PREFACE

> *The events in our lives happen in a sequence in time but in their significance to ourselves they find their own order . . . the continuous thread of revelation.*
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> ~ Eudora Welty

Now is an exciting and pivotal time to be an educator. Neuroimaging and brain mapping research has extended beyond the confines of studying medical and psychological diseases and has opened windows into the brain. We can now see brain activity as information from the senses that is categorized and organized into working, relational, and, ultimately, long-term memories. In short, we can now see what happens to brain activity and structure when teachers teach and when students learn. Educators can now relate the powerful discoveries of learning brain research to classrooms and curriculum by incorporating research-based learning strategies to help students learn more effectively and joyfully. The potential for discovering the most effective ways to educate students is unlimited.

These chapters demonstrate specific classroom strategies that have been developed from research in how the brain accumulates, connects, stores, and retrieves learned material. Information obtained through brain imaging such as positron emission tomography (PET scans), functional magnetic resonance imaging (fMRI), and quantitative electroencephalography brain wave monitoring (qEEG) during the learning process have given us a *science* of education to add to our already powerful knowledge of the *art* of teaching. Educational professionals who understand the relevant aspects of brain development, alertness, attention, and memory storage and retrieval, and who use the strategies derived from this research, will find their work becoming more effective and exciting and will find their students more engaged.

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MEMORY, LEARNING, AND TEST-TAKING SUCCESS

The past two decades have provided extraordinary progress in our understanding of the nature of learning. Never before have neuroscience and classroom instruction been so closely linked. Because advances in technology enable us to view the working brain as it learns, educators can now find evidence-based neuroimaging and brain-mapping studies to determine the most effective ways to teach.

Brain Plasticity and Pruning

Learning causes growth of brain cells. For a long time, scientists held a misconception about brain growth: they believed it stopped at birth and was followed by a lifetime of brain cell death. Now we know that although most of the neurons where information is stored are present at birth, there is lifelong growth of the support and connecting cells that enrich the communication between neurons. These dendrites sprout from the arms (axons) or the cell body of the neuron.

Dendrites increase in size and number in response to learned skills, experience, and information. New dendrites grow as branches from frequently activated neurons. This growth is stimulated by proteins called neurotrophins. Nerve growth factor is one of these neurotrophins. Although the brain measurements of neurotrophins are highest during childhood (when the brain's connecting cells are undergoing their greatest growth and development), as students continue to learn, neurotrophin activity is elevated in the brain regions responsible for new learning (Kang, Shelton, Welcher, & Schuman, 1997).

Memory is strengthened by insight; when students understand concepts well, it is much easier for them to remember relevant facts. This memory strengthening is what occurs when students use analogies, metaphors, and personal anecdotes to connect new information to their own stored internal graphic organizers—their neuron-dendrite networks.

Repetition and Consolidation

Multiple mechanisms work to maintain stored memory, including recollection, familiarity, and priming. Once the information is remembered correctly and used with executive functions, it still needs to be reviewed on a regular basis, but at gradually lengthening intervals. This repetition, after the first correct response, results in reinforcement of the neuronal connections along the lengths of the axons and dendrites and across the synapses. The more the neural connections are activated by the stimulation that practice brings, the more dendrites grow to strengthen the connections between the neurons.

Gray Matter

fMRI studies during the learning of a motor movement (in this case learning to play the piano) revealed that during these initial learning stages, a large portion of the brain's motor control region is activated. With practice and improved skill levels, smaller and smaller regions of the brain are activated during the piano playing. In professional musicians, only very tiny regions of the motor cortex are involved in their playing. The conclusion drawn was that because practice makes the neural networks more efficient, it took less brain metabolism to carry out the same activity. The result is that there is freeing up of brain energy and areas to be used for other things (Jancke, 2000).

When the brain perceives information repeated in multiple ways, there is a *priming* process that makes encoding of that information more efficient. That is why writing a vocabulary word in a sentence, hearing classmates read their sentences, and then following the direction to use the word in conversation during that day will result in more successful long-term memory storage and retrieval than just memorizing the definition (Koutstaal et al., 1997).

No objective neuroimaging or brain wave analysis data demonstrate any negative effects of joy and exuberance in classrooms, yet that has become the spoken or unspoken mandate. Now there is the hard science that proves the negative brain impact of stress and anxiety and the beneficial changes in the brain that are seen when children are motivated by and personally connected to their lessons. It is valuable to students for teachers to become familiar with this evidence and pass it along to parents, administrators, and legislators to promote change from without, but it is critical to begin (or continue) using the strategies that are shown to reduce stress in classrooms. Even before the mandates catch up with the brain research, teachers are the frontline professionals who can use the techniques to keep this generation of students from falling into the abyss of joyless, factory-style education.

When children experience instruction that is founded on brain-based strategies that engage their interests and also reduce stress, they become more successful and happier learners. The common theme to the brain research about stress and knowledge acquisition is that superior learning takes place when stress is lowered and learning experiences are relevant to students' lives, interests, and experiences. Lessons must be stimulating and challenging, without being intimidating, for the increasing curriculum standards to be achieved. Otherwise the stress, anxiety, boredom, and alienation that students experience block the neuronal transmission, synaptic connections, and dendrite growth that are the physical and now visible manifestations of learning.

Gray Matter

Stress in the classroom or elsewhere, especially when associated with anxiety or fear, releases a chemical called TMT, or trimethyltin, into the brain. TMT disrupts brain cell development. When it is present in brain regions during short stressful periods, there is impaired short-term memory and work efficiency. After extended periods of stress, TMT is associated with reduction in long-term memory storage and retrieval, motivation, and creative problem solving. While students under stress may appear to work "harder," the quality of the work decreases (Kato & McEwen, 2003).

Assessment Accommodations for Students with ADD

Just as teaching students with learning differences means setting appropriately high, but not necessarily uniform, standards and expectations for speed of learning, assessing should also be differentiated. Especially considering the underdeveloped maturation of the frontal lobes of many students with ADD, it is unreasonable to have identical expectations for their frontal lobe executive function performance on assessments.

These students' brains may not do well with rote memorizing or even relational memory that is based on rote memorized patterns, algorithms, or abstractions such as, "When two vowels go walking, the first does the talking." More specific testing would be appropriate, such as looking at math problems with the solutions worked out and selecting which one is done correctly. They could match correctly spelled words with their meanings instead of having to memorize the definitions. Then they could have their tests returned with any mistakes clearly marked. For the matches they get wrong, they will then see the correct definition matched with the correct word and be required to use the word correctly in a sentence that clearly shows its meaning.

Toll the Death Knell for the Bell Curve

I taught for several years at a school where almost half of the students entering my 5th grade class had inadequate math preparation and told me that they were poor math students. "I'm just dumb at math," "I never get it," and "I hate math and it's my worst subject" were their literal comments. Their parents had similar predictions: "My daughter is creative and loves school but has never been good at math" or, "He just is bad at math and always has been. We'd like to start with a tutor right away."

Age 10 is much too young to determine anyone's academic potential, yet these children and adults were discouraged about math. Regardless of past academic experiences or the admonitions of previous teachers about students' deficiencies, it is critical that students be seen as potentially successful individuals and that teachers proceed optimistically with the brain-based strategies that can help them reach their potential.