Understanding How the Brain Thinks (Part 1 of 7)

By Judy Willis MD
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Former neurologist and teacher Judy Willis will be presenting a 5-part series on how young brains develop neurologically; she'll also offer some research-based classroom strategies to teach critical thinking and other 21st century skills.

Understanding How the Brain Works

For 21st century success, now more than ever, students will need a skill set far beyond the current mandated standards that are evaluated on standardized tests. The qualifications for success in today's ever-changing world will demand the ability to think critically, communicate clearly, use continually changing technology, be culturally aware and adaptive, and possess the judgment and open-mindedness to make complex decisions based on accurate analysis of information. The most rewarding jobs of this century will be those that cannot be done by computers.

For students to be best prepared for the opportunities and challenges awaiting them, they need to develop their highest thinking skills -- the brain's *executive functions*. These higher-order neural networks are undergoing their most rapid development during the school years, and teachers are in the best position to promote the activation of these circuits. With the help of their teachers, students can develop the skillsets needed to solve problems that have not yet been recognized, analyze information as it becomes rapidly available in the globalized communication systems, and to skillfully and creatively take advantage of the evolving technological advances as they become available.

Factory Model of Education Prepares for "Assembly Line" Jobs

Automation and computerization are exceeding human ability for doing repetitive tasks and calculations, but the educational model has not changed. The factory model of education, still in place today, was designed for producing assembly line workers to do assigned tasks correctly. These workers did not need to analyze, create, or question.

Ironically, in response to more information, many educators are mandated to teach more rote facts and procedures, and students are given bigger books

with more to memorize. In every country where I've given presentations and workshops, the problem is the same: overstuffed curriculum.

Even in countries where high-stakes standardized testing is not a dominant factor, school curriculum and emphasis have changed to provide more time for this additional rote memorization. Creative opportunities -- the arts, debate, general P.E., collaborative work, and inquiry -- are sacrificed at the altar of more predigested facts to be passively memorized. These students have *fewer* opportunities to discover the connections between isolated facts and to build neural networks of concepts that are needed to transfer learning to applications beyond the contexts in which the information is learned and practiced.

The High Costs of Maintaining the Factory Model

If students do not have opportunities to develop their higher order, cognitive skillsets they won't develop the reason, logic, creative problem solving, concept development, media literacy, and communication skills best suited for the daily complexities of life or the professional jobs of their future. Without these skills, they won't be able to compete on the global employment market with students currently developing their executive functions.

Instead, the best jobs will go to applicants who analyze information as it becomes available, adapt when new information makes facts obsolete, and collaborate with other experts on a global playing field. All these skills require tolerance, willingness to consider alternative perspectives, and the ability to articulate one's ideas successfully.

As educators, it is our challenge to see that all students have opportunities to stimulate their developing executive function networks so when they leave school they have the critical skillsets to choose the career and life paths that will give them the most satisfaction.

Executive Function = Critical Thinking

What my field of neurology has called "*executive functions*" for over 100 years are these highest cognitive processes. These executive functions have been given a variety of less specific names in education terminology such as *higher order thinking* or *critical thinking*. These are skillsets beyond those computers can do because they allow for flexible, interpretive, creative, and multidimensional thinking -– suitable for current and future challenges and opportunities. Executive functions can be thought of as the skills that would make a corporate executive successful. These include planning, flexibility, tolerance, risk assessment, informed decision-making, reasoning, analysis,

and delay of immediate gratification to achieve long-term goals. These executive functions further allow for organizing, sorting, connecting, prioritizing, self-monitoring, self-correcting, self-assessing, abstracting, and focusing.

The Prefrontal Cortex: Home to Critical Thinking

The executive function control centers develop in the *prefrontal cortex* (PFC). The PFC gives us the *potential* to consider and voluntarily control our thinking, emotional responses, and behavior. It is the reflective "higher brain" compared to the reactive "lower brain". This prime real estate of the PFC comprises the highest percentage of brain volume in humans, compared to all other animals, which is roughly 20% of our brains.

Animals, compared to humans, are more dependent on their reactive lower brains to survive in their unpredictable environments where it is appropriate that automatic responses not be delayed by complex analysis. As man developed more control of his environment, the luxury of a bigger reflective brain correlated with the evolution of the PFC to its current proportions.

The prefrontal cortex is the last part of the brain to mature. This maturation is a process of neuroplasticity that includes 1) the pruning of unused cells to better provide for the metabolic needs of more frequently used neurons and 2) strengthening the connections in the circuits that are most used. Another aspect of neuroplasticity is the growth of stronger and increased numbers of connections among neurons. Each of the brain's over one billion neurons holds only a tiny bit of information. It is only when multiple neurons connect through their branches (axons and dendrites) that a memory is stored and retrievable.

This prefrontal cortex maturation, the pruning and strengthening process, continues into the twenties, with the most rapid changes in the age range of 8-16. Electricity flows from neuron to neuron through the axons and dendrites. This electrical flow carries information and also provides the stimulus that promotes the growth of these connections. Each time a network is activated -- the information recalled for review or use -- the connections become stronger and faster (speed through a circuit is largely determined by the layers of myelin coating that are built up around the axons -- this is also in response to the flow of the electric current of information transport when the circuit is activated). The stimulation of these networks during the ages of their rapid development strongly influences the development of the executive functions -- the social-emotional control and the highest thinking skillsets that today's students will carry with them as they leave school and become adults.

Preparing Students for the Challenges and Opportunities of the 21st Century

We have the obligation to provide our students with opportunities to learn the required foundational information and procedures through experiences that stimulate their developing neural networks of executive functions. We activate these networks through active learning experiences that involve students' prefrontal cortex circuits of judgment, critical analysis, induction, deduction, relational thinking with prior knowledge activation, and prediction. These experiences promote creative information processing as students recognize relationships between what they learn and what they already know. This is when neuroplasticity steps in and new connections (dendrites, synapses, myelinated axons) physically grow between formerly separate memory circuits when they are activated together. This is the physical manifestation of the "neurons that fire together, wire together" phenomenon.

Unless new rote memories are incorporated into larger, relational networks, they remain isolated bits of data in small, unconnected circuits. It is through active mental manipulation with prior knowledge that new information becomes incorporated into the already established neural network of previously acquired related memory.

Teaching that Strengthens Executive Function Networks

Making the switch from memorization to mental manipulation is about applying, communicating, and supporting what one already knows. The incorporation of rote memorization into the sturdy existing networks of long-term memory takes place when students recognize relationships to the prior knowledge stored in those networks.

When you provide students with opportunities to apply learning, especially through authentic, personally meaningful activities with formative assessments and corrective feedback throughout a unit, facts move from rote memory to become consolidated into related memory bank, instead of being pruned away from disuse.

The disuse pruning is another aspect of the brain's neuroplasticity. To best support the frequently used networks, the brain essentially dissolves isolated small neural networks of "unincorporated" facts and procedures that are rarely activated beyond drills and tests.

In contrast, opportunities to process new learning through executive functions promote its linkage to existing related memory banks through the growth of linking dendrites and synapses.

Students need to be *explicitly taught* and given opportunities to practice using executive functions to organize, prioritize, compare, contrast, connect to prior knowledge, give new examples of a concept, participate in open-ended discussions, *synthesize* new learning into concise summaries, and *symbolize* new learning into new mental constructs, such as through the arts or writing across the curriculum.

How to Engage Students' Developing Neural Networks to Promote Executive Function

The recommendations here are a few of the ways to engage students' developing networks of executive functions while they are undergoing their most rapid phase of maturation during the school years. Part 2 of this blog will delve more deeply into the mental manipulation strategies that promote consolidation of new input into existing memory circuits.

Judgment: This executive function, when developed, promotes a student's ability to monitor the accuracy of his or her work. Guidance, experiences, and feedback in estimation; editing and revising one's own written work; and class discussions for conflict resolution can activate the circuitry to build judgment.

Prioritizing: This executive function helps students to separate low relevance details from the main ideas of a text, lecture, math word problem, or complete units of study. Prioritizing skills are also used when students are guided to see how new facts fit into broader concepts, to plan ahead for long-term projects/reports, and to keep records of their most successful strategies that make the most efficient use of their time.

Setting goals, providing self-feedback, monitoring progress: Until students fully develop this PFC executive function, they are limited in their capacity to set and stick to realistic and manageable goals. They need support in recognizing the *incremental progress* they make as they apply effort towards their larger goals (see my previous two blogs about the "video game" model: How to Plan Instruction Using the Video Game Model and A Neurologist Makes the Case for the Video Game Model as a Learning Tool).

Model Metacognition Development Yourself

Planning learning opportunities to activate executive function often means going beyond the curriculum provided in textbooks. This is a hefty burden when you are also under the mandate of teaching a body of information that exceeds the time needed for successful mental manipulation.

When you do provide these executive function-activating opportunities, students will recognize their own changing attitudes and achievements. Students will begin to experience and comment on these insights, "I thought … would be boring, but it was pretty interesting" and "This is the first time I really understood … " or simply, "Thanks" and "That was cool."

These student responses are teachable moments to promote metacognition. Consider sharing the processes you use to create the instruction that they respond to positively. These discussions will help students recognize their abilities to extend their horizons and focus beyond simply getting by with satisfactory grades. They can build their executive functions of long-term goal-directed behavior, advance planning, delay of immediate gratification. In this way, they can take advantage of opportunities to review and revise work -- even when it has been completed -- rather than to be satisfied with "getting it done." Your input can help students see the link between taking responsibility for class participation, collaboration, and setting high self-standards for all classwork and homework, such that they can say, "I did my best and am proud of my efforts."

As written on the gate of my college, the message we can send our students is:

Climb high. Aim Far.
Your goal the sun;
Your aim the stars.