understandable that administrators and teachers want additional time for academics, particularly in a culture where high stakes tests are so important, but eliminating recess is not a good tradeoff. "If productivity, accountability, and scores on high-stakes tests are a major concern, would it not make sense to ensure that students are in the best mind–brain shape they can be in when taking these and other tests?" (Sousa, 2022, p. 227). Recess is like a workout for the brain, keeping it sharp and focused, which is necessary for productivity in the classroom and good scores on high-stakes tests. "When you cut down recess, you are removing time that kids can run around. And when they run around, their brains are getting a bubble bath of good neurochemicals, neurotransmitters and endorphins. These help memory and mood. A simple burst of exercise helps students focus better" (as cited in Kris, 2019).

Incorporating Movement in Lessons. "When teachers weave in purposeful movement, they enhance students' comprehension and retention" (Kris, 2021). Incorporating movement into a lesson is not just for fun but it actually helps students remember the material. One study showed that students who used movement in their learning strategy remembered 76% of the material, while those who used only thinking techniques without movement only remembered 37% (Kris). Movement does not have to be a class dance party - though that can be an effective brain break; movement can be seamlessly integrated into lessons all while students reap the benefits. Below are some practical strategies to incorporate movement into classroom lessons.

Conga Line (Ferlazzo, 2020): The conga line can be used with any subject and any unit. Students are numbered off as 1s and 2s, and then the 1s face the 2s. This can be in lines or in two circles. Teachers pose a discussion question for the class and determine which group will answer first (e.g. the 2s answer and then the 1s answer). When the music plays, one group moves to the right, and when the music stops everyone has a new partner. These steps can be repeated several times to maximize movement, and so students hear a number of different perspectives. Some possible discussion questions based on subject area include:

- <u>Math:</u> Explain two ways to solve this problem; How do you know your answer is reasonable?; Which strategy is the most effective for solving this problem?

- Social Studies: What was the leading cause of ___?; How did ___ impact the world we live in today?; Who was the most influential person during ___?

- Science: What are the benefits and limitations of this model?; What is the cause/effect of ___?; Discuss your initial hypothesis and your reasoning behind it.

- English Language Arts: Have students react to a quote from a novel or short story; How did the character change from the beginning of the story to the end?; How did the setting help to move the plot forward?

The prompts listed are very general, whereas teachers can be as specific as they want to with the content that they are covering. The congo line can be used at any point in a unit but it does work well as an opening activity to get students thinking about common themes.

Gallery Walks: A gallery walk is when students walk around to view different items around the room related to a lesson. Gallery walks are beneficial because they not only get students moving around the room, but they can also be multisensory (which also aids in retention). Displays might include photos, cartoons, articles, poems, videos, graphics, or audio recordings. Students can walk around and discuss the items with classmates, or they can write their reactions on sticky notes and leave them in each area.

Congruent / Novel / Self-Referential Movement: "Congruent movement involves engaging in physical activity that matches a concept" (Kris, 2021). This might be kids forming a number line to add/subtract, or counting steps around the edge of the classroom to learn perimeter. "Novel movement asks students to do something unfamiliar to acquaint them with a new concept – such as physics students holding on to a tilting, spinning wheel to experience torque" (Kris). "Self-referential movements involve students casting themselves as a character in the story of a concept" (Kris). Self-referential movement might have the most flexibility, as it allows for some creativity on the part of the participants. Examples of self-referential movement include students acting out photosynthesis in science class, or multiplication in math. "According to research, role-playing in science helped students achieve a more accurate understanding of a concept" (Kris).

Total Physical Response (Gonzalez, 2019): "Developed for use with second-language learners in the 1960's, Total Physical Response (TPR) simply has students act out physical gestures to represent vocabulary words" (Gonzalez). TPR forces students to think outside of the box, as they must use their bodies to define a word or concept. Further, students must come up with the gesture themselves, which gives them ownership and helps them to remember the word. TPR has been shown to be extremely effective with both children and adults. TPR can be used in any content area and actually, in any language.

Section 3 Key Terms

<u>Attention Deficit Hyperactivity Disorder (ADHD)</u> - A chronic condition including attention difficulty, hyperactivity, and impulsiveness

<u>Hippocampus</u> - Structure in temporal lobe; plays a key role in learning and memory

<u>Multisensory Learning</u> - The assumption that individuals learn better if they are taught using more than one sense

<u>Prefrontal Cortex</u> - The cerebral cortex covering the front part of the frontal lobe; brain region associated with EF skills

<u>Zone of Proximal Development (ZPD)</u> - The space between what a learner can do without assistance and what a learner can do with adult guidance or in collaboration with more capable peers

Section 3 Reflection Questions

1. How do you think your classroom climate is affected when students are in the "downtime" of their circadian rhythm? What can you do to promote learning during this time?
2. Before this lesson, what were your thoughts on taking away recess as a punishment? Have your views changed? Why or why not?
3. What are the risks of teaching below or above a student's zone of proximal development?
4. What responsibility do you feel that you have as a teacher to promote the positive mental health of students?

Section 3 Activities

1. Take an old lesson plan, or create one for an upcoming unit, and add a multisensory component. That is, as part of the lesson or practice, include multisensory learning options.
    a. Follow the same directions but include an activity that utilizes movement.
2. Create a formative assessment choice board with multisensory options (e.g. Create a one-pager, record a podcast, construct a model, etc).
3. Design an age-appropriate daily check-in activity for your class.

Conclusion

Neuroeducation is an interdisciplinary research field, combining the disciplines of education, neuroscience, and psychology. While research in the field has not been formally implemented into educational practice or policy, neuroeducation explores how children learn and how to apply brain-based teaching and best practices to the classroom. There is growing interest in the field of neuroeducation with the goal of applying neuroscientific research in the classroom to promote better learning, social-emotional experiences, and overall improved outcomes for students.

Case Study

Mr. Parsons is a math teacher at Howard High School. Mr. Parsons teaches all grade levels at the high school and is an overall effective teacher. Students like Mr. Parsons and they look forward to his class. However, Mr. Parsons is struggling with engagement and achievement in his 5th period (12:30 PM) sophomore algebra class. He starts each class by reviewing homework from the night before, and then he teaches the new material. At the end of class, he tries to give "choice time," with the options of math games, math art (algebraic color-by-numbers), or partner review. During instruction, Mr. Parsons does the majority of the talking, and then students have time to practice. Mr. Parsons' colleague told him about neuroeducation and how it offers strategies to improve his classroom practices. Mr. Parsons is willing to try anything, and is particularly interested in learning more about the prime time for learning during the class period, and whether or not he should adjust the way he structures the teaching of new material.

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