

Introduction to Reading

Why are you reading about the brain in a math class? In college, you will be expected to take more and more responsibility for your own learning. So it makes sense that it is useful to understand how learning actually occurs. New scientific discoveries in the last decade have greatly increased what we know about the human brain and how it stores information. This has led to a field called *Brain-Based Learning* which applies information about the physiology of the brain to education and learning

Your brain is a physical structure just like your muscles. You are probably aware that there are strategies to use in working muscles to increase strength, endurance or lose fat. In other words, every physical activity is not equally effective for every goal. The same is true with learning. One person might spend hours and hours “studying” and yet remember less than someone who spent less time but used the time better. As a college student, you have a lot going on. You want to use your time efficiently and productively.

We also know from research that people learn better when they understand the reason behind the activities and learning. So as you read this information, we would like you to think about two questions.

- First, how does this information relate to your TRS 82 class – the way the class is structured and the types of activities and assignments? This will help you understand why the course is designed the way it is and what you should be getting out of the different elements.
- Second, how can you use this information to enhance your own learning in this class and in others? Think about behavior in class, when and for how long you study, and different strategies for studying. While these excerpts come from a book written for educators, the information can be useful to the learner as well.

**Excerpt from: *Research-Based Strategies to Ignite Student Learning* by Judy Willis, pp 1-2
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 a 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).

Once these dendrites are formed, the brain’s plasticity allows it to reshape and reorganize the networks of dendrite-neuron connections in response to increased or decreased use of these pathways (Giedd et al., 1999).

Examples of brain plasticity have been noted when people repeatedly practice activities controlled by parts of their visual, motor, sensory, or coordination systems for specialized learned activities. Blind people who read Braille have significantly larger somatosensory cortexes, where the sense of touch in their right fingers is processed. Similarly, violin players who use the fingers of their left hands to do the complicated movements along the strings have larger somatosensory regions in the area of their parietal lobe associated with the fingers of the left hand.

A 2004 report in *Nature* found that people who learned how to juggle increased the amount of gray matter in their occipital lobes (visual memory areas). When they stopped practicing the juggling, the new gray matter vanished. A similar structural change appears to occur in people who learn—and then don't practice—a second language. The decrease in connecting dendrites and other supporting brain connecting cells that are not used is called pruning. The loss of native language ability, juggling skills, or learned academic material that is not practiced is the flip side of the brain's growth response to learning. It is the "use it or lose it" phenomenon. The process is called "pruning" because the brain pathways and connections that are used regularly are maintained and "hard-wired," while others are eliminated, or pruned.

**Excerpt from, *Research-Based Strategies to Ignite Students* by Judy Willis, pp 4-5
Helping Students Grow More Brain Connections**

In the classroom, the more ways the material to be learned is introduced to the brain and reviewed, the more dendritic pathways of access will be created. There will be more synaptic cell-to-cell bridges, and these pathways will be used more often, become stronger, and remain safe from pruning.

For example, offering the information visually will set up a connection with the occipital lobes (the posterior lobes of the brain that process optical input). Subsequently or simultaneously having students *hear* the information will hook up a dendritic circuit with the temporal lobes (the lobes on the sides of the brain that process auditory input and play an important role in the regulation of emotion and memory processing). This duplication results in greater opportunity for future cues to prompt the brain access to this stored information.

Multiple stimulations mean better memory. The more regions of the brain that store data about a subject, the more interconnection there is. This redundancy means students will have more opportunities to pull up all those related bits of data from their multiple storage areas in response to a single cue. This cross-referencing of data strengthens the data into something we've learned rather than just memorized.

For example, when we learn about our cars, we store the information in brain association areas under multiple categories that relate to the context with which new information about cars is learned. When we see a car, it goes into the visual image cortex. When we see the word C-A-R spelled out, that information goes into a language-association

region. After learning about the internal combustion engine, the association is made with “jet and rocket engines are also powered by internal combustion.” Later we build associational memories with the cars we’ve grown up with.

Because the information about cars is stored in multiple brain areas, and cross-referencing occurs among these areas when we think about cars, connecting networks of dendrites sprout among these memory storage areas. This circuitry permits multiple cues or stimuli to call forth all our car knowledge instantaneously. Just seeing the word “car” will put our recall systems online to provide all the stored data we have connected pertaining to cars. We may not need all that information, but because the associations activate these circuits, any of the stored information that we do need will be rapidly and efficiently accessible.

That is the reason for teaching important material through multiple learning pathways such as several senses (hearing, seeing, touching) as well as through several subjects (cross-curricular topics).

Excerpt from: *Research-Based Strategies to Ignite Student Learning* by Judy Willis, pp 6-10
Memory

Working memory, or short-term memory, involves the ability to hold and manipulate information for use in the immediate future. Information is held in working memory for only about 20 minutes. The challenge students face is to move information from their working memories into their long-term memories. If they don’t do this in about 20 minutes, that information can be lost. (Think about the last time someone gave you driving directions that seemed so clear when you heard them, but were lost to you once you made the second right turn.) To keep this newly learned material from slipping away, it needs to enter the network of the brain’s wiring. Students can retain the new information by activating their previously learned knowledge that relates to the new material. This prior knowledge exists in stored loops of brain cell connections (circuits of neurons connected by branching axons and dendrites that carry the information as electrochemical signals). Effective teaching uses strategies to help students recognize patterns and then make the connections required to process the new working memories so they can travel into the brain’s long-term storage areas.

Gray Matter

Although it is commonly believed that brain cell growth stops after age 20, that is not completely true. New connecting cells, called dendrites, can be formed throughout life. It is true that the neurons where memory storage takes place are not replenished; however, their extensions, these dendrites, continue to sprout and connect and form new circuits with other dendrites throughout life (Martin & Morris, 2002). These neural networks, similar to electricity circuitry, are the roadways that connect various parts of the brain. Just like traffic flow in a busy city, the more alternative pathways there are to connect with a memory, the more efficiently the traffic will flow, and the more rapidly that memory will be retrieved when needed.

After repeated practice, working memories are set down as permanent neuronal circuits of axons and dendrites ready to be activated when the information is needed. When a memory has been recalled often, its neuronal circuits are highly developed because of their repeated activation. A phrase that describes this construction of connections based on repeated association of one piece of information with another is "Cells that fire together, wire together." When neurons fire in sync with one another, they are more likely to form new connections. As the connections grow stronger by repeated stimulation, a given neuron becomes more likely to trigger another connected neuron (Chugani, 1998).

Like an exercised muscle, these circuits then become more efficient and easier to access and activate. Practice results in repeated stimulation of the memory circuit. Like hikers along a trail who eventually carve out a depression in the road, repeated practice stimulates cells in the memory circuit so that the circuit is reinforced and becomes stronger. This means it can be quickly turned from off to on, and switched on through a variety of cues coming in from the senses.

Recall the first few times you learned and practiced a new computer process, such as making a Web page or using e-mail. At first you may have followed step-by-step written or verbal instructions. You possibly needed to rely on those instructions multiple times as you repeated the task, until one day, the process became automatic and you could even carry on a conversation while doing the job. That working memory was embedded by repetition into long-term memory, but it still needed periodic repetition for it to remain in your active memory bank and not gradually fade from disuse. Even if it did fade when you were away from your computer during summer vacation, however, the neuronal circuit or brain cell network that was created was still physically present in your brain, just like that hiking trail under the winter's snow. It was just in strong, like data taken off your computer desktop and put into the hard drive, and it took less time to refresh it than it did to learn it the first time.

Learning promotes learning. Engaging in the process of learning actually increases one's capacity to learn. Each time a student participates in any endeavor, a certain number of neurons are activated. When the action is repeated, such as when performing a follow-up science lab experiment or rehearsing a song, or when the information is repeated in subsequent curriculum, these same neurons respond again. The more times one repeats an action or recalls the information, the more dendrites sprout to connect new memories to old, and the more efficient the brain becomes in its ability to retrieve that memory or repeat that action.

Eventually, just triggering the beginning of the sequence results in the remaining pieces falling into place. This repetition-based sequencing is how you are able to do many daily activities almost without having to think about them, such as touch-typing or driving a car. The reason for this ability goes back to the construction and strengthening of those memory pathways in the brain.

Build stronger memory circuits. Some of the strategies suggested by neuroimaging are ones that have students personalize information to be learned, thereby further activating the areas of the brain that help form memories. Others encourage students to connect with the information with as many senses as possible. They can visualize an electron orbiting the nucleus of an atom, mimic the buzz of electricity as it whizzes by, or feel a tingling associated with the electron's negative charge by rubbing a balloon against their arm and feeling their hair move. If they then draw a sketch of their visualizations and verbally communicate them to partners, or write about them in their own words, multiple brain pathways will be stimulated to enter long-term memory because they have personalized and interacted with the information.